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Association Between County-Level Change in Economic Prosperity and Change in Cardiovascular Mortality Among Middle-aged US Adults

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IMPORTANCE After a decline in cardiovascular mortality for nonelderly US adults, recent stagnation has occurred alongside rising income inequality. Whether this is associated with underlying economic trends is unclear.

OBJECTIVE To assess the association between changes in economic prosperity and trends in cardiovascular mortality in middle-aged US adults.

DESIGN, SETTING, AND PARTICIPANTS Retrospective analysis of the association between change in 7 markers of economic prosperity in 3123 US counties and county-level cardiovascular mortality among 40- to 64-year-old adults (102 660 852 individuals in 2010).

EXPOSURES Mean rank for change in 7 markers of economic prosperity between 2 time periods (baseline: 2007-2011 and follow-up: 2012-2016). A higher mean rank indicates a greater relative increase or lower relative decrease in prosperity (range, 5 to 92; mean [SD], 50 [14]).

MAIN OUTCOMES AND MEASURES Mean annual percentage change (APC) in age-adjusted cardiovascular mortality rates. Generalized linear mixed-effects models were used to estimate the additional APC associated with a change in prosperity.

RESULTS Among 102 660 852 residents aged 40 to 64 years living in these counties in 2010 (51% women), 979 228 cardiovascular deaths occurred between 2010 and 2017. Age-adjusted cardiovascular mortality rates did not change significantly between 2010 and 2017 in counties in the lowest tertile for change in economic prosperity (mean [SD], 114.1 [47.9] to 116.1 [52.7] deaths per 100 000 individuals; APC, 0.2% [95% CI, −0.3% to 0.7%]). Mortality decreased significantly in the intermediate tertile (mean [SD], 104.7 [38.8] to 101.9 [41.5] deaths per 100 000 individuals; APC, −0.4% [95% CI, −0.8% to −0.1%]) and highest tertile for change in prosperity (100.0 [37.9] to 95.1 [39.1] deaths per 100 000 individuals; APC, −0.5% [95% CI, −0.9% to −0.1%]). After accounting for baseline prosperity and demographic and health care–related variables, a 10-point higher mean rank for change in economic prosperity was associated with 0.4% (95% CI, 0.2% to 0.6%) additional decrease in mortality per year.

CONCLUSIONS AND RELEVANCE In this retrospective study of US county-level mortality data from 2010 to 2017, a relative increase in county-level economic prosperity was significantly associated with a small relative decrease in cardiovascular mortality among middle-aged adults. Individual-level inferences are limited by the ecological nature of the study.

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Cardiovascular mortality rates for nonelderly adults in the US over the last decade have stopped declining and, for some populations, have even increased.[1-3] The factors driving these trends in cardiovascular mortality are poorly understood but may be related to underlying economic trends given the strong association between cardiovascular disease and economic indicators such as income.[4]

Understanding how economic trends have influenced cardiovascular mortality is crucial for devising strategies to address this stagnation. This is especially true given rising levels of income inequality within the US.[5] The economic recovery after the 2008-2009 recession has been uneven, leading to significant disparities in economic prosperity between different areas of the US. Several studies have demonstrated the association between individual-level social determinants of health, as well as markers of community-level economic activity and cardiovascular health and mortality.[6-8] However, due to the cross-sectional design of many of these studies, it is unclear whether changes in economic prosperity correspond to changes in health outcomes and whether stagnating mortality rates could be associated, in part, with worsening community economic prosperity.

This study evaluated whether changes in relative economic prosperity in the postrecession period have been associated with trends in cardiovascular mortality rates for middle-aged adults—the segment of the population in which the departure from long-standing secular declines in cardiovascular mortality has been previously noted—using county-level mortality and economic data.[3]

Key Points

Question Are changes in county-level economic prosperity associated with changes in cardiovascular mortality among middle-aged adults (aged 40-64 years) in the US?

Findings In this retrospective analysis of county-level mortality data from 3123 US counties from 2010 to 2017, every 10-point greater change in economic prosperity from baseline to follow-up (range, 5 to 92) was significantly associated with a 0.4% lower cardiovascular mortality rate per year among middle-aged adults.

Meaning In US counties from 2010 to 2017, a relative increase in economic prosperity was associated with a small relative decrease in cardiovascular mortality among middle-aged adults.

Methods

This analysis was considered exempt from review by the University of Pennsylvania institutional review board guidelines because it uses publicly available data routinely collected for public health purposes.

