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Original article: *The association between income and life expectancy revisited: deindustrialisation, incarceration, and the political economy of public health*

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Abstract

Background: The health gap between the top and the bottom of the income distribution is widening rapidly in the United States, but the lifespan of America's poor depends substantially on where they live. We ask whether two major developments in American society, deindustrialisation and incarceration, can explain variation amongst states in life expectancy of those in the lowest income quartile.

Methods: Life expectancy estimates at age 40 of those in the bottom income quartile were used to fit panel data models examining the relationship with deindustrialisation and incarceration between 2001 and 2014 for all U.S. states.

Results: A one standard deviation increase in deindustrialisation (mean = 11.2, s.d. = 3.5) reduces life expectancy for the poor by 0.255 years (95% CI: 0.090-0.419) and each additional prisoner per 1000 residents (mean = 4.0, s.d. = 1.5) is associated with a loss of 0.468 years (95% CI: 0.213-0.723). Our predictors explain over 20% of the state level variation in life expectancy amongst the poor and virtually the entire increase in the life expectancy gap between the top and the bottom income quartiles since the turn of the century.

Conclusions: In the U.S. between 2001 and 2014, deindustrialisation and incarceration subtracted roughly two and a half years from the lifespan of the poor, pointing to their role as major health determinants. Future research must remain conscious of the upstream determinants and the political economy of public health. If public policy responses to growing health inequalities are to be effective, they must consider strengthening industrial policy and ending hyper-incarceration.

Key words: Life expectancy; inequality; deindustrialisation; incarceration; political economy of public health

Key messages

- Deindustrialisation and incarceration constitute major upstream determinants of inequalities in life expectancy in the United States.
- Future research must look beyond proximal mechanisms of disease to the political and economic determinants of public health.
- If public policy responses to growing health inequalities are to be effective, they must consider strengthening industrial policy and ending hyper-incarceration.

The association between income and life expectancy revisited

Deindustrialisation, incarceration, and the political economy of public health

Introduction

Reducing health inequalities is one of the most important challenges facing contemporary society. Not only is this an issue of fairness and social justice, but such inequalities also generate substantial economic costs, including lower productivity, reduced tax revenue, greater welfare payments, and higher treatment costs.[1] Moreover, as the latest American Presidential Elections demonstrated, they may even have a profound political impact, with poor health outcomes fuelling the Trump vote.[2] Previous research has revealed substantial inequalities in life expectancy in the United States between income groups, genders, ethnicities, and geographies alike.[3] However, most attention has focused on proximal causes of these disparities, especially unhealthy behaviours like smoking and poor diets,[4] or on the social determinants of health, such as income inequality, unemployment, racial discrimination, or neighbourhood context.[5] Few studies have sought to examine the more distal political and economic roots of these determinants, i.e. the *causes of the causes* of health inequality. The purpose of this study is to investigate, for the first time, deindustrialisation and incarceration as *upstream determinants* of life expectancy in the bottom income quartile in the United States.

In a recent paper, Chetty et al.[6] examine the relationship between income and life expectancy in the United States between 2001 and 2014. They demonstrate how

life expectancy tends to rise with income and how health inequalities between top and bottom income groups have widened rapidly over time. Moreover, whilst the rich tend to live longer everywhere, life expectancy amongst the poor shows significant geographical variation. The authors suggest a role for local area characteristics but refrain from further analysis. We shed light on state level determinants of life expectancy in the bottom income quartile, drawing on the interface of two principal literatures. First, we leverage insights from studies in the U.S. and elsewhere documenting the health effects of economic shocks and social dislocation.[7-11] These studies track the deleterious impacts of rapid industrial decline, heightened inequality, and rampant unemployment. Second, we take our cues from research on the relation between punishment and public health in post-industrial America[12-18] showing that prisons and jails both manifest and precipitate ethno-racial inequities, serve as vectors for ill health, stigmatise former inmates in ways that harm their life chances, and destabilise social relations and health in sending communities. Rather than being a simple measure of crime or mere racial animosity, (hyper-)incarceration is construed as a punitive political response to pervasive social division and insecurity wrought by accelerated economic stratification, as evidenced by the *triple filter of class, race, and place* whereby the penal apparatus distinctly targets poor African Americans of post-industrial wastelands.[19] On the other hand, in some urban areas, the loss of productive workers, resulting family disruptions, and reduced opportunities for ex-prisoners have all contributed to economic decline.[20] Gargantuan growth in incarceration has fostered further economic decay, fuelled by the aggressive criminalisation of urban spaces by means of selective targeting and preferential confinement, higher probability of incarceration, and longer sentences for society's most vulnerable.[19-22]

Against this backdrop, we hypothesise a causal link from deindustrialisation and incarceration to life expectancy amongst the poor. We use panel data analysis to examine the validity of these hypotheses. Our Appendix Table A1 provides a typology of the existing literature on the topic and situates the current study, which, by virtue of constituting the first upstream analysis of its kind of health inequality in America, addresses a major gap in scientific knowledge.

