NOVEL ESTIMATES OF MORTALITY ASSOCIATED WITH POVERTY IN THE U.S.*

David Brady
(ORCID 0000-0002-4059-3272)
University of California, Riverside & WZB Berlin Social Science Center

Ulrich Kohler
(ORCID 0000-0002-5614-6063)
University of Potsdam

Hui Zheng
(ORCID 0000-0003-3085-4560)
The Ohio State University

January 22, 2023

Word Count (excluding figures, references, and appendices): 598

Replication Materials: Brady, D., Kohler, U and Zheng, H. Novel Estimates of Mortality Associated with Poverty in the U.S. -- Replication materials. Version: 1.0.0. SowiDataNet-Datorium. https://doi.org/10.7802/2528

* Direct correspondence to David Brady, School of Public Policy, University of California, INTS 4133, 900 University Ave., Riverside, CA 92521; dbrady@ucr.edu. We thank Phil Cook, Linda George, Ken Land, Bruce Link, Rourke O'Brien, Megan Reynolds, Florencia Torche, *JAMA* reviewers, and *JAMA Internal Medicine* editors for suggestions. This project was partially supported by National Institute of Aging, R03 Grant 1R03AG062842-01A1. The PSID data was partly supported by the National Institutes of Health under grant number R01 HD069609 and R01 AG040213, and the National Science Foundation under award numbers SES 1157698 and 1623684. The Cross-National Equivalent File project is supported by the National Institute on Aging (Grant: 5-R01AG040213-10) and the Eunice Kennedy Shriver National Institute of Child Health and Human Development (Grants: 1-R03HD091871-01, 1-R03HD100924-01) and was conducted by The Ohio State University.

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The U.S. perennially has far higher poverty than peer rich democracies.[1] America's high poverty presents an enormous challenge to population health given considerable research demonstrates that being poor is bad for one's health.[2] Despite prior research on income and mortality, the quantity of mortality associated with poverty in the U.S. remains unknown (see Appendix A for a literature review). We estimated the relationship between poverty and mortality and quantified the proportion and number of deaths associated with poverty.

We analyzed the Panel Study of Income Dynamics 1997-2019 merged with the Cross-National Equivalent File (see Appendix B).[3,4] This longitudinal survey observed mortality from surviving family members and validated with the National Death Index. Innovatively, our higher quality household income measure included all income sources, cash and near cash transfers, and taxes and tax credits, and was adjusted for household size.[5] Following leading international poverty research, poverty was measured relatively as less than 50% of the median income (see Appendix C).[1] Current poverty was observed contemporaneously in each year, and cumulative poverty was the proportion of the past ten years. Cox hazard regression models were estimated on 18,995 aged 15+ respondents (135,790 person-years) (see Appendix D).

Current poverty is associated with a greater mortality hazard of 1.42 [95% CI, 1.26-1.60]. Cumulative poverty – being always poor versus never poor in the past ten years – is associated with a greater mortality hazard of 1.71 [95% CI, 1.45-2.02]. Results were robust to adjustment for self-rated health, overweight/obesity, smoking, acute health events, chronic disease, and other confounders, and a wide variety of alternative details (see Appendix E).

Figure 1 shows the poor's survival mainly begins to diverge from the not poor around age 40. The gap between the poor and not poor's survival grows until a peak near 70 when it begins to converge.

[FIGURE 1 ABOUT HERE]

Figure 2 compares the number of deaths associated with poverty to other major causes and risk factors of death (see Appendix F). In 2019, among those aged 15+, 6.5% [95% CI, 4.1-9.0%] of deaths and 183,003 [95% CI, 116,173-254,507] deaths were associated with current poverty and 10.5% [95% CI, 6.9-14.4%] of deaths and 295,431 [95% CI, 193,652-406,007] deaths were associated with cumulative poverty. Current poverty was associated with greater mortality than major causes like accidents, lower respiratory diseases, and stroke. In 2019, current poverty was also associated with greater mortality than many far more visible causes – 10 times as many deaths as homicide, 4.7 times as many deaths as firearms, 3.9 times as many deaths as suicide, and 2.6 times as many deaths as drug overdose. Cumulative poverty was associated with about 60% greater mortality than current poverty. Hence, cumulative poverty was associated with greater mortality than even obesity and dementia. Heart disease, cancer and smoking were the only causes or risks with greater mortality than cumulative poverty.

[FIGURE 2 ABOUT HERE]

Because the U.S. consistently has high poverty, these estimates can contribute to understanding why the U.S. has comparatively lower life expectancy. Because certain ethno-racial minority populations are far more likely to be poor, our estimates can improve understanding of racial inequalities in life expectancy. The mortality associated with poverty also results in enormous economic costs. Therefore, benefit-cost calculations of poverty-reducing social policies should incorporate the benefits of lower mortality.[6] Finally, poverty likely aggravated the mortality impact of COVID. Therefore, the mortality associated with poverty may have likely increased after our analyses ended in 2019. Ultimately, we propose poverty should be considered a major risk factor for death in the U.S.

NOTES

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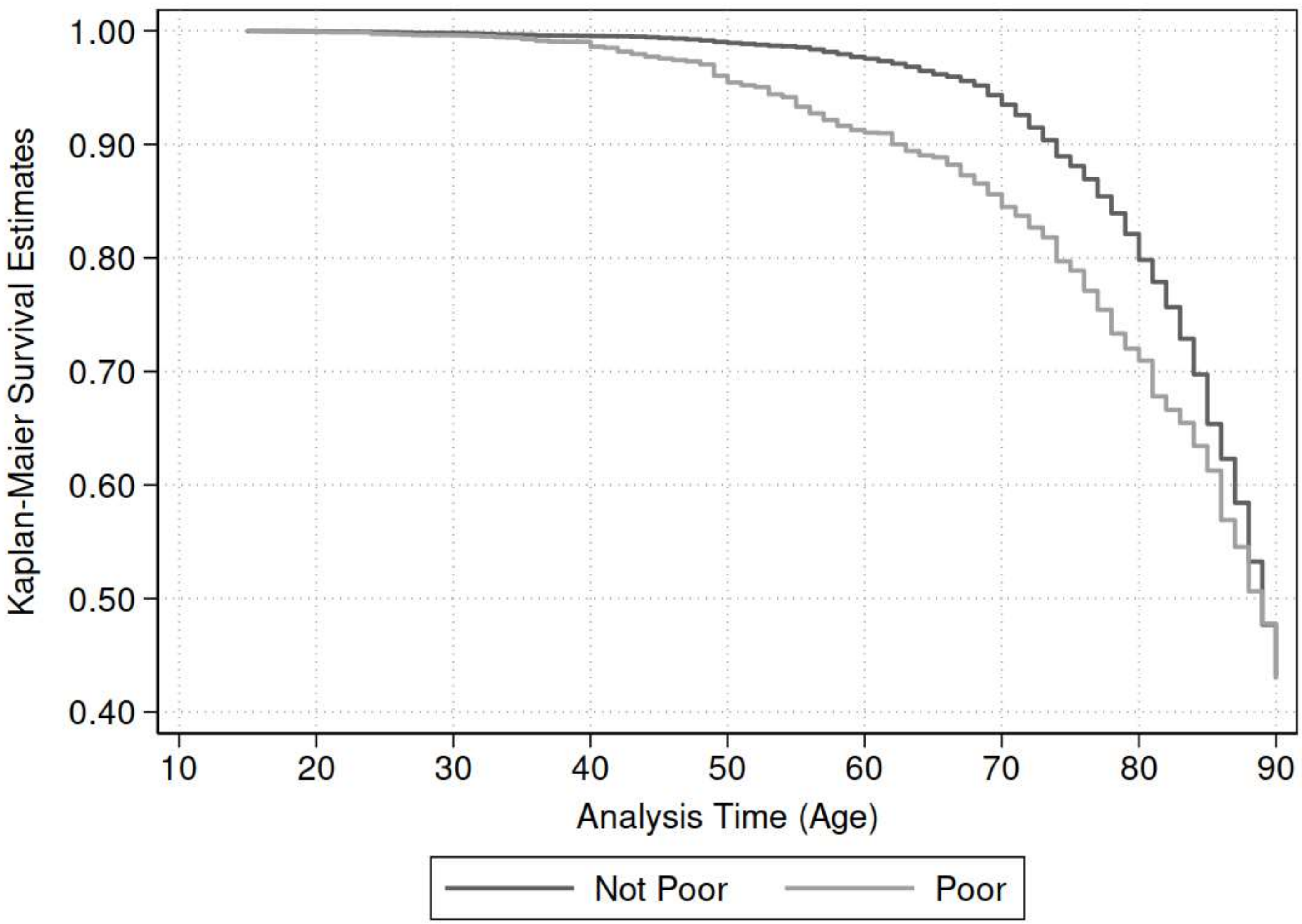

