

# Inequalities of Income and Inequalities of Longevity: A Cross-Country Study

Eric Neumayer, PhD, and Thomas Plümper, PhD

**Objectives.** We examined the effects of market income inequality (income inequality before taxes and transfers) and income redistribution via taxes and transfers on inequality in longevity.

**Methods.** We used life tables to compute Gini coefficients of longevity inequality for all individuals and for individuals who survived to at least 10 years of age. We regressed longevity inequality on market income inequality and income redistribution, and we controlled for potential confounders, in a cross-sectional time-series sample of up to 28 predominantly Western developed countries and up to 37 years (1974–2011).

**Results.** Income inequality before taxes and transfers was positively associated with inequality in the number of years lived; income redistribution (the difference between market income inequality and income inequality after taxes and transfers were accounted for) was negatively associated with longevity inequality.

**Conclusions.** To the extent that our estimated effects derived from observational data are causal, governments can reduce longevity inequality not only via public health policies, but also via their influence on market income inequality and the redistribution of incomes from the relatively rich to the relatively poor. (*Am J Public Health.* 2016;106:160–165. doi:10.2105/AJPH.2015.302849)

**P**ublic policies affect not only health and mortality at the individual level, but also the inequality of longevity—inequality in the number of years lived. For example, higher tobacco<sup>1</sup> and alcohol<sup>2</sup> taxes reduce consumption, as do nonfiscal regulatory measures such as restrictions on smoking in closed spaces. This reduces avoidable mortality from lung cancer and liver cirrhosis. More directly, governments implement health and safety regulations, influence total health spending and its allocation, and regulate the coverage of health insurance across individuals. All factors that reduce premature deaths also reduce longevity inequality.

Although these pathways are generally well understood, another mechanism surprisingly has no cross-country evidence: the influence of income inequality and income redistribution on lifetime inequality. Low income has multiple direct and indirect negative consequences for individual health.<sup>3–5</sup> This does not necessarily imply that greater income inequality leads to greater inequality in health outcomes at the population level. However, greater income

inequality is typically associated with a higher prevalence of poverty.

A higher prevalence of poverty, all other things being equal, increases the number of premature deaths and therefore leads to greater longevity inequality.<sup>6</sup> Poverty is, for example, linked to unhealthy diets and lack of physical activity, thus contributing to the emergence of diabetes and cardiovascular diseases such as coronary heart disease and strokes, as well as increased alcohol and tobacco consumption, which contributes to lung cancer, diseases of the liver, and many other diseases.<sup>5</sup> Poor people enjoy fewer opportunities for recreational activities and report higher levels of stress and mental health problems, which reduce the capacity to cope

with life's adversities.<sup>7</sup> Poverty also diminishes individual investment in education, which has been shown to be an important predictor of subsequent mortality.<sup>8</sup>

Greater income inequality, however, need not represent a higher prevalence of poverty, but could instead reflect a higher concentration of incomes at the top of the income distribution at the expense of the share held by individuals in the middle. It is therefore important not to equate the effect of income inequality on longevity inequality with the effect of poverty on longevity inequality. Income inequality affects inequality in longevity through societal effects that go well beyond any potential direct impacts on individuals' behavior as a function of their low disposable personal income.<sup>9</sup>

In some countries, high income inequality tends to result in the spatial segregation of rich and poor. Poor communities and neighborhoods have lower levels of social cohesion, support, and capital; receive lower-quality public services; and experience higher rates of crime, social disorder, and violence, with potentially negative health consequences.<sup>10,11</sup>

Economic inequality also affects political decision-making. Poor people are less likely to vote and have little influence on political decisions, whereas the very rich can exercise a strong influence via lobbying and donations. More economically unequal societies will thus be characterized by more unequal access to political decision-making.<sup>12,13</sup> This in turn creates political incentives to skew policies toward benefiting the relatively rich at the

## ABOUT THE AUTHORS

Eric Neumayer is with the Department of Geography and Environment, London School of Economics and Political Science, London, UK. Thomas Plümper is with the Department of Socioeconomics, Vienna University of Economics and Business, Vienna, Austria.

Correspondence should be sent to Eric Neumayer, Dept of Geography & Environment, London School of Economics and Political Science, Houghton St, London WC2A 2AE, UK (e-mail: e.neumayer@lse.ac.uk). Reprints can be ordered at <http://www.ajph.org> by clicking the "Reprints" link.