Mortality Data

We obtained restricted mortality data from the National Center for Health Statistics, which includes details on every recorded death in the US including age, sex, year of death, race/ethnicity, cause of death, and county of residence at the time of death from January 2010 to December 2017.[9]

Change in Economic Prosperity

Change in economic prosperity was based on the Distressed Communities Index, which is composed of 7 markers of economic activity drawn from the US Census Bureau's American Community Survey 5-Year Estimates and Business Patterns data sets and is available for all counties with more than 500 residents.[10] We calculated the absolute change in the following markers of economic prosperity between the baseline (2007-2011) and follow-up (2012-2016) periods: (1) housing occupancy rate, (2) ratio of the county median household income to state median household income, (3) percentage of 25- to 64-year-old adults working, (4) percentage of the adult population with a high school education, (5) percentage of the population with income above the poverty threshold, (6) percentage change in the number of business establishments between the first and last years of the time period, and (7) percentage change in the number of jobs between the first and last years of the time period. Change in economic prosperity was then determined by ranking counties for change in each of these markers on a scale from 0 to 100 and calculating an unweighted mean of these ranks. Counties with a higher mean rank had a greater increase, or lower decrease, in economic prosperity relative to counties with a lower mean rank. Change in economic prosperity follows an approximately normal distribution (eFigure 1 in the Supplement). Baseline (2007-2011) economic prosperity levels were determined by taking the mean of the rankings of the baseline value of each economic prosperity marker on a scale of 0 to 100, with a higher rank indicating greater relative baseline economic prosperity compared with a lower-ranked county. Tertiles of baseline economic prosperity levels across the US are displayed in eFigure 2 in the Supplement.

Data sources for other demographic and health care-related covariates included are listed in eMethods 1 in the Supplement.

Outcomes

The primary outcome measure was the annual percentage change (APC) in county-level, aggregated, age-adjusted (to the 2000 US population) cardiovascular mortality rates per 100 000 individuals for 40- to 64-year-old adults. Distributions for baseline and change in mortality are displayed in eFigure 3 in the Supplement and yearly mortality levels across the US by tertiles are displayed in eFigures 4, 5, 6, 7, 8, 9, 10, and 11 in the Supplement.

Secondary outcomes included mortality from cardiovascular disease subgroups (ischemic heart disease and stroke), all causes, diseases of the circulatory system (a broader definition of cardiovascular disease), and cancer. Cause of death was based on *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* codes and utilized previously used classifications (eTable 1 in the Supplement).[11]

Statistical Analysis

Counties were divided into tertiles based on change in prosperity. Annual, population-weighted, mean mortality rates were calculated for each tertile. Mean APC in mortality rates from 2010 to 2017 was estimated for each tertile using the generalized linear mixed model (GLMM), described here, with a linear year predictor.

To estimate the additional APC associated with a relative change in economic prosperity, we used GLMMs, which allow for the analysis of longitudinal and hierarchical data with nonnormal distributions. A negative binomial distribution with a log link was used (eMethods 2 in the Supplement). The primary model included baseline economic prosperity, year, and an interaction between year and change in prosperity (on a continuous scale). The interaction term was the primary variable of interest with an interpretation as the estimated difference in the APC between 2 counties with a difference of 10 ranks for mean rank for change in economic prosperity. The model included county-level time-varying demographic and health care–related variables: proportion of county residents that are female, non-Hispanic Black, Hispanic, have diabetes, have obesity, and have health insurance, and density of hospital beds and primary care physicians and 1 time-invariant variable: proportion of residents living in rural areas in 2010. A spatial power covariance structure accounted for the longitudinal nature of the data and state random intercepts for clustering of counties within states. Random effects were assumed to have a normal distribution with a mean of zero. Robust standard errors were used.

Secondary analyses included examining secondary outcomes as listed above. Given significant differences in cardiovascular mortality between non-Hispanic White and racial and ethnic minority populations, as well as between men and women previously noted,[3] we analyzed race and ethnicity subgroups and male and female mortality rates separately. Racial and ethnic groups with small numbers of residents in many counties were not included in subgroup analyses due to statistical instability. Deaths were assigned to sex and race/ethnicity subgroups based on reported values on death certificates, which have been shown to adequately classify Black and White race as well as Hispanic ethnicity (greater than 90% agreement between death certificates and self-reported race and ethnicity).[12] Mortality rates for other age groups were also analyzed.

For each model, we calculated the absolute additional annual change in mortality rates associated with a change in prosperity (based on the population-weighted median mortality rate in 2010). We also constructed GLMMs with alternative distributions, with change in economic prosperity as a quadratic term and as a categorical variable to assess whether our findings were robust to the model assumptions. We also constructed alternative conditional GLMMs without state random effects, which allowed comparison of goodness-of-fit statistics of different models (which was not possible in the primary analysis). The primary GLMM was also estimated stratified by different levels of baseline economic prosperity, and with change in each of the prosperity markers separately.