Figure 1. Survival Curve for Currently Poor and Not Poor Individuals in the U.S. (Source: PSID-CNEF 1997-2019, See Appendix D).

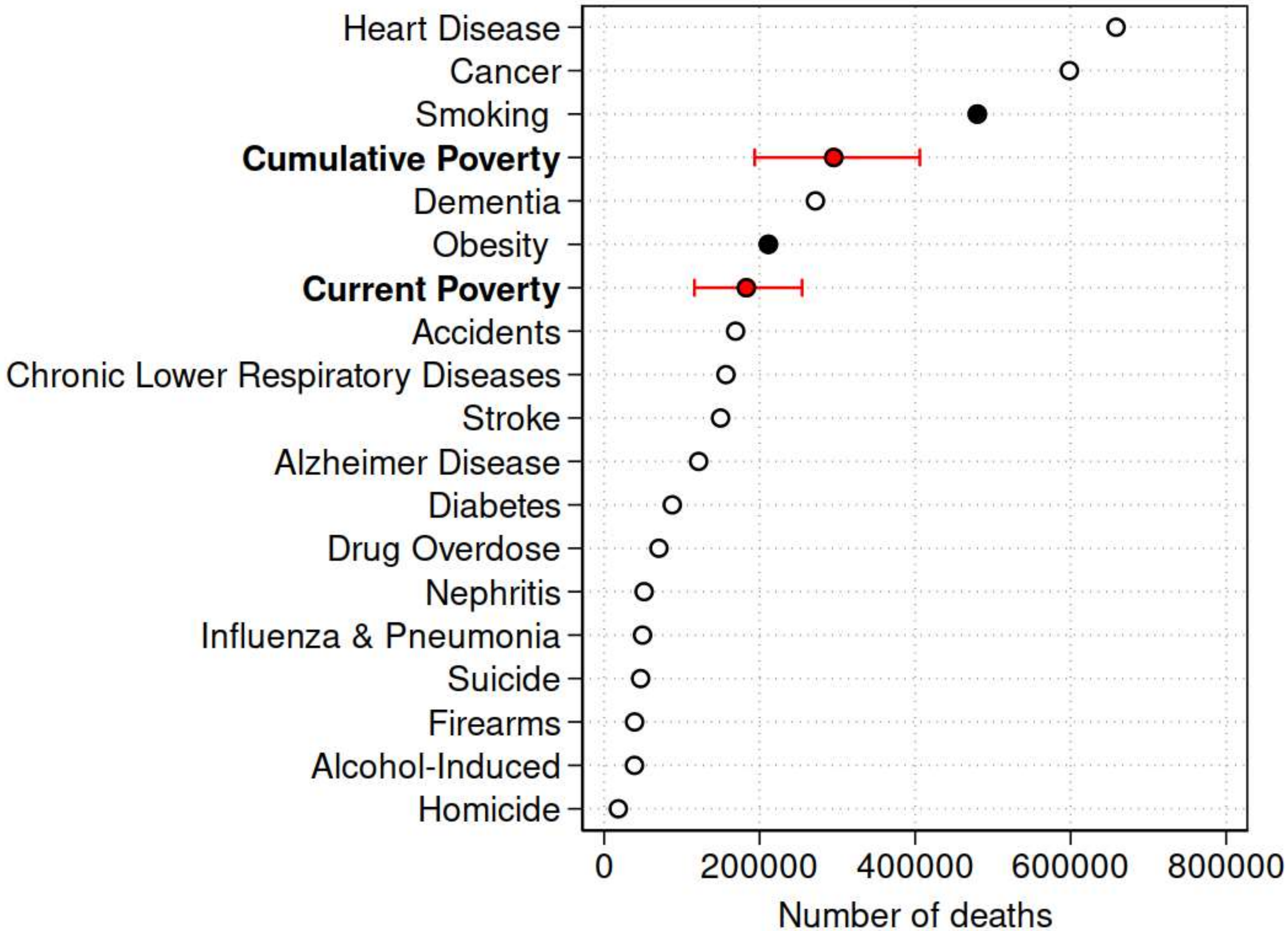

Figure 2. Number of Deaths Associated With Cumulative and Current Poverty, and Major Causes (hollow dots) and Risk Factors (filled dots) in the U.S. in 2019 (Sources: see Appendix F).

APPENDICES

Contents

APPENDIX A: Prior Research on Income, Poverty and Mortality.

Unfortunately, the quantity of mortality associated with poverty in the U.S. remains unknown. We assert this claim despite the clear contributions of several relevant literatures. Of course, literatures on the relationship between income and mortality and the income-health gradient directly informed this analysis (e.g. Backlund et al. 1996; Chetty et al. 2016; Deaton 2016; Phelan et al. 2004; Schwandt et al. 2022; Venkataramani et al. 2021; Wilkinson 2007; Woolf and Schoomaker 2019). As well, the extensive literature on the relationships between poverty, income, social class and health generally motivated our study (e.g. Adler et al. 1994; Angell 2016; Ansell 2021; Brady and Burton 2016; Brady et al. 2022; Braverman et al. 2005; Chokshi 2018; Emerson 2009; Link and Phelan 1995; Lynch et al. 1997; Rylko-Bauer and Farmer 2016; Thomson et al. 2022; Venkataramani et al. 2021).

Before reviewing studies of the specific poverty-mortality relationship, we briefly review the income-mortality literature. We concentrate on two of the most relevant examples that also use the PSID (Dowd et al. 2011; McDonough et al. 1997), and one highly visible and influential recent study (Chetty et al. 2016).

McDonough and colleagues (1997) examine 14 ten-year panels 1968-1989. They collapse the temporal variation into logistic regression models with predictors measured in the first five years and mortality observed in the subsequent five years. Like us (see Appendix D), Dowd and colleagues (2011) use Cox models to estimate the risk of mortality over 10-year follow-up periods after the 1970, 1980, and 1990 survey waves. They advance beyond prior studies by using continuous rather than categorical income. Using social security and tax records on 1.4 billion 40-73 year old U.S. residents, Chetty and colleagues (2016) show relative pretax household earnings (plus unemployment benefits) predict mortality and life expectancy.