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expense of the relatively poor, for example, by lower government investment in goods such as publicly funded education or recreational and health care facilities that benefit people independently of their personal income.

In ongoing research, we model a specific pathway through which greater income inequality affects longevity inequality via a lower share of public-to-total health expenditures at the country level. The poor are dependent on public health expenditures because they cannot afford substantial investments in private health care, unlike the rich, who can buy better health care privately.

Though research has occasionally tested the theory that redistributive policies and longevity inequality are associated at the country level,<sup>14</sup> we were the first to empirically study the relationship between market inequality and redistributive government policies on inequality in longevity, in a pooled analysis of up to 22 Western developed countries plus the Czech Republic, Estonia, Israel, Poland, the Slovak Republic, and Slovenia over up to 37 years (with considerably fewer years for some, particularly the non-Western, countries).

We used the Gini coefficient as our preferred measure of inequality, but different inequality measures that capture the entire distribution tend to produce similar results in the analysis of longevity.<sup>15</sup> The Gini coefficient is the most popular measure of inequality in the social sciences. It describes how far the Lorenz curve deviates from the line of perfect equality.

The Lorenz curve is a cumulative distribution function. It sorts all individuals according to the dimension in which inequality is measured (age at deaths in our case; Figure 1). Accordingly, in our context individuals are sorted from those who died at birth on the left to those who lived to the age of 110 years on the right. The Lorenz curve depicts the proportion of the total time lived by the bottom deciles of the entire cohort. Logically, all individuals together lived 100% of all the years. If, hypothetically, every individual reached exactly the same age, then the lowest 10% of the population would live 10% of all years lived, 20% of the individuals would live 20% of all years lived, and so on. The function of perfect equality is represented by the straight line from the origin to the

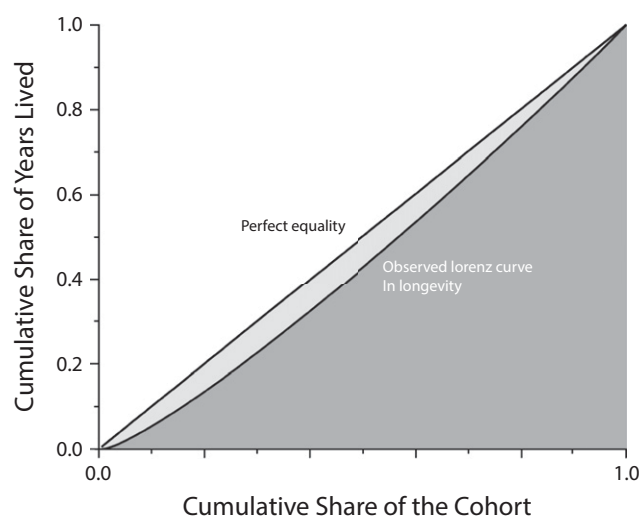


FIGURE 1—The Gini Coefficient of Longevity Inequality in the United States: 2010

upper right corner. If only 1 individual survived birth, then one would get total inequality. All individuals except 1 would live 0% of the total time, and the last individual would live 100% of the total time lived.

Figure 1 plots an actual Lorenz curve based on actual US longevity data for 2010. The further away the Lorenz curve is from the diagonal, the larger the inequality in the data. The Gini coefficient measures the area between the Lorenz curve and the line of perfect equality (the light gray area) as a proportion of the total area below the line of equality in the quadrant. As Figure 1 shows, longevity is relatively equally distributed. Not surprisingly, in light of natural constraints on the number of years anyone can live, longevity is more equally distributed than incomes.

Because infant mortality has a relatively strong effect on longevity inequality, most demographers analyze not the entire range of life tables, but typically left-truncated ones of those who have survived beyond the age of 5, 10, or 15 years.<sup>16,17</sup> We report analyses of Gini coefficients over both the entire life tables (0–110 years) and for those who survived to the age of 10 years (10–110 years) to eliminate the potentially strong influence of child mortality, but our findings also held for other thresholds.