All analyses were weighted by the relevant county population, unless specified otherwise. Data are presented as means with SDs or 95% CIs or medians and interquartile ranges (IQRs). All *P* values were 2-sided and values of less than or equal to .05 were considered statistically significant. Because of the potential for type I error due to multiple comparisons, findings for secondary analyses and secondary end points should be interpreted as exploratory. All statistical analyses were conducted using SAS version 9.4 (SAS Institute).

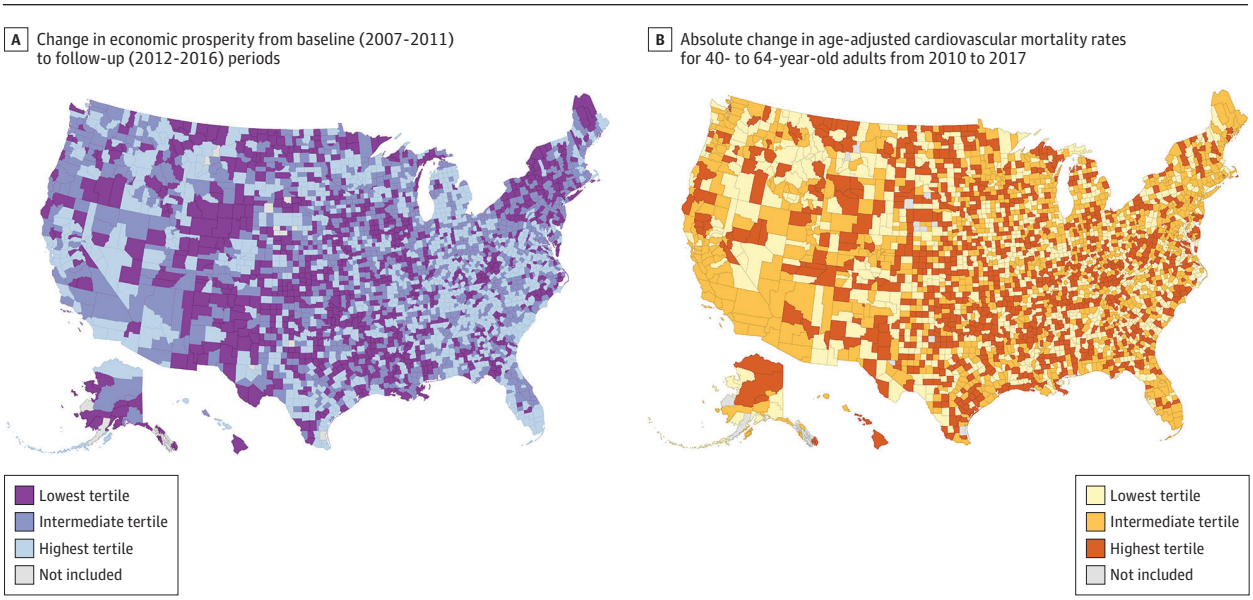
Results

A total of 3123 US counties were included (**Figure 1**), with 20 counties excluded that had economic prosperity markers unavailable. Data on covariates were available for all included counties. Mean rank for change in economic prosperity ranged from 5.4 to 91.9 overall (mean [SD], 49.9 [13.9]), from 5.4 to 43.8 in the lowest tertile, 43.8 to 56.0 in the intermediate tertile, and 56.1 to 91.9 in the highest tertile for change in economic prosperity. In 2010, a total of 102 660 852 individuals aged 40 to 64 years lived in the included counties (51.0% women). Demographic and health care–related variables, in 2010, for the 3 groups of counties are listed in **Table 1**. Counties in the lowest tertile for change in prosperity had the lowest median population (7078; IQR, 3172-16 684), highest percentage of residents in rural areas (25.9%; IQR, 10.9%-53.3%), highest percentage of residents with diabetes (9.1%; IQR, 8.0%-10.4%) and obesity (29.3%; IQR, 26.9%-32.4%), lowest median number of primary care physicians per 100 000 residents (68.5; IQR, 47.2-88.7), and the lowest percentage of county residents with health insurance (85.8%; IQR, 81.3%-89.9%). The mean prevalence of diabetes and obesity increased significantly in all 3 groups of counties from 2010 to 2016 (eTable 2 in the Supplement). The total number of 40- to 64-year-old residents decreased in counties in the lowest tertile for change in prosperity, but increased in the other 2 groups of counties over the study period (eTable 3 in the Supplement). County characteristics by baseline prosperity tertiles are listed in eTable 4 in the Supplement.

Between the baseline and follow-up periods, counties in the lowest tertile for change in economic prosperity experienced a median decrease in 4 of 7 markers of prosperity: housing occupancy rate, ratio of county median household income to state median household income, percentage of 25- to 64-year-old adults working, and percentage of the population with income above the poverty threshold (**Table 2**). These counties experienced a median increase in the percentage of adults with a high school education. The median percentage change in business establishments over a period increased from −4.9% (IQR, −7.8% to −1.4%) in the baseline period to −1.7% (IQR, −5.0% to 1.1%) in the follow-up period. The median percentage change in employment over each period increased from −3.7% (IQR, −8.5% to 1.4%) to 0% (IQR, −6.1% to 4.7%).