There are at least four distinctions between our study and these prior income-mortality studies. First, we use a superior measure of income. As we explain in Appendix C, this is essential for poverty measurement. Our measure of "post-fisc" income includes all income sources (e.g. earnings, capital income, private pensions) and incorporates taxes, tax credits (e.g. the Earned Income Tax Credit), and cash and near cash transfers (e.g. the Supplemental Nutritional Assistance Program). It is essential to incorporate all transfers and tax credits because they smooth and stabilize consumption, and improve short and long-term well-being (Brady et al. 2018; Brady et al. 2022; Brady and Parolin 2020; Jenkins 2011; Smeeding 2016). In addition, following prevailing standards in international income measurement, we adjust for household size with the equivalence scale of the square root of household members (Baker et al. 2022; Brady 2009; Brady et al. 2018; Brady and Parolin 2020; Smeeding 2016). This "equivalized" measure appropriately incorporates the economies of scale of households.

This measure of post-fisc equivalized income far outperforms cruder measures of income (or wealth, occupation or earnings) as a proxy for permanent/long-term income (Brady et al. 2018), is far more consequential to subsequent life chances (Brady et al. 2020) and long-term health (Brady et al. 2022), and better explains Black-White inequalities (Brady et al. 2020).

By contrast, Dowd and colleagues (2011) and McDonough and colleagues (1997) both use the PSID's "edited family income measure". Their measure only includes labor market income, capital income, pensions, and select cash transfers (Dowd et al. report including alimony/child support, but McDonough et al. do not). Their measure does not incorporate taxes or tax credits. McDonough and colleagues also measure income coarsely, collapsing the interval distribution of income down to six binary categories of $15-20,000. Chetty and colleagues (2016) only measure income as pretax household labor market earnings plus tax exempt interest income and unemployment benefits. They omit taxes, tax credits, and other cash and near cash transfers. Indeed, even though Chetty and colleagues' sample was 40-73 years old, they exclude Social Security and disability benefits, and private and public pensions. None of these studies appears to adjust for household size using an equivalence scale.

To provide concrete empirical illustration of the differences between income measures, Table A1 summarizes the correlations between our measure of post-fisc equivalized income and "household labor market income" in the 2019 survey wave (see Appendix B on the PSID and CNEF). While the correlation is fairly strong between the two income measures in the overall sample, there is still a meaningful discrepancy. Moreover, in the bottom half of the income distribution – the most relevant population for comparing the poor to non-poor – the two measures only correlate 0.60. Hence, there are many cases where our measure of post-fisc equivalized income and cruder measures of income are quite different.

Table A1. Correlations Between Post-Fisc Equivalized Income and Household Labor Market Income in 2019 PSID-CNEF Wave (Source: See Appendix B).

	Pearson's R	Weighted N
Full Sample	0.83	18,379
Bottom Half of Income Distribution	0.60	9,975

Second, we examine a broader age range including all 15+ years old. McDonough and colleagues (1997) only examine respondents aged 45-64 (at the mid-point of their ten-year panels). Dowd and colleagues (2011) only analyze 35-64 year olds. Chetty and colleagues (2016) only analyze 40-73 year olds (and only actually observe income when aged 40-61 years old).

Third, compared to prior PSID-based studies, our sample incorporates advances in data quality (e.g. Dowd et al. 2011; McDonough et al. 1997). Notably, the PSID has significantly improved the measurement of mortality in more recent waves of data since McDonough and colleagues (1997) and Dowd and colleagues (2011) analyzed the data. As well, our data includes a much more recent time period. For instance, Dowd and colleagues examine 1970-2000, and McDonough and colleagues examine 1968-1989.

Fourth, we concentrate solely on the precise disadvantage between the poor versus others. Income coefficients predicting mortality average information from differences in mortality across the entire income distribution. For instance, income coefficients include the advantages of high income individuals versus middle income individuals. By contrast, our estimates strictly concentrate on the mortality disadvantage of the poor against the non-poor. Income and poverty coefficients would be more similar if the effect of income on mortality is linear. However, both Dowd and colleagues (2011) and McDonough and colleagues (1997) convincingly demonstrate that income has a non-linear relationship with mortality and additional increments of low incomes are particularly consequential (also Backlund et al. 1996). Because there are diminishing returns to higher incomes, income coefficients for mortality will underestimate the effect of poverty on mortality.

In addition to affecting the coefficients, there are subtle, substantive differences when focusing on poverty versus the entire income distribution. Whereas reducing income disparities would partly redistribute and compress the variation in the risk of mortality, poverty reduction should unambiguously reduce mortality and lengthen population life expectancy. Raising the poor to a moderate income level would reduce that group's exposure to the risk of mortality without necessarily affecting the mortality risk of the rest of the population. This would reduce the number of deaths and extend life expectancy without obvious offsetting mortality-increasing consequences.

Despite the need to focus on poverty specifically, only a handful of studies truly aim to assess the specific relationship between poverty and mortality. Unfortunately, all these studies used old and weaker data. They also used even weaker income measures than the income-mortality studies above. Moreover, prior studies typically used the U.S. government's deeply problematic official poverty measure (see Appendix C). Probably partly as a result of these data and measurement issues, these studies have widely varying estimates. To the best of our knowledge, only one study has estimated what proportion of deaths are attributable to poverty and that study uses data from 1971 to 1984 (Hahn et al 1996). For all these reasons, the quantity of mortality associated with poverty in the contemporary U.S. remains unknown.

Perhaps most recently, Crimmins and colleagues (2009) analyze the National Health and Nutrition Examination Survey (NHANES) 1988-1994 and 1999-2004 to estimate mortality for <1.25 of the official poverty measure among aged 20+. As explained in Appendix C, the official poverty measure is flawed and lacks validity and reliability. As detailed above and in Appendix C, we also use a far superior income measure that is not available in the NHANES. Perhaps as a result, Crimmins and colleagues estimate dramatically and perhaps implausibly larger risk ratios for poverty: "The percent dying in an age group is two to four times higher among the poor" (p.289). They find very large risk ratios of 2.58 among 20-29 year olds, 3.96 among 30-39 year olds, and 2.86 among 50-59 year olds. They estimate being poor has a much larger effect (odds ratio [OR] 5.92) on mortality than smoking (OR 1.75), heavy drinking (OR 1.37), or no exercise (OR 1.08) (see their Model 3 in Table 5, p.290). From this, they conclude (p.290) "The poor have life expectancy about 20 years shorter than the nonpoor." We cannot identify all of the reasons why our results differ so substantially from Crimmins and colleagues. Because Crimmins and colleagues' poverty estimates are old and so dramatically higher than ours and even their own estimates of consequential risk factors like smoking and obesity, we propose there is a clear need for our study. We underline advantages in terms of data quality and recency, and income and poverty measures. As well, Crimmins and colleagues did not estimate the PAF and number of deaths.

Oh (2001) uses the PSID like us, but given timing, is forced to only use the 1972 to 1992 waves. Like the PSID income-mortality studies above, this involves weaker mortality data. Like Crimmins and colleagues, Oh measures poverty as 1.25x the official poverty measure. While finding that poverty does increase the mortality risk (e.g. odds ratios of ~1.7), Oh mainly concentrates on the effects of the number and length of poverty spells for mortality. This slightly different focus means her analysis informs our analysis of cumulative poverty more than our analysis of current poverty. Moreover, the final models also include several controls that one might reasonably debate as being potentially endogenous and post-treatment to poverty.

Hahn and colleagues analyze the poverty-mortality relationship among 9,852 Black and White people aged 25-74 years old in the NHANES I. They use Cox models to predict mortality by 1981-1984 of those initially surveyed 1971-1975. They use the government's official poverty measure. They then calculate the population attributable risk (PAR) based on the 1971-1984 and 1991 poverty rates. They estimate: (i) in 1973, 6.0% of U.S. mortality among Black and White people aged 25-84 was attributable to poverty; and (ii) in 1991, 5.9% of U.S. mortality among Black and White people aged 25-84 was attributable to poverty. To the very best of our knowledge, this is the only study to estimate what share of deaths are attributable to poverty in the U.S. Although they offer an estimate for 1991 (28 years older than our 2019 estimates), their estimates are actually based on data from 1971-1984 (35-48 years older than our 2019 wave).