Longevity inequality declined in all countries in our sample over the past 2 centuries. This development was paralleled by a large increase in life expectancy. Because of

the strong association between these trends, some argue that inequality in longevity should only be analyzed with controls for life expectancy included in the analysis.<sup>15</sup> However, rather than increases in life expectancy causing more equality in longevity, both trends are likely determined by the same factors: the sharp decline in infant mortality and the somewhat less pronounced decline in premature mortality.<sup>14,17</sup>

Despite the dramatic decline in longevity inequality over the past 2 centuries, substantial differences in longevity inequality persist across countries. Even for the seemingly similar countries included in our sample, lifetime inequality varied moderately over time and across countries; it varied more over longer periods and larger sets of countries.<sup>16,17</sup> A good example is provided by comparing Sweden, one of the most equal, and the United States, one of the most unequal countries, in 1975 and in 2010. Figures A and B (available as a supplement to the online version of this article at <http://www.ajph.org>) plot mortality rates by age for these 2 countries in these 2 years. Both countries experienced significant increases in life expectancy and reductions in longevity inequality. However, the differences between these countries over 35 years were largely stable. The United States lagged behind the development in lifetime inequality in Sweden, reaching Sweden's level of longevity inequality from 1975 only 35 years later in 2010.

## METHODS

As our measure of longevity inequality, we computed Gini coefficients from internationally comparable life tables from the Human Mortality Database.<sup>18</sup> It provides age-specific mortality data for 37 countries and, depending on the country, some with time series of up to 200 years. Our sample size was much smaller and entirely determined by the availability of data for our explanatory variables. We used annual data, but our results did not change substantively if we employed 3- or 5-year averaged data instead. We included average life expectancy as a control variable in our estimation models, but all results held regardless of whether we included life expectancy.

### Explanatory Variables

As our measures of market income inequality and income redistribution, we used (1) the Gini coefficient of incomes before taxes and transfers, which for simplicity we call market or pretax income inequality, and (2) the absolute difference between the Gini coefficient of incomes before taxes and transfers and the Gini coefficient of incomes after taxes and transfers. A greater absolute difference does not necessarily imply that more income in absolute amounts was redistributed. Rather, it implies that income was redistributed in a way that resulted in a larger reduction in income inequality. For example, redistributing income from upper-middle-income brackets to lower-middle-income brackets has a smaller influence on our measure of income redistribution than the redistribution of an equally sized sum from high- to low-income brackets. This feature made this operationalization attractive for our research. Our data came from the Organisation of Economic Co-operation and Development.<sup>19</sup>

Life expectancy at birth, computed from the life tables, was a control variable. Further, we sourced data on gross domestic product per capita in 1000 constant purchasing power parity dollars and total health expenditures per gross domestic product from the Organisation of Economic Co-operation and Development and the World Health Organization's European Health for All database.<sup>19,20</sup> We took the logarithm of both variables and included their second-degree polynomial terms to account for potential nonlinear effects. Finally, we

accounted for cross-country differences in lifestyle and health and safety regulations that affected longevity inequality. We thus included the logarithm of average alcohol per capita consumption in liters of pure alcohol. Because we had no data with comprehensive coverage on tobacco consumption or on lifestyle choices and health and safety regulations that resulted in death attributable to external causes, we accounted instead for the mortality consequences of these by including mortality rates from lung cancer and from external causes per 1000 inhabitants (all data from the Organisation of Economic Co-operation and Development and World Health Organization).

Countries with large population sizes could be inherently more heterogeneous, but population size did not contribute significantly to our estimation model and we therefore did not include it as a control variable. We linearly interpolated (but did not extrapolate) missing observations on the explanatory variables. Appendix A (available as a supplement to the online version of this article at <http://www.ajph.org>) provides summary descriptive variable information.

### Estimation

Our data were temporally dependent and would exhibit serially correlated errors, as evidenced by a Cumby-Huizinga test for autocorrelation, if we did not control for temporal dependency. We therefore included the lagged dependent variable, after which the same test failed to reject the hypothesis of no autocorrelation. With the lagged dependent variable included in the estimations, the coefficients of explanatory variables  $b$  represent their short-run marginal effects, whereas their long-run marginal effects are  $b/(1 - p)$ , with  $p$  the estimated coefficient of the lagged dependent variable.

In addition to being temporally dependent, the data also exhibited strong trends over time. Medical and other progress that reduces infant mortality and premature deaths over time exerts a strong influence on longevity inequality, but this progress is impossible to observe and measure. It should, however, lead to an upward trend in life expectancy and a downward trend in longevity inequality, which was common to all countries in our sample. We dealt with this complication by adding year-specific fixed effects to the lagged dependent variable in our model specification and by controlling for life expectancy.