Counties in the intermediate tertile experienced a median decrease in 3 markers: housing occupancy rate, percentage

Figure 1. Counties by Tertile of Change in Economic Prosperity and Change in Age-Adjusted Cardiovascular Mortality Rates (40- to 64-Year-Old Adults)



Maps are based on the US National Atlas Equal Area Projection and reflect county geographic size and not population. A, Change in economic prosperity is the unweighted mean of the ranks for change in the 7 markers of economic prosperity between baseline (2007-2011) and follow-up (2012-2016). A higher mean rank indicates a greater relative increase or lower relative decrease in economic prosperity compared with other counties. The mean rank for change in economic prosperity ranged from 5.4 to 43.8 for the lowest tertile (n = 1041), 43.8 to 56.0 for the intermediate tertile (n = 1041), and 56.1 to 91.9 for the highest tertile (n = 1041); 20 counties did not have data available and were not included. The lightest hue indicates relative improvement in prosperity.

B, The change in age-adjusted cardiovascular mortality was −611 to −14 deaths per 100 000 individuals in the lowest tertile (n = 1041), −14 to 21 in the intermediate tertile (n = 1041), and 21 to 666 in the highest tertile (n = 1041); 20 counties did not have data available and were not included. The lightest hue indicates a declining or stable cardiovascular mortality rate.

The primary analysis in Table 3 accounts for changes in mortality rates across all years from 2010 to 2017. Distribution of baseline economic prosperity levels and annual cardiovascular mortality rates across the US are available in eFigures 2, 4, 5, 6, 7, 8, 9, 10, and 11 in the Supplement.

of 25- to 64-year-old adults working, and percentage of the population with income above the poverty threshold. There was no change in the median ratio of county median household income to state median household income. The median percentage change in business establishments over a period increased from −6.5% (IQR, −9.1% to −3.8%) to 0.6% (IQR, −2.4% to 3.6%). The median percentage change in employment over each period increased from −6.3% (IQR, −11.1% to −1.7%) to 4.2% (IQR, −0.8% to 9.2%).

Counties in the highest tertile experienced a median increase in all markers of economic prosperity. The median percentage change in business establishments over a period increased from −7.4% (IQR, −10.9% to −4.2%) to 2.0% (IQR, −1.1% to 6.3%). The median percentage change in employment over each period increased from −8.7% (IQR, −14.0% to −3.6%) to 8.1% (IQR, 2.3% to 13.6%).

The mean (SD) (population-unweighted) baseline prosperity levels were 53.3 (28.0) in the lowest tertile, 52.5 (28.4) in the intermediate tertile, and 44.2 (29.4) in the highest tertile for change in prosperity.

Primary Analysis

There were 979 228 cardiovascular deaths among 40- to 64-year-old adults between 2010 and 2017. Age-adjusted cardiovascular mortality rates did not change significantly from 2010 to 2017 in counties in the lowest tertile for change in prosperity (mean [SD], 114.1 [47.9] to 116.1 [52.7] deaths per 100 000 individuals; mean APC, 0.2% [95% CI, −0.3% to 0.7%]). Mortality rates decreased significantly in the intermediate tertile (mean [SD], 104.7 [38.8] to 101.9 [41.5] deaths per 100 000 individuals; mean APC, −0.4% [95% CI, −0.8% to −0.1%]) and highest tertile for change in prosperity (mean [SD], 100.0 [37.9] to 95.1 [39.1] deaths per 100 000 individuals; mean APC, −0.5% [95% CI, −0.9% to −0.1%]) (**Figure 2**; eTable 5 in the Supplement). After accounting for baseline economic prosperity and time-varying demographic and health care-related factors, for every 10-point higher mean rank for change in economic prosperity, counties had an additional 0.40% (95% CI, 0.22% to 0.58%) decrease in mortality per year (**Table 3**). Distribution of random effects, sensitivity tests, and goodness-of-fit statistics in the conditional GLMMs suggest that the main model was appropriately specified (eFigure 12, eTable 6, and eTable 7 in the Supplement).