There are also a few older analyses. Zick and Smith (1991) analyze event history models of the effect of the official poverty measure on mortality, using the 1968-1983 waves of the PSID. Those authors find that official poverty only increases mortality for women, but not men. However, their models include several controls that could be partly post-treatment to poverty. Gortmaker (1979) uses structural equation models to estimate the effect of extreme poverty on infant mortality among White births in 1964-1965. He finds: "poverty is associated with relative risks of neonatal and postneonatal mortality 1.5 times greater than that experienced by infants not born in poverty, independent of a variety of maternal and familial characteristics and the birth weight of the infant" (p.280). Menchik (1993) examines logistic regression models of the failure to survive 17 years among a panel of older men observed 1966-1983. His estimates are more difficult to interpret as all models also adjust for prior wealth and permanent earnings, which are highly correlated with poverty. Given the age of these studies, weak poverty measures, and data limitations, these studies lack representativeness for the contemporary U.S.

A few analyze macro-level relationships between poverty and mortality. For example, Hilemeier and colleagues (2003) show simple bivariate correlations and regressions between cross-sectional child poverty and infant and child mortality. Fritzell and colleagues (2014) conduct pooled time series for 30 countries 1978-2010. Closely related to these studies is the large literature on macro-level analyses of inequality and population health (e.g. Emerson 2009;

Wilkinson 2007). While this literature is certainly theoretically and substantively valuable, the lack of individual-level data and analyses prevents one from estimating the quantity of mortality associated with poverty in the U.S.

APPENDIX B: Details on the PSID, CNEF and Sample.

The PSID is a longitudinal, nationally representative study fielded annually 1968-1997 and biannually since. Indeed, the PSID is the longest running nationally representative panel survey in the world. We select the years 1997-2019 because 1997 is when (a) the latest consistent cross-sectional weights are available and harmonized for all years; (b) to ensure consistent timing of biannual survey waves (i.e. data was collected annually before 1998); and (c) because the PSID's mortality data quality improved since the 1990s.

We also use the Cross-National Equivalent File (CNEF), which is a supplement to the PSID (Frick et al. 2007). The CNEF distinctively provides the higher quality income measures incorporating taxes, tax credits, and transfers.

We merge the CNEF with a variety of additional PSID variables in a dataset we call the "WZB-PSID File." The codebook for this dataset and the Stata code for building the file is already available at the first author's website: https://bradydave.wordpress.com/code-data/. The dataset is "semi-public" as the PSID will not allow us to freely distribute the data and requires all users of the PSID to register and procure the data directly from the PSID. That said, we plan to post the focused data file in a data repository.

All respondents aged 15+ with valid data are included in the analyses. We exclude respondents below age 15 because there are too few observed deaths in the PSID for that age group. The sample size varies by model. However, the results would be consistent if we maintained the same number of cases across models. The main models include between 12,947-18,995 respondents and 81,500-135,790 person-years (see Appendix D).

Table B1 displays descriptive statistics for our main models (see model 3, in Tables D1-D2 in Appendix D). As mentioned in the text, *mortality* was observed from surviving family members and matched with the National Death Index based on first and last name, social security number, birth month and year, and date and location of death.

Table B1. Descriptive Statistics for Main Models.

	Mean	**SD**
Panel A: Current Poverty Models (N=130,208)		
Mortality	0.012	0.110
Current Poverty	0.170	0.376
Sex=Male	0.483	0.500
Black	0.130	0.337
Other Race	0.122	0.327
Lead Education	13.366	2.709
Panel B: Cumulative Poverty Models (N=125,350)		
Mortality	0.013	0.111
Cumulative Poverty	0.166	0.278
Sex=Male	0.482	0.500
Black	0.131	0.337
Other Race	0.111	0.314
Lead Education	13.400	2.653

Table B2 reports the basic mortality prevalences for those in poverty and not in poverty within the sample. We first report these prevalences among all observations in the analytical sample, which includes multiple repeating observations for respondents. We also report these patterns based on the last observation for each respondent. The last observation for each case is determined because it is either the 2019 wave, the last observation before attrition, or the last observation because of mortality. As a result, mortality is obviously much higher in this last observation. As is clear from Table B2, mortality is much more common among currently poor respondents relative to currently non-poor respondents. As well, mortality is much more common among those who were poor for all of the past five survey waves versus those who were never poor in the past five survey waves.

Table B2. Mortality Prevalences (%) by Poverty Among All and Last Observations.

	Percentage	N
All Observations		
Current Poverty	2.1%	31,176
Not Current Poverty	1.0%	99,032
Cumulative Poverty=1	2.8%	9,170
Cumulative Poverty=0	0.9%	66,223
Last Observations		
Current Poverty	15.9%	4,148
Not Current Poverty	9.0%	12,754
Cumulative Poverty=1	19.9%	1,186
Cumulative Poverty=0	8.1%	8,400

APPENDIX C: Justification of Poverty Measurement.

We define poverty with the classic, simple conceptualization of a shortage of resources compared with needs (Smeeding 2016). Following the overwhelming majority of leading international poverty research (see e.g. Baker et al. 2022; Brady 2009; Brady and Parolin 2020; Emerson 2009; Jenkins 2011; Smeeding 2016), we use a relative measure of poverty. A relative measure defines poverty as a shortage of resources relative to needs defined by the prevailing standards of each year in the U.S. Both international and U.S.-specific studies show relative measures better predict well-being, health, and life chances; are more valid for leading conceptualizations of poverty (e.g., capability deprivation and social exclusion); are more reliable for over-time and cross-place comparisons; and are justified because of the absence of defensible absolute alternatives with fewer problems (Brady 2009; Brady and Burton 2016; Brady and Parolin 2020; Emerson 2009; Smeeding 2016).

Our measure of poverty sets the poverty threshold at 50% of the median equivalized "post-fisc" household income (see Appendix A). Again, this follows the prevailing international scientific standards (Brady 2009; Brady and Parolin 2020; Smeeding 2016). People are coded as poor if their equivalized household income is below this threshold (reference=not poor). We measure income with the CNEF's high-quality measure of post-fisc household income that incorporates taxes, tax credits, and transfers (Brady et al. 2018). We equivalize by dividing by the square root of the number of household members – the most common equivalence scale for adjusting for household size (Smeeding 2016). The poverty thresholds are established with cross-sectional population weights in the entire (not just aged 15+) sample in each year.

Current poverty was observed contemporaneously in each survey wave. *Cumulative poverty* was measured as the proportion in poverty of the last five bi-annual survey waves (i.e. ten years). Measuring cumulative poverty as the proportion of an extended period of time is a standard and well-established approach in the poverty literature (see e.g. Brady and Burton 2016; Jenkins 2011).

Unlike prior poverty-mortality analyses, we explicitly avoid the flawed official poverty measure (OPM) because it has widely-critiqued and well-documented validity and reliability problems (Baker et al. 2022; Brady 2009; Brady and Parolin 2020; Katz 1989; O'Connor 2001; Smeeding 2016). Indeed, National Academy of Sciences panels in 1995 (Citro and Michael 1995) and 2019 (National Academy of Sciences 2019) both thoroughly critiqued the OPM.