Finally, we accounted for remaining cross-sectional heterogeneity by including health care system fixed effects. We relied on Böhm et al.'s classification,<sup>21</sup> which groups countries into types of health care systems according to the private, societal, or state organization of the regulation, financing, and provision of health care. We categorized national systems into national health service (Denmark, Finland, Iceland, Norway, Portugal, Spain, Sweden, United Kingdom); national health insurance (Australia, Canada, Ireland, New Zealand, Italy); social health insurance (Austria, Germany, Luxembourg, Switzerland); social-based mixed type (Slovenia); etatist social health insurance, which we subdivided into Western (Belgium, France, Netherlands, Israel, Japan) and Eastern (Czech Republic, Estonia, Poland, Slovakia); and private health care system (United States). Our estimator was ordinary least squares with standard errors clustered on countries.

## RESULTS

Table 1 presents estimation results covering the entire sample with interpolated data, once for the Gini coefficient of longevity over the entire life tables and once for the Gini coefficient calculated conditionally on survival to the age of 10 years as dependent variables. Results were very similar for both measures of longevity inequality. Appendix A provides further estimation results, always for both dependent variables. One set of estimations restricted the sample to available data without missing values in between available data points linearly interpolated, to check that results were not driven by the data interpolation. Another set of estimations restricted the sample to the more homogeneous 22 Western developed countries to check whether the results were driven by the presence of Eastern European countries and Israel in the sample. Among the developed countries, the United States was the most unequal in longevity, with relatively high market inequality and relatively low income redistribution. A final set of estimation models therefore additionally dropped the United States from the sample to check whether this country alone determined the results. Results on our variables of principal interest were very robust across these different samples.

TABLE 1—Estimation Results for Gini Coefficient of Longevity in 28 Countries: 1974–2011

| Variable                                 | Entire Life Table, Coefficient (95% CI) | Conditional on Survival to Age of 10 Years, Coefficient (95% CI) |
|--|---|--|
| Lagged dependent variable                | 0.8523** (0.7750, 0.9296)               | 0.8299** (0.7372, 0.9226)  |
| Life expectancy                          | −0.0004* (−0.0007, −0.0000)             | −0.0003* (−0.0007, −0.0000)                                      |
| GDP per capita (log)                     | 0.0231 (−0.0109, 0.0570)                | 0.0204 (−0.0091, 0.0499)   |
| GDP per capita (log) squared             | −0.0011 (−0.0027, 0.0005)               | −0.0010 (−0.0024, 0.0004)  |
| Health expenditures to GDP (log)         | −0.0021 (−0.0095, 0.0052)               | −0.0009 (−0.0074, 0.0057)  |
| Health expenditures to GDP (log) squared | 0.0006 (−0.0011, 0.0022)                | 0.0003 (−0.0012, 0.0018)   |
| Alcohol consumption per capita (log)     | 0.0000 (−0.0002, 0.0003)                | 0.0001 (−0.0001, 0.0004)   |
| Lung cancer mortality rate               | 0.0010 (−0.0006, 0.0027)                | 0.0007 (−0.0007, 0.0022)   |
| External cause mortality rate            | 0.0029** (0.0017, 0.0042)               | 0.0037** (0.0020, 0.0055)  |
| Pretax income inequality                 | 0.0069** (0.0030, 0.0108)               | 0.0083** (0.0042, 0.0125)  |
| Income redistribution                    | −0.0065* (−0.0115, −0.0015)             | −0.0076** (−0.0125, −0.0028)                                     |

Note. CI = confidence interval; GDP = gross domestic product. Results based on 476 observations. Year and health care system fixed effects included (coefficients not shown).

\* $P < .05$ ; \*\* $P < .01$ .

The estimated coefficients of the lagged dependent variables of between 0.78 and 0.85 were safely below the unit root threshold of 1. Life expectancy had the expected negative effect on inequality. Gross domestic product per capita had a nonlinear effect. The 2 polynomial terms were jointly significant, with the estimated marginal effect being positive but statistically insignificant at low levels of gross domestic product per capita, turning negative and statistically significant just beyond mean per capita income levels, thus in part suggesting a Kuznets curve–type relationship between per capita income and inequality in longevity, similar to the inverted U-shaped relationship between per capita income and income inequality famously suggested by Nobel Prize winner Simon Kuznets in the 1950s.<sup>22</sup>

Total health expenditures had no statistically significant effect on longevity inequality, except in 1 model (Appendix A) in which the 2 polynomials were jointly statistically significant, suggesting a significantly negative marginal effect at lower expenditure levels that became positive but statistically insignificant at higher expenditure levels. It might be surprising that for the most part we did not find total health spending to have a statistically significant effect, even though higher total health care spending reduces longevity inequality if it is focused on reducing premature mortality. However, in relatively developed countries, additional resources for health care