Secondary Analyses

Ischemic heart disease mortality rates decreased significantly in all 3 groups of counties (mean APC, −0.7% [95% CI, −1.2% to −0.2%] for counties in the lowest tertile, −1.3% [95%, −1.7% to −0.9%] for counties in the intermediate tertile, and −1.7% [95% CI, −2.3% to −1.1%] for counties in the highest tertile for change in prosperity) (Figure 2; eTable 8 in the Supplement). Stroke mortality rates did not change signifi-

Table 1. County Characteristics (2010) by Tertile of Change in Economic Prosperity[a]

Characteristic	Median (IQR)		
	Lowest tertile	Intermediate tertile	Highest tertile
No. of counties[b]	1041	1041	1041
Demographics			
County population (No. of individuals aged 40-64 y)[c]	7078 (3172-16 684)	11 944 (5051-31 658)	8964 (4052-23 813)
Percentage of residents living in rural areas[d]	25.9 (10.9-53.3)	8.6 (1.6-27.3)	4.5 (1.1-20.3)
Percentage of residents aged 40-64 y[e]			
Women	50.9 (50.0-51.6)	51.2 (50.7-51.9)	51.2 (50.5-51.7)
Men	49.1 (48.4-50.0)	48.8 (48.1-49.3)	48.8 (48.3-49.5)
Hispanic (all races)	3.3 (1.6-9.7)	5.2 (2.4-12.9)	9.1 (2.8-20.8)
Non-Hispanic Black	6.2 (1.5-13.9)	8.8 (2.9-15.7)	7.4 (2.6-18.6)
Non-Hispanic White	82.1 (67.3-92.2)	75.0 (55.5-88.6)	68.9 (49.9-83.0)
Cardiovascular risk factors			
Percentage of residents aged ≥20 y[f]			
Diabetes	9.1 (8.0-10.4)	8.9 (7.8-10)	8.5 (7.6-9.5)
Obesity	29.3 (26.9-32.4)	27.9 (24.3-30.7)	26 (22.9-29.5)
Health care–related variables			
Primary care physicians per 100 000 residents[g]	68.5 (47.2-88.7)	70.8 (55.7-88.1)	73.6 (55.6-90.2)
Hospital beds per 100 000 residents[h]	314.2 (191.0-445.5)	268.6 (195.1-390.7)	256.8 (166.3-356.7)
Health insurance coverage, percentage of residents aged 40-64 y[i]	85.8 (81.3-89.9)	85.2 (80.7-89.4)	83.4 (79.9-86.7)

Abbreviation: IQR, interquartile range.

[a] Change in economic prosperity is the unweighted mean of the ranks for change in the 7 markers of economic prosperity between baseline (2007-2011) and follow-up (2012-2016). A higher mean rank indicates a greater relative increase or lower relative decrease in economic prosperity compared with lower-ranked counties. The mean rank for change in economic prosperity ranged from 5.4 to 43.8 for the lowest tertile, 43.8 to 56.0 for the intermediate tertile, and 56.1 to 91.9 for the highest tertile.

[b] Includes all US counties except for 20 counties that did not have economic prosperity markers available.

[c] Unweighted calculation. All other calculations weighted by county population.

[d] Rural areas are defined by the US Census Bureau as areas with fewer than 2500 residents.

[e] Sex, race, and ethnicity as reported on death certifications. Racial/ethnic groups other than Hispanic (all races), non-Hispanic Black, or non-Hispanic White were not included in analyses due to the small number across most US counties.

[f] Diabetes and obesity prevalence are based on self-reported diagnosis, height, and weight from the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System.

[g] The number of primary care physicians per county was obtained from the Health Resources & Services Administration Area Health Resource File.

[h] The number of hospitals beds per county was obtained from the American Hospital Association annual survey.

[i] Proportion of county residents with health insurance was obtained from the US Census Bureau's Small Area Health Insurance Estimates program.

cantly in the 3 tertiles. Change in economic prosperity was associated with change in ischemic heart disease (−0.51% [95% CI, −0.74% to −0.29%]) and stroke (−0.26% [95% CI, −0.47% to −0.04%]) mortality rates (Table 3). All-cause mortality rates increased in counties in the lowest and intermediate tertiles (mean APC, 0.9% [95% CI, 0.7% to 1.2%] and 0.6% [95% CI, 0.3% to 0.9%], respectively) but did not change significantly in the highest tertile (mean APC, 0.01% [95% CI, −0.3% to 0.3%]) (Figure 2; eTable 9 in the Supplement). Change in economic prosperity was significantly associated with change in all-cause mortality rates (−0.47% [95% CI, −0.58% to −0.35%]) (Table 3).