The OPM thresholds are widely understood to be far too low and the family size adjustments are incoherent (Baker et al. 2022; Katz 1989; Citro and Michael 1995; O'Connor

2001; Smeeding 2016). Also, the OPM's definition of income ignores taxes and tax credits, and inconsistently includes some transfers but omits others. For example, Temporary Assistance for Needy Families (TANF) and Old Age Survivor's Insurance (OASI, i.e. "Social Security") count as income, but the Supplemental Nutritional Assistance Program (SNAP), housing subsidies, childcare vouchers, and tax credits like the Earned Income Tax Credit (EITC) and Child Tax Credit (CTC) do not. Indeed, almost all of the government's transfers to address the COVID pandemic would be ignored by the OPM. Since the 1990s, the EITC grew into the largest assistance program for families with children. In recent years, and especially by President Biden, the CTC has been substantially expanded as well. Government spending on each of SNAP, the EITC and the CTC are now dramatically larger than on TANF. Therefore, over-time comparisons based on the OPM are particularly unreliable. Because the PSID post-fisc income measure comprehensively includes all income sources, transfers, and taxes, it is also inappropriate to apply the OPM threshold to this income measure.

It should also be noted that, despite some popular impressions, the OPM was problematic from the beginning. The OPM is often attributed to Orshansky. However, O'Connor (2001: 184) explains, "No one was more surprised, though, than Orshansky herself, who had never meant her measures as official government standards. Concerned primarily with suggesting a way to vary the measure for family size, Orshansky took pains to recognize that her work was at best an 'interim standard,' 'arbitrary, but not unreasonable,' and minimalistic at best." Katz (1989: 116) quotes Orshansky as writing, "'The best that can be said of the measure,' she wrote, 'is that at a time when seemed useful, it was there.'" The standard of needs underlying the OPM never had a clear scientific basis (Katz 1989; O'Connor 2001). Using data from the mid-1950s, Orshansky developed a rule of thumb that food amounted to roughly one-third of expenses for typical HHs on average. The evidence was never clear that this applied to low-income HHs, however. Further, the Johnson administration ended up using the "economy food plan", which was about 25% below the "low-cost food budget" used by Orshansky (Katz 1989). The economy food plan was meant for emergencies and on a temporary basis. Also, the food budgets were not subsequently revised. In the late 1960s, the government began updating the OPM thresholds using the consumer price index rather than calibrating the thresholds according to changing food budgets. This had the consequence of severing any tie to the food budget as a standard of needs. Indeed, Katz (1989: 116) quotes Orshansky as writing: "This meant, of course, that the food-income relationship which was the basis for the original poverty measure no longer was the current rationale." Moreover, and as is well known, food is certainly much less than 1/3rd of HH expenses today. As a result, the OPM effectively ignores the increased costs of important household needs like childcare and healthcare, which were less essential or much cheaper when the OPM was created.

Despite the many problems with the OPM, we test the OPM in robustness checks in Appendix E. In robustness checks in Appendix E, we also test an anchored measure. Anchored measures fix the threshold to 50% of the 1997 median equivalized post-fisc income and then adjust household income for inflation (Smeeding 2016). Although a relative measure may be less sensitive to the business cycle and economic development (or, e.g. the 2008 recession, overly sensitive), an anchored measure is more responsive (Brady and Parolin 2020).

The robustness analyses show broadly similar results with our preferred relative measure, the OPM and the anchored measure. Therefore, while we strongly advocate for using the more reliable, valid and best available measure of poverty, our conclusions do not actually depend on poverty measurement. Table C1 shows the results for model 3 with the alternative poverty measures for both current and cumulative poverty. As is clear, the substantive sizes of the hazard ratio, PAF and number of deaths are similar with all three measures. The confidence intervals for each of the three estimates overlap across all three measures. For instance, using only one decimal place, all three measures of current poverty generate a hazard ratio that rounds to 1.4 and all three measures of cumulative poverty generate a hazard ratio that rounds to 1.7.

Table C1. Comparison of Model 3 Results with Alternative Poverty Measures.

Panel A. Current Poverty.

	Relative Poverty	*OPM*	*Anchored Poverty*
Poverty-Related Mortality Hazard Ratio	1.42 [1.26, 1.60]	1.36 [1.17, 1.60]	1.40 [1.24, 1.58]
Proportion of Deaths Attributable to Poverty (PAF)	0.065 [0.041, 0.090]	0.056 [0.026, 0.089]	0.061 [0.037, 0.087]
Number of Deaths Due to Poverty in 2019	183003 [116173, 254507]	159143 [74715, 251584]	172922 [105044, 245735]
N Persons	17088	17103	17088
N Observations	130208	129632	130208
N Deaths	1538	1518	1538
BIC	1092336	1078873	1092522

Panel B. Cumulative Poverty.

	Relative Poverty	*OPM*	*Anchored Poverty*
Poverty-Related Mortality Hazard Ratio	1.71 [1.45, 2.02]	1.73 [1.39, 2.14]	1.68 [1.42, 1.99]
Proportion of Deaths Attributable to Poverty (PAF)	0.105 [0.069, 0.144]	0.106 [0.061, 0.157]	0.101 [0.064, 0.140]
Number of Deaths Due to Poverty in 2019	295431 [193652, 406007]	300690 [171759, 443907]	284009 [181027, 396231]
N Persons	16251	16255	16251
N Observations	125350	125494	125350
N Deaths	1515	1515	1515
BIC	1082524	1082442	1082668

To confirm that the PSID accurately represents U.S. poverty, we compared our poverty estimates against the Luxembourg Income Study (LIS) in Table C2. The LIS is an archive of harmonized individual-level nationally representative datasets and for the U.S. uses the Census

Bureau's March Current Population Survey. It is widely used to estimate poverty rates and is generally considered the international gold standard (Smeeding 2016). To be clear, the CNEF and LIS may have slightly different income definitions and components. However, both use the National Bureau of Economic Research's TAXSIM model to construct post-tax income and both use population weights that enable national representativeness. For this comparison, we use population weights and select only those aged 15+ as that is the analytical sample.

Table C2. Comparison of Proportion in Poverty Among Aged 15+ in PSID and LIS (population-weighted)**.**

	PSID Mean (SE)	***PSID N***	***LIS Mean (SE)***	***LIS N***
Odd Years 1997-2019	0.171 (0.001)	197,532	0.165 (0.0003)	2,139,716
1997	0.167 (0.003)	13,193	0.145 (0.001)	100,301
2019	0.191 (0.003)	17,653	0.173 (0.001)	156,925

Table C2 shows that the poverty rates are similar across the PSID and LIS. The PSID has a slightly higher poverty rate in odd years 1997-2019, and even more so in the single years 1997 and 2019. However, it seems fair to conclude the PSID reasonably approximates the poverty rates with the much larger LIS/CPS surveys.

APPENDIX D: Cox Models.

We use Cox models, which are a standard event history modeling technique (e.g. Dowd et al. 2010). The analyses were conducted in Stata v17, although we obtained identical results with R. For replication and transparency, we will make the data and code publicly available. We use attained age as the time metric. For respondents who died, exposure to mortality risk was calculated as age of death. For the surviving respondents, we computed exposure to mortality risk as the age of last contact or the last survey these individuals participated in. The Cox models weight respondents based on the last observed weight for each respondent.

The models include several control variables. All time-varying variables – including poverty – are measured over time. For instance, we even use PSID waves prior to 1997 to ensure we include all prior information on respondents. *Sex* is measured with a binary measure indicating male (reference=female). *Race* is measured with self-reported binary categories for Black and Other Race (reference=White). The "head" of the household is defined as the respondent with the highest labor market earnings, with ties broken by age and for remaining ties with the PSID's indicator for the household's reference person. *Head's education* is measured with binary categories for less than high school and college+ (reference=some college/high school). *Self-rated health* is the classic five category measure (5=excellent, 4=very good, 3=good, 2=fair, 1=poor). Body Mass Index (*BMI)* categories are measured with binary indicators for 11-18, 18.5-24.99, 25-29.99, 30-34.99, and above 35. *Smoking* status is measured with a self-reported indicator (reference=not a smoker). *Acute events* are measured with a binary measure of whether the respondent has ever had a doctor inform them they had a stroke or heart attack. *Chronic conditions* is a binary measure if the respondent reports any of the following: asthma, high blood pressure, cancer, diabetes, arthritis or lung disease.