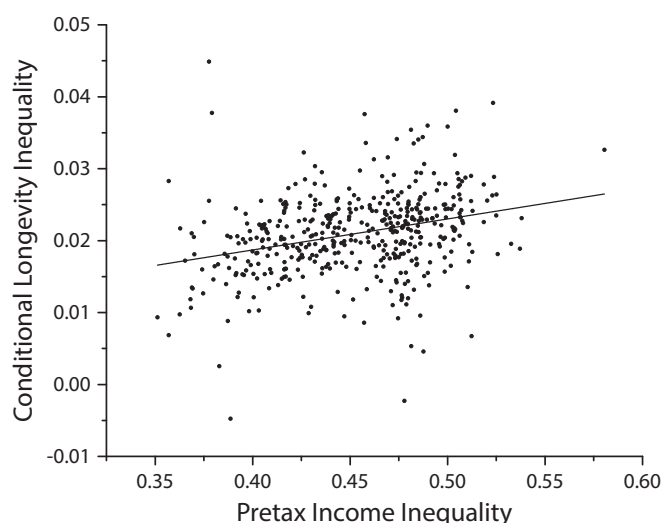
often go into cutting-edge medical treatment, which prolongs the lives of some, often the already elderly, but does not systematically prevent premature deaths. In other words, moving from high to even higher spending on health care does not necessarily reduce inequality in longevity. Even the contrary is possible: if additional health care spending benefits mainly those who would otherwise not receive it because they are considered to be too old for some treatments, then additional health spending may actually increase longevity inequality. Neither average alcohol consumption nor the lung cancer mortality rate had a statistically significant impact on longevity inequality, whereas a higher mortality rate from external causes was predicted to increase longevity inequality, as expected.

Greater pretax income inequality was statistically significantly related to greater longevity inequality, whereas the opposite held true for greater income redistribution. The estimated substantive effects were similar, but in the opposite direction. Across all estimated models, including those reported in Appendix A, an additional percentage point in the Gini coefficient of pretax income inequality was predicted to increase the Gini coefficient of longevity by between 0.0069 and 0.0129 percentage points in the short run and, correspondingly, by between 0.046 and 0.058 percentage points in the long run. A percentage point reduction from the Gini coefficient of pretax income inequality to the Gini coefficient

of posttax income inequality was predicted to decrease the Gini coefficient of longevity by between 0.0064 and 0.0102 percentage points in the short run and by between 0.043 and 0.051 percentage points in the long run.

These effects are substantively important because the standard deviations in both market income inequality and income redistribution were about 4.4 and 5.6 times as large as the standard deviations in, respectively, longevity inequality over the entire life tables and longevity inequality conditional on survival to the age of 10 years. For the Gini coefficient of longevity derived from the entire life tables, varying pretax income inequality or income redistribution by 1 standard deviation results in a long-run change in longevity inequality by, respectively, 19% and 18% of its standard deviation. For the Gini coefficient of longevity conditional on survival to the age of 10 years, the figures were 25% and 23%, respectively.

Figures 2 and 3 illustrate the long-term effects of our 2 main explanatory variables graphically. These figures plot the conditional longevity inequality—that is, longevity inequality minus the predicted effects of the control variables—against income inequality and income redistribution, respectively, together with the corresponding regression lines. The figures refer to longevity inequality derived from the entire life tables, but they would look very similar for longevity inequality conditional on survival to the age of 10 years.

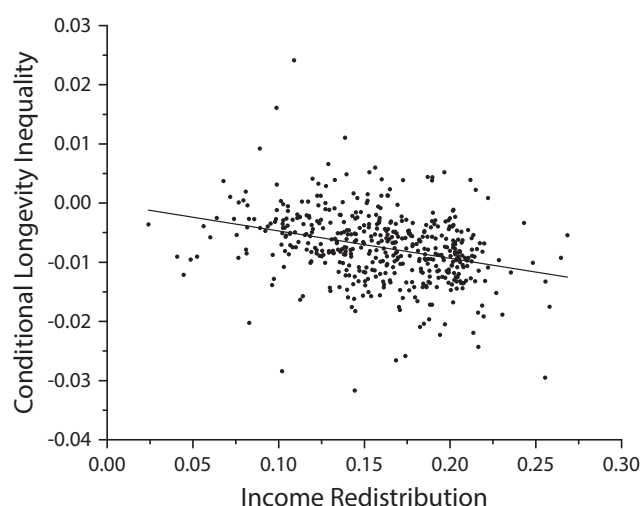


**FIGURE 2—The Long-Term Effect of Pretax Income Inequality on Longevity Inequality in 28 Countries: 1974–2011**

## DISCUSSION

Health inequalities, of which inequality in the number of years lived forms a very important component, matter. Many argue that society should be more averse to, or less tolerant of, health inequalities than income inequalities.<sup>23</sup> By contrast with income, which is instrumental only, health is regarded as a special good, providing both instrumental