Trends in cardiovascular mortality rates in each tertile for change in economic prosperity by race and ethnicity subgroups as well as for men and women are displayed in eTables 10 and 11 in the Supplement. The association between change in economic prosperity and additional APC in cardiovascular mortality rates was significant for each race and ethnicity subgroup (non-Hispanic Black: −0.60% [95% CI, −0.92% to −0.27%], non-Hispanic White: −0.53% [95% CI, −0.72% to −0.33%], and Hispanic [all races]: −0.57% [95% CI, −1.05% to −0.08%]) and for women (−0.58% [95% CI, −0.88% to −0.27%]) and men (−0.35% [95% CI, −0.57% to −0.12%]) (Table 3). Mortality rates for other age groups (20-39 years of age and 65 years and older), cancer-specific mortality, and mortality from disease of the circulatory system are listed in eTables 12 and 13 in the Supplement. The association between change in economic prosperity and change in cardiovascular mortality rates was statistically significant in each tertile of baseline prosperity levels (eTable 14 in the Supplement). Increase in each of the individual economic prosperity markers, except the proportion of adults with a high school education, was associated with a significant decrease in the APC for cardiovascular mortality (eTable 15 in the Supplement).

Discussion

From 2010 to 2017, US counties with the lowest relative improvements in economic prosperity experienced no change in cardiovascular mortality rates for middle-aged adults. During this period, cardiovascular mortality rates declined significantly in the remainder of US counties. A relative increase

Table 2. Economic Prosperity Markers by Tertile of Change in Economic Prosperity (Values Not Weighted by County Population)[a]

	Lowest tertile			Intermediate tertile			Highest tertile		
	Baseline (2007-2011)	Follow-up (2012-2016)	Change	Baseline (2007-2011)	Follow-up (2012-2016)	Change	Baseline (2007-2011)	Follow-up (2012-2016)	Change
No. of counties[b]	1041			1041			1041		
Mean population across time period (adults aged 40-64 y)[c]	17 351 277	17 191486	−159 791	41 638 173	42 354 659	716 486	42 328 045	44 332 251	2 004 206
Baseline economic prosperity level, mean (SD)[d]	53.3 (28.0)			52.5 (28.4)			44.2 (29.4)		
Economic prosperity marker, median (IQR)									
Housing occupancy rate, %	90.1 (87.2 to 92.5)	88.5 (85.5 to 91.2)	−1.3 (−2.9 to −0.1)	90.6 (88.1 to 93.1)	90.4 (87.6 to 93.0)	−0.2 (−1.6 to 1.0)	89.9 (86.6 to 92.5)	90.7 (87.6 to 93.2)	0.8 (−0.5 to 2.2)
Ratio of county median household income to state median household income	0.9 (0.8 to 1.0)	0.8 (0.7 to 0.9)	−0.03 (−0.1 to 0.002)	0.9 (0.8 to 1.0)	0.9 (0.8 to 1.0)	−0.003 (−0.03 to 0.03)	0.9 (0.8 to 1.0)	0.9 (0.8 to 1.1)	0.03 (0.0 to 0.1)
Proportion of working adults aged 25-64 y, %[e]	70.1 (64.4 to 76.8)	67.8 (61.1 to 74.9)	−2.2 (−4.4 to −0.7)	71.2 (65.9 to 76.4)	70.9 (65.0 to 76.0)	−0.3 (−1.6 to 0.8)	69.7 (62.8 to 75.0)	70.9 (64.0 to 76.6)	1.1 (−0.1 to 2.6)
Proportion of adults with a high school education, %	85.0 (79.6 to 89.1)	86.6 (80.4 to 90.2)	1.1 (0.1 to 2.3)	85.8 (80.5 to 89.4)	87.7 (83.2 to 91.1)	1.8 (0.9 to 3.0)	84.3 (77.5 to 88.6)	87.1 (81.6 to 90.9)	2.8 (1.5 to 4.3)
Proportion of the population with income above the poverty threshold, %	85.2 (81.0 to 88.8)	83.3 (78.4 to 87.2)	−1.8 (−3.5 to −0.5)	85.3 (81.5 to 88.8)	84.6 (80.6 to 88.8)	−0.7 (−1.7 to 0.5)	84.2 (79.5 to 88.4)	85.3 (81.2 to 89.0)	0.6 (−0.6 to 2.3)
Percentage change in business establishments[f]	−4.9 (−7.8 to −1.4)	−1.7 (−5.0 to 1.1)	3.0 (−1.4 to 6.7)	−6.5 (−9.1 to −3.8)	0.6 (−2.4 to 3.6)	7.0 (3.3 to 10.4)	−7.4 (−10.9 to −4.2)	2.0 (−1.1 to 6.3)	10.0 (5.7 to 14.2)
Percentage change in employment[g]	−3.7 (−8.5 to 1.4)	0.0 (−6.1 to 4.7)	3.3 (−5.3 to 10.4)	−6.3 (−11.1 to −1.7)	4.2 (−0.8 to 9.2)	10.8 (3.7 to 17.7)	−8.7 (−14.0 to −3.6)	8.1 (2.3 to 13.6)	17.3 (9.0 to 24.7)

Abbreviation: IQR, interquartile range.