After obtaining the hazard ratios from the Cox model, we calculate the population attributable mortality risk fraction (PAMRF or PAF, for brevity) using the following formula:

$$PAF = \frac{\sum_j \left(C_j RR_j - C_j \ RR_j\right)}{\sum_j \left(C_j RR_j\right)} \tag{1}$$

where j represents the categories of poverty status, C_j is the proportion of j_{th} poverty status in the population, and RR_j is the relative mortality risk of j_{th} poverty status relative to the reference category (those not in poverty), which can be obtained from the hazard ratios in the Cox model.

C_j is the counterfactual proportion of the j_{th} poverty status in the population when all the respondents in this trajectory are assigned to the reference category. For example, in Model 3 of Table D1, the poverty-related mortality hazard ratio is 1.42. The proportion of population aged 15 and older in poverty in 2019 is 0.164 according to the Luxembourg Income Study Database (LIS). Then the PAF associated with poverty is ((1.42*0.164+1*0.836)-1)/(1.42*0.164+1*0.836) = 0.065. The total number of deaths aged 15 and older in the U.S. in 2019 is 2,824,597 according to National Vital Statistics Reports (NVSR). Therefore, the number of deaths associated with poverty in 2019 is 183,003 (=0.065*2,824,597). To approximate some uncertainty in the estimates, we report 95% confidence intervals for the poverty-related mortality hazard ratio, the PAF and the number of deaths due to poverty.

We tested the proportional hazards assumption on the basis of Schoenfeld residuals after fitting Model 3 in Table D1 and Table D2. Tests failed to reject this assumption for current poverty (rho: -0.04, chi-square 3.00, p=0.08) and cumulative poverty (rho: -0.01, chi-square 0.26, p=0.61). To further illustrate the proportional hazards assumption, we display the log-log plot of survival <stphplot> from Stata for model 3 in Figure D1.

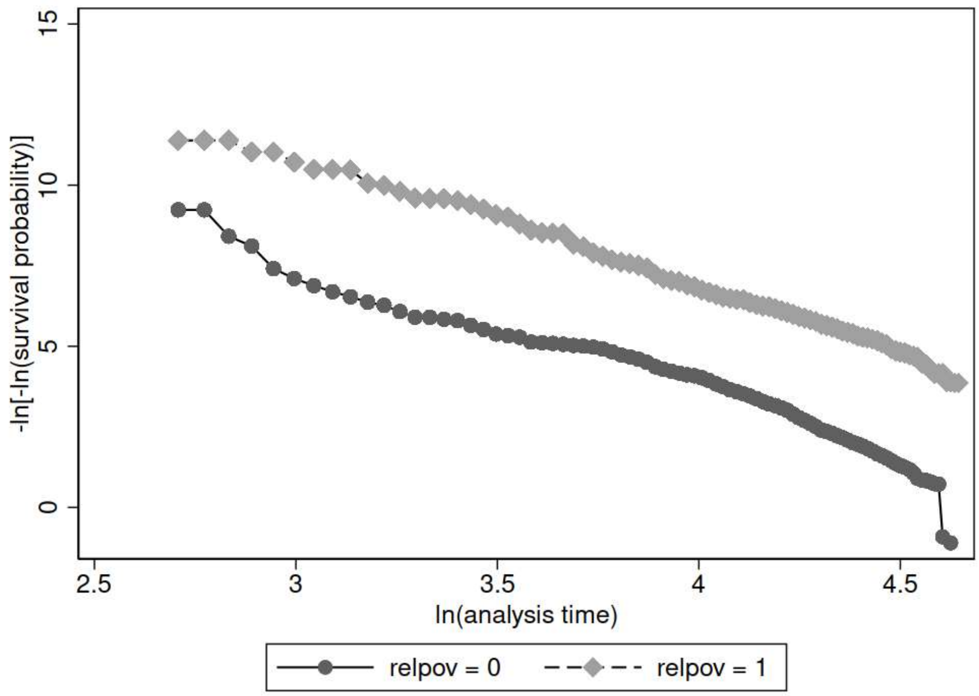

Figure D1. Plot for Proportional Hazards Assumption Corresponding to Model 3 in Table D1.

Table D1 shows the Cox models for current poverty. Table D2 repeats the same sequence of Cox models for cumulative poverty. Models 1-3 adjust for pre-treatment controls: year in Model 1, sex and race in Model 2, and head of household's education in Model 3. The results are similar across models with both current and cumulative poverty, which confirms the robustness of the results. The third models in Tables D1 and D2 serve as our principal models. The reason these are our principal models is because the additional controls in models 4-8 are likely endogenous to and post-treatment for poverty. Such post-treatment controls block some of the pathways from poverty to mortality and hence conceal some of poverty's potential effects.

In addition to these nine models for each measure of poverty, we conducted a wide variety of robustness checks, which we discuss in Appendix E.

<u>Table D1.</u> Current Poverty-Related Mortality Hazard Ratios from Cox Model, Estimated Proportion of All-Cause Mortality Attributable to Relative Poverty, and Estimated Number of Deaths Due to Relative Poverty in 2019.

	Model 1	*Model 2*	***Model 3***	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*	*Model 9*
Poverty-Related Mortality Hazard Ratio	1.45 [1.30, 1.61]	1.43 [1.28, 1.60]	1.42 [1.26, 1.60]	1.34 [1.18, 1.53]	1.44 [1.26, 1.65]	1.37 [1.20, 1.56]	1.40 [1.23, 1.59]	1.39 [1.22, 1.58]	1.37 [1.19, 1.58]
Proportion of Deaths Attributable to Poverty (PAF)	0.068 [0.046, 0.091]	0.066 [0.044, 0.090]	0.065 [0.041, 0.090]	0.053 [0.029, 0.080]	0.068 [0.041, 0.097]	0.057 [0.031, 0.084]	0.061 [0.036, 0.089]	0.060 [0.035, 0.087]	0.058 [0.031, 0.087]
Number of Deaths Deaths Due to Poverty in 2019	192183 [131040, 257138]	187620 [125028, 254254]	183003 [116173, 254507]	151099 [81463, 226193]	191206 [114972, 273473]	160382 [88512, 237964]	173705 [102659, 250165]	169462 [97716, 246786]	162781 [87268, 244590]
Controls Included	Year	M1 + gender & race	M2 + head's education	M3 + self rated health	M3 + BMI categories	M3 + smoking status	M3 + acute events	M3 + chronic conditions	M3 + all controls
N Persons	18995	17304	17088	13960	12947	13649	13652	13648	12945
N Observations	135790	133018	130208	99446	81500	92754	92746	92679	81325
N Deaths	1557	1554	1538	1401	1093	1260	1255	1256	1084
BIC	1103082	1099718	1092336	1021103	773485	900172	893577	895342	759478

<u>Table D2.</u> Cumulative Poverty-Related Mortality Hazard Ratios from Cox Model, Estimated Proportion of All-Cause Mortality Attributable to Cumulative Poverty, and Estimated Number of Deaths Due to Cumulative Poverty in 2019.