and intrinsic value to human beings.<sup>24</sup> Health inequality is regarded as undesirable because inequalities in health represent inequalities in people's functional capabilities.<sup>23</sup> This is clearest and most extreme for inequality in longevity: the prematurely dead have been deprived of everything. Income inequality and income redistribution can have important effects on inequality in longevity, as our



**FIGURE 3—The Long-Term Effect of Income Redistribution on Longevity Inequality in 28 Countries: 1974–2011**

analysis of observational cross-national time-series data showed.

Previous studies focused on analyzing the effect of income inequality on health outcomes in single countries, predominantly in the United States,<sup>25–29</sup> but also in Brazil,<sup>30</sup> Canada,<sup>31</sup> Italy,<sup>32</sup> Norway,<sup>33</sup> and a few others. Although results have been somewhat mixed, a meta-analysis found income inequality to be associated with a modest excess risk of premature mortality.<sup>34</sup> Cross-country studies have typically focused on the effect of income inequality on aggregate population health rather than on measures of inequality in health or mortality.<sup>35</sup>

Our analysis differed from these existing studies by analyzing the effect of economic inequality on longevity inequality, both measured at the country level, across a large cross section of countries—up to 28 countries over the period 1974 to 2011. We found evidence that greater inequalities of income were associated with greater inequalities of longevity, after adjustment for a large number of potentially confounding factors. This evidence was robust independently of whether we analyzed inequality in longevity over the entire life tables or conditionally on having survived to the age of 10 years. This suggests that our results were not driven by changes in child mortality across countries and time. Our results were also independent of whether we interpolated missing data, and they were robust to dropping potential outlier countries from the cross-country analysis.

Previous studies that explicitly focused on longevity inequality measured at the country level decomposed longevity inequality by inequality in educational achievement or socioeconomic status or some other factor. One study found that educational inequalities could explain a substantial part of life span variation in 11 European countries.<sup>8</sup> Another study found socioeconomic inequality to be important for accounting for the variance in adult life span in the United States.<sup>17</sup> In the same study, the researchers used bivariate plots and found no clear relationship between income inequality or inequality in educational achievement and inequality in longevity, all measured at the country level, in a panel of countries. However, such bivariate plots fail to control for important confounding variables and exogenous trends. A further study decomposed in detail the effects



of population differences in the spread, allocation, and timing of the principal causes of death in Sweden and the United States to explore variability in longevity.<sup>36</sup> To the best of our knowledge, ours was the first cross-country study that estimated the effects of economic inequality on longevity inequality with a multivariate statistical model.

## Limitations

We did not directly test the causal mechanisms by which economic inequality affected longevity inequality. We are tackling this limitation in ongoing research.

It is unclear whether our results can be generalized to countries outside our sample, for example, to developing countries. Finally, as with all studies that use observational data, causal inferences from our analysis cannot be made with certainty.

## Conclusions

Traditionally, scholarship in public health has focused on the effects of health care spending and its allocation as well as the effects of health care systems on health inequalities. We showed that income inequality and policies that reduce it have a substantively important association with longevity inequality in a cross-country study. Societies that are more unequal in income are also more unequal in number of years lived. We believe that this is an important argument for income redistribution, and one that is left out in the recent public debate about the rise and consequences of income inequality,<sup>37</sup> though public health scholars are ahead of social scientists in this regard.<sup>38</sup>

Governments can indirectly influence income inequality before taxes and transfers via, for example, investment in education and infrastructure and the regulation of markets. They can redistribute incomes directly via taxes and transfers. Governments can thus affect longevity inequality well beyond any specific health care policies or health and safety regulations. **AJPH**

## CONTRIBUTORS

Both authors contributed equally to all aspects of the study.

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## HUMAN PARTICIPANT PROTECTION

No protocol approval was needed because the analysis used publicly available observational data.

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