[a] Change in economic prosperity is the unweighted mean of the ranks for change in the 7 markers of economic prosperity between baseline (2007-2011) and follow-up (2012-2016). A higher mean rank indicates a greater relative increase or lower relative decrease in economic prosperity compared with lower-ranked counties. The mean rank for change in economic prosperity ranged from 5.4 to 43.8 for the lowest tertile, 43.8 to 56.0 for the intermediate tertile and 56.1 to 91.9 for the highest tertile.

[b] Includes all US counties except for 20 counties with economic prosperity markers unavailable.

[c] Based on mean population during the baseline (2007-2011) or follow-up (2012-2016) periods.

[d] Baseline economic prosperity is the unweighted mean rank (scaled from 0 to 100) of 7 markers of economic prosperity in the baseline period (2007-2011).

[e] Indicates percentage of all 25- to 64-year-old residents in a county (including those not in the labor pool) who are employed. This differs from the employment rate, which is limited to individuals in the labor pool.

[f] Relative percentage change in the number of business establishments between the first and last years of the time period.

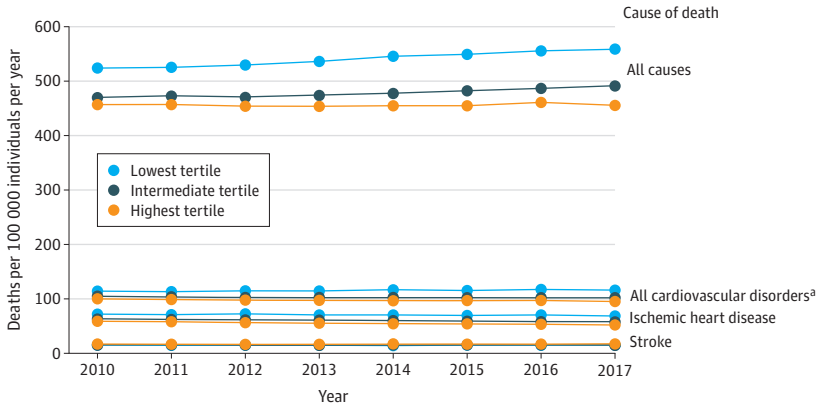
[g] Relative percentage change in the number of jobs between the first and last years of the time period.

in county-level economic prosperity was associated with a relative decrease in annual cardiovascular mortality rates for middle-aged adults in the US during this period.

There may be multiple mechanisms by which economic factors influence health. Job insecurity and income volatility may be associated with cardiovascular events.[4,13,14] Worsening economic prosperity may lessen social cohesion and increase income inequality, contributing to a community's health.[15] The postrecession period in the US has seen the rise of "deaths of despair" (eg, deaths from drug poisoning, suicide, alcoholic liver disease), which have also been attributed to worsening social cohesion.[16] This study suggests that in certain areas of the country, a relative decrease or stagnation in economic prosperity was associated with mortality from causes beyond those typically considered as deaths of despair. Possible biological mechanisms for how economic stress can worsen cardiovascular health include upregulation of inflammation.[17] It is also possible that worsening economic prosperity may lead healthy individuals to emigrate, resulting in higher mortality rates for the remaining population. Counties in the lowest tertile for change in economic prosperity had a declining population; however, the analysis accounted for changes in age structure as well as changes in the prevalence of 2 important cardiovascular risk factors: diabetes and obesity.

A larger rural population was noted in counties with a decrease or stagnation of economic prosperity, in line with prior studies that have described an increase in cardiovascular mortality rates in the past decade in rural areas.[2,18,19] Rural areas of the US experienced a disproportionately greater increase in unemployment during the 2008-2009 economic recession and have not experienced the same level of recovery as other parts of the country.[20] This analysis also found that the association between economic prosperity and cardiovascular mortality was significant for non-Hispanic Black and Hispanic individuals, along with non-Hispanic White individuals. Studies of deaths of despair have highlighted the association between economic factors and

Figure 2. Population-Weighted Mean Annual Age-Adjusted Mortality Rates (40- to 64-Year-Old Adults) by Tertile of Change in Economic Prosperity



Change in economic prosperity is the unweighted mean of the ranks for change in the 7 markers of economic prosperity between baseline (2007-2011) and follow-up (2012-2016). A higher mean rank indicates a greater relative increase or lower relative decrease in economic prosperity compared with lower-ranked counties. The mean rank for change in economic prosperity ranged from 5.4 to 43.8 for the lowest tertile (n = 1041), 43.8 to 56.0 for the intermediate tertile (n = 1041), and 56.1 to 91.9 for the highest tertile (n = 1041). Counties with economic prosperity markers unavailable were not included.

[a] All cardiovascular disorders include ischemic heart disease and stroke.