	Model 1	*Model 2*	***Model 3***	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*	*Model 9*
Poverty-Related Mortality Hazard Ratio	1.70 [1.49, 1.95]	1.72 [1.48, 1.99]	1.71 [1.45, 2.02]	1.58 [1.32, 1.89]	1.63 [1.34, 1.99]	1.59 [1.33, 1.90]	1.62 [1.36, 1.93]	1.65 [1.38, 1.96]	1.55 [1.27, 1.90]
Proportion of Deaths Attributable to Poverty (PAF)	0.103 [0.074, 0.135]	0.105 [0.073, 0.139]	0.105 [0.069, 0.144]	0.086 [0.050, 0.127]	0.094 [0.053, 0.139]	0.088 [0.052, 0.128]	0.092 [0.055, 0.132]	0.096 [0.059, 0.136]	0.083 [0.042, 0.129]
Number of Deaths Due to Poverty in 2019	292052 [209047, 380857]	296481 [206529, 393222]	295431 [193652, 406007]	244291 [140232, 358642]	265468 [149378, 393927]	248677 [145670, 361665]	259542 [156695, 372104]	270487 [165411, 385486]	234257 [118630, 363021]
Controls Included	Year	M1 + gender & race	M2 + head's education	M3 + self rated health	M3 + BMI categories	M3 + smoking status	M3 + acute events	M3 + chronic conditions	M3 + all controls
N Persons	17796	16349	16251	13173	12305	12892	12895	12891	12303
N Observations	129786	127513	125350	96034	78927	89646	89619	89575	78760
N Deaths	1529	1528	1515	1394	1086	1252	1247	1248	1077
BIC	1090875	1088448	1082524	1015399	768762	894380	887939	889639	754678

Model 3 of Table D1 shows current poverty is associated with a greater mortality hazard of 1.4 (95% CI, 1.3-1.6). In 2019, about 6.5 percent (CI, 4.1-9.0) of and 183,003 (CI, 116,173-254,507) deaths were associated with current poverty. In model 3 of Table D2, cumulative poverty is associated with a greater mortality hazard of 1.7 (CI, 1.5-2.0). In 2019, about 10.5 percent (CI, 6.9-14.4) of and 295,431 (CI, 193,652-406,007) deaths were associated with cumulative poverty.

Models 4-9 adjust for – in the last valid observation – self-rated health, body-mass index, smoking, prior heart attack and stroke events, chronic conditions, and all controls. These models addressed selection resulting from health or health behaviors causing both poverty and/or mortality. These models also adjusted for health/health behavior differences between the poor and non-poor. Again, because health/health behaviors are endogenous to poverty and thus likely mediate some of its effects, the poverty coefficients in models 4-9 are likely lower than the true total effect. Still, we suggest it is worthwhile to show the relationship between poverty and mortality even net of health or health behaviors.

Across models 4-9 in Table D1, current poverty is associated with a greater mortality hazard of 1.3-1.4. In 2019, 5.3-6.8 percent of and 151,099-191,206 deaths were associated with current poverty. Across models 4-9 in Table D2, cumulative poverty is associated with a greater mortality hazard of 1.6-1.7. In 2019, 8.3-9.6 percent of and 234,257-270,487 deaths were associated with cumulative poverty. Thus, the estimates were similar in magnitude when adjusting for health and health behaviors. The results held regardless of whether poverty was measured currently or cumulatively.

APPENDIX E: Robustness Checks.

We conducted a wide variety of additional analyses to ensure our results are robust. Again, our principal estimate is from model 3 of Tables D1 and D2. In this robustness analysis, we also include the estimates from the seven other models in Tables D1 and D2. In addition, we conducted the following additional analyses based on model 3: (a) adding additional controls (i.e. marital status, binary for children in the household, and employment status), (b) jacknifing by dropping one year at a time, (c) jacknifing by dropping one 5-year age group at a time, (d) using the OPM and an anchored poverty measure instead of our preferred relative measure, (e) not using population weights, and (f) considering left truncation.

Our robustness analysis generates a large number of estimates for the hazard ratio. We are not particularly concerned with any one estimate. Indeed, many of these estimates are certainly less credible than the estimate in model 3 of Tables D1-D2. For instance, it is certainly preferable to use population weights rather unweighted data. The question is whether the distribution of estimates centers near our reported estimate in model 3 of Tables D1-D2.

Figure F1 shows the kernel density to visualize the distribution of the estimated hazard ratios. The vertical red lines indicate the hazard ratio from model 3 of Tables D1-D2. As is clear, the vast majority of the estimates are near and roughly normally distributed around the vertical red lines. Figure F1 confirms that our reported estimates are representative of reasonable alternative estimates. As we explain in Figure F2, there are a small number of unusually lower hazard ratios. However, even those lower estimates are statistically significantly positive.

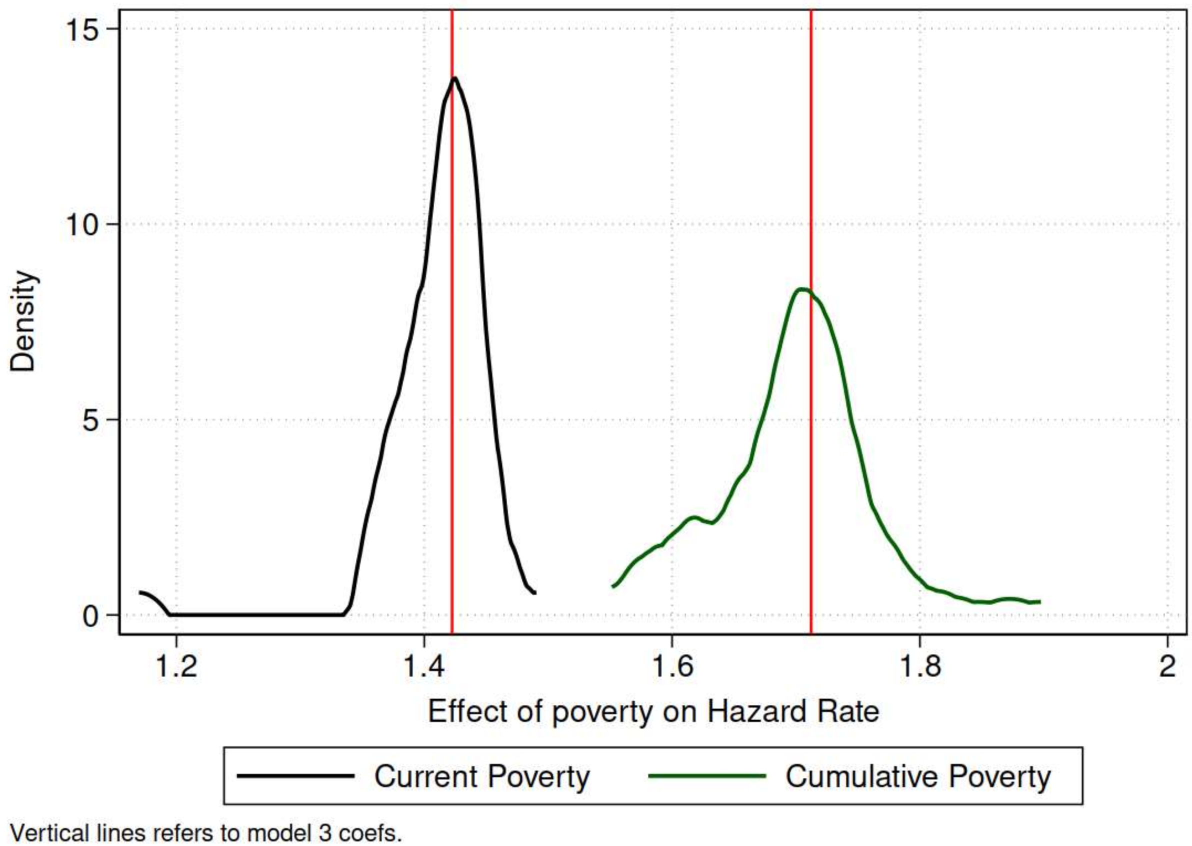

Figure F1. Kernel Density of Hazard Ratios for Poverty in Cox Models of Mortality.