Table 3. Generalized Linear Mixed-Effects Model Estimates for Relative Additional Percentage Change in Mortality per Year With 10-Point Greater Change in Economic Prosperity[a,b]

	Additional absolute change in mortality rate per year with 10-point greater change in economic prosperity, deaths per 100 000 individuals per year (95% CI)[c]	Additional annual percentage change in mortality per year with 10-point greater change in economic prosperity, % (95% CI)[d]
Primary outcome: age-adjusted cardiovascular mortality rate		
All residents aged 40-64 y	0.40 (0.22 to 0.58) fewer deaths	−0.40 (−0.58 to −0.22)
Secondary outcomes		
Age-adjusted cardiovascular mortality rate		
Individuals aged 40-64 y		
Female	0.34 (0.16 to 0.51) fewer deaths	−0.58 (−0.88 to −0.27)
Male	0.50 (0.18 to 0.82) fewer deaths	−0.35 (−0.57 to −0.12)
Non-Hispanic Black	1.16 (0.53 to 1.80) fewer deaths	−0.60 (−0.92 to −0.27)
Non-Hispanic White	0.49 (0.31 to 0.67) fewer deaths	−0.53 (−0.72 to −0.33)
Hispanic (all races)	0.41 (0.06 to 0.76) fewer deaths	−0.57 (−1.05 to −0.08)
Age-adjusted ischemic heart disease mortality rate[e]		
All individuals aged 40-64 y	0.30 (0.17 to 0.43) fewer deaths	−0.51 (−0.74 to −0.29)
Age-adjusted stroke disease mortality rate[e]		
All individuals aged 40-64 y	0.04 (0.01 to 0.07) fewer deaths	−0.26 (−0.47 to −0.04)
Age-adjusted all-cause mortality rate		
All individuals aged 40-64 y	2.15 (1.62 to 2.68) fewer deaths	−0.47 (−0.58 to −0.35)

[a] Model adjusted for baseline economic prosperity, year, percentage of residents living in rural areas in 2010, and the following time-varying covariates: percentage of residents who are female (except for sex subgroups), percentage of residents who are non-Hispanic Black (except for racial/ethnic subgroups), percentage of residents who are Hispanic (except for racial/ethnic subgroups), percentage of adult residents with diabetes, percentage of adult residents with obesity, primary care physicians per 100 000 residents, hospital beds per 100 000 residents, and percentage of residents with health insurance.

[b] Change in economic prosperity is the unweighted mean of the ranks for change in the 7 markers of economic prosperity between baseline (2007-2011) and follow-up (2012-2016). A 10-point greater change indicates 10 ranks higher for mean rank for change in economic prosperity on a scale ranging from 5.4 to 91.9.

[c] Indicates the estimated absolute difference in the number of deaths per 100 000 individuals per year (based on population-weighted median mortality rate in 2010) between 2 counties with a difference of 10 ranks for mean rank for change in economic prosperity, holding all other variables constant.

[d] Regression estimate for interaction term between year and change in economic prosperity. Indicates the estimated difference in the annual percentage change in mortality between 2 counties with a difference of 10 ranks for mean rank for change in economic prosperity, holding all other variables constant.

[e] Subset of deaths from all cardiovascular disorders (primary outcome).

mortality for non-Hispanic White individuals.[21,22] However, the current analysis suggests that for cardiovascular mortality, the association between economic prosperity and mortality at the county level is significant for non-Hispanic Black

and Hispanic populations as well. This is plausible given the greater prevalence of cardiovascular risk factors, such as diabetes and obesity, and on average higher rates of poverty among non-Hispanic Black and Hispanic populations in the US compared with the non-Hispanic White population.[23-25]

Limitations

This study has several limitations. First, due to the observational design of the study, the associations noted cannot be concluded to be causal. Second, unmeasured confounding is likely, although several important demographic and health care–related variables were accounted for that have a plausible association with cardiovascular mortality. Third, because the economic prosperity markers were not available for each individual year, it is not possible to rule out potential reverse causality, ie, an increase in cardiovascular mortality leading to worsening prosperity. However, it does allow for an analysis of the overall direction of change in prosperity in counties over the study period. Fourth, because all data are aggregated at the county level, inferences at the individual level cannot be made. Fifth, the analysis relies on the recorded cause of death; it is possible that deaths from cardiovascular disease may be miscoded.[26] However, when a broader definition (mortality from diseases of the circulatory system) was used, the results were concordant to the main analysis. Sixth, these results may not be generalizable beyond the study period of 2010 to 2017 and may not reflect the potential influence that economic distress related to the coronavirus disease 2019 pandemic may have on cardiovascular mortality.

Conclusions

In this retrospective study of US county-level mortality data from 2010 to 2017, a relative increase in county-level economic prosperity was significantly associated with a small relative decrease in cardiovascular mortality among middle-aged adults. Individual-level inferences are limited by the ecological nature of the study.

ARTICLE INFORMATION

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