Figure F2 provides more precise detail on the distribution of estimates in Figure F1. The top row and vertical red lines indicate the hazard ratios from model 3 in Tables D1-D2 (with confidence intervals). The next two rows show the seven other models in Tables D1-D2, which are near and generally consistent with the main estimate. The fourth row adds additional control variables (i.e. marital status, binary for children in the household, and employment status). Some of those controls could plausibly be at least partly endogenous to poverty (albeit poverty is also endogenous). Therefore, these estimates could underestimate the hazard ratio. Still, the fourth row shows estimates similar to model 3 of Tables D1-D2.

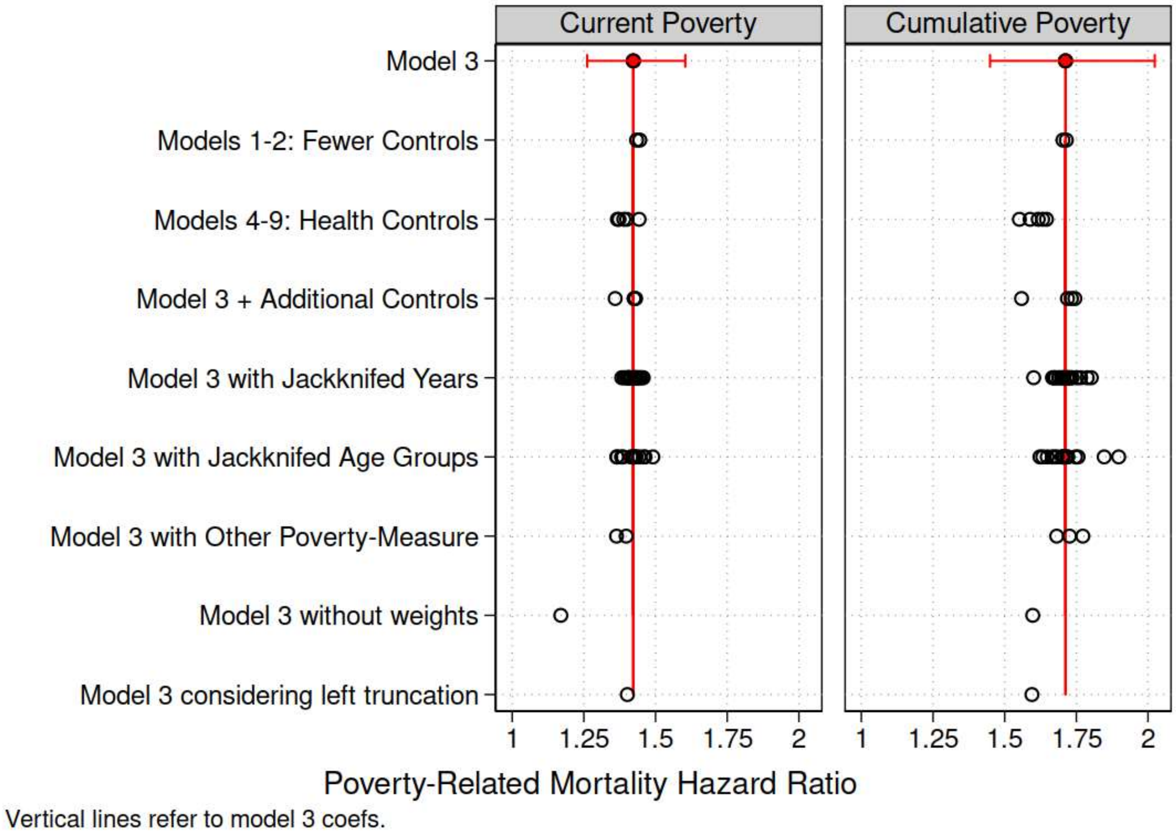

Figure F2. Precise Distribution of Hazard Ratios for Poverty in Cox Models of Mortality.

The fifth and sixth rows show the hazard ratio while jackknifing by years or 5-year age groups. The results exhibit some heterogeneity but are fairly normally distributed around the model 3 Table D1 and Table D2 estimates. The seventh row shows that the hazard ratio would be substantively similar with the OPM or anchored poverty measures. The eighth row shows that when using no weights, the hazard ratio for poverty to mortality would be smaller. We emphasize that it is not defensible to use no weights. Nevertheless, we emphasize that the hazard ratios would still be statistically significantly different from zero. Further, these lowest bounds estimates are outliers compared to the vast majority of hazard ratios in the robustness analyses. Finally, the last row shows the results are similar when considering left truncation.

As mentioned above, these analyses use the last observed weight for each respondent. Unfortunately, Stata's Cox models command does not allow for time-varying weights. However, R does have a Cox models command that allows for time-varying weights. Therefore, we also replicated the analyses while using R. In Table F1, we compare the main model 3 from Stata alongside two estimations of model 3 using R: (a) model 3 using the last observed weight, and (b) model 3 using time-varying weights. Unfortunately, R does not allow for weights of zero, which sometimes occur in the time-varying weights. Therefore, model 3 using time-varying weights is forced to drop some observations with zero weights. This means the models with time-varying weights have smaller Ns. Nevertheless, as is clear from Table F1, the results are nearly identical with time-varying weights. As well, we are able to replicate the Stata results for model 3 with the last weight in R.

Table F1. Comparison of Model 3 with Stata and R and Using Time-Varying Weights.

Panel A. Current Poverty.

	Stata Last Observed Weight	*R Last Observed Weight*	*R Time-Varying Weights*
Poverty-Related Mortality Hazard Ratio	1.42 [1.26, 1.60]	1.42 [1.26, 1.60]	1.40 [1.25, 1.58]

Panel B. Cumulative Poverty.

	Stata Last Observed Weight	*R Last Observed Weight*	*R Time-Varying Weights*
Poverty-Related Mortality Hazard Ratio	1.71 [1.45, 2.02]	1.71 [1.45, 2.02]	1.69 [1.43, 1.99]

Finally, for future robustness analyses by others, we reiterate that we will make the data and code publicly available.

APPENDIX F: Sources and Details for Figure 2.

Figure 2 is simply intending to illustrate how the magnitude of mortality associated with poverty compares to major, well-studied and highly visible precursors to death. We conjecture that poverty is reasonably compared with other (and more visible and more widely studied) risk factors like obesity and smoking. Of course, underlying risk factors like poverty, obesity and smoking influence actual proximate causes (e.g. Angell 2016; Link and Phelan 1995),

For the major causes of death, we use the estimates from the 2019 National Vital Statistics Reports (Xu et al. 2021). We specifically use Table 6, which provides major causes of death for each age group (and allows us to calculate sums for aged 15+). Because we sum the numbers of deaths for those only aged 15+, these are not the total number of deaths as we exclude those aged 0-14.

For the smoking estimates, we used the CDC (2020). The reported figure is 480,000 deaths per year. Their estimate does not distinguish by age. Therefore, we presume all 480,000 deaths occurred among those aged 15+ - even if some small number of smoking-related deaths may have occurred among those <15.

For the obesity estimates, we relied on others' studies. In 2000, obesity accounts for between 111,909 (about 4.7%) (Flegal et al., 2005) and 365,000 deaths (about 15.2%) per year (Mokdad et al., 2004). Preston and colleagues (2018) suggests obesity accounts for about 7.4% of deaths at ages 40-84 in 2011. We multiply Preston and colleagues PAF of 0.074 against the total number of deaths of 2,824,597 in 2019 (Xu et al. 2021), which gives us an estimate of 209,020 deaths.

APPENDIX G: References for Appendices.

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