Data and methods

Our dependent variable is annual state level life expectancy at age 40 stratified by income quartile for men and women for all 50 U.S. states between 2001 and 2014. These public-use data from the Health Inequality Project (HIP) are generated from 1.4 billion tax records between 1999 and 2014 linked to mortality data from Social Security Administration (SSA) death records.[6] Deindustrialisation is measured by the annual state level job destruction rate for manufacturing (NAICS sector 31-33), the number of jobs lost to establishment contraction or closure in a year divided by the employment at the beginning of the year. Data on employment and job destruction come from the U.S. Census Statistics of U.S. Businesses Employment Change Data Tables. State level incarceration rates from the Bureau of Justice Statistics express the count of prisoners serving sentences of more than one year per 1000 state residents. Table 1 provides summary statistics of these variables, and Appendix Table A2 presents the correlation matrix.

[*Table 1 about here*]

We draw on a series of data sources to conduct a sensitivity analysis. We extract data on drug overdose mortality rates at the state level. We calculate the state fraction of those earning less than $25 000 p.a. who are without any form of health insurance; who, at the time of being surveyed, are current smokers; who have gone without physical exercise in the past 30 days; and who are overweight or obese. The same variables are also calculated for those earning more than $75 000 p.a. as proxy controls for the top income quartile. These income thresholds, roughly corresponding to our income quartiles, are the ones defined by the Centers for Disease Control and Prevention's survey design. We also assess the robustness of our predictors to expenditure on social security, healthcare, and welfare, labour force participation rate, relative size of the manufacturing sector, GDP per capita, economic growth, and homicide rate. Full variable definitions and sources are provided in Table 2.

[*Table 2 about here*]

In our analysis, we estimate fixed effects panel data models. Fixed effects models allow the constant element of the composite error term to be arbitrarily correlated with the explanatory variables and are thus frequently preferred in econometric analysis to adjust for potential bias caused by time-invariant variable omission. Our decision is supported by a Hausman test ($\chi^2 = 30.998$ on 15 degrees of freedom, p-value = 0.009). This is the equivalent of having a dummy variable for each state, thereby estimating only the variation within states over time. Our fixed effects model looks as follows:

$$LE_{it} = \alpha_i + \delta_t + \beta_1 DI_{i,t-1} + \beta_2 IR_{i,t-1} + \beta_3 C'_{it} + \epsilon_{it}$$

where LE_{it} is life expectancy in the bottom income quartile for state i at time t; α_i and δ_t are individual and time effects, respectively; *DI* is deindustrialisation and *IR* the incarceration rate at time t-1, thus allowing for lagged effects; *C* designates a set of control variables; and ε_{it} is the stochastic disturbance. All analyses were conducted using the R software.[23]

Findings

In Figure 1, life expectancy at age 40 in the bottom income quartile is plotted against job destruction rate in manufacturing, lagged one year, as a measure of deindustrialisation. A linear estimator is used to measure the gradient between the two variables, which is negative. Thus, an increase in deindustrialisation in a given year is negatively associated with life expectancy amongst the poor in the following year. The second scatterplot (Figure 2) is similar, only this time life expectancy at age 40 is plotted against state level incarceration rates per 1000 U.S. residents, also lagged one year. The slope is negative and steep, indicating a pronounced inverse association between life expectancy and high imprisonment. The time series plot in Figure 3 compares the level of life expectancy in the bottom income quartile between states characterised by low and high incarceration rates over time. The plot conveys how inequalities between low- and high-incarceration states are distinct: poor lives are over 1.5 years shorter in states in the top incarceration decile (mean IR = 6.946 prisoners per 1000 residents) relative to states in the bottom decile (mean IR = 1.852

prisoners per 1000 residents) and there is some indication of a growing gap. Moreover, Appendix Figures A1 and A2 enable an approximate estimation of the long-term effects of deindustrialisation and the legacy of slavery. That former slave states are to incarceration what Rust Belt states are to deindustrialisation is reflected in how eight out of the top ten incarcerator states in this time period are former slave states. (See Table 2 for definitions of Rust Belt and former slave states.)

[*Figures 1-3 about here*]

The relationship between deindustrialisation, incarceration, and life expectancy is further examined using fixed effects panel data models, all adjusted for aggregate time trends using year dummies. We also estimate autocorrelation and heteroskedasticity consistent standard errors for all regressions. Our baseline model is displayed in the first row of Table 3, indicating that a one percentage point increase in deindustrialisation (mean = 11.2, s.d. = 3.5) reduces life expectancy for the poor by 0.073 years (95% CI: 0.026-0.119). Each standard deviation from the average job destruction rate equates to 0.255 years of life expectancy (95% CI: 0.090-0.419). Relative to the average state, those states characterised by a job destruction rate in manufacturing of 20% or more lost at least another 0.641 years. In the case of incarceration (mean = 4.0, s.d. = 1.5), each additional prisoner per 1000 residents is associated with a loss of 0.468 years (95% CI: 0.213-0.723) and each standard deviation is equivalent to 0.702 years (95% CI: 0.319-1.08). Compared to the poor living in the average state, those living in states characterised by high incarceration (such as Louisiana, with a mean incarceration rate of 8.370 prisoners per 1000 residents) lost more than two years of life expectancy. The model meets all diagnostic

criteria and explains over 20% of the state level variation in life expectancy amongst the poor, as evidenced by an adjusted R^2 value equal to 0.221.

[*Table 3 about here*]

We conduct a sensitivity analysis where state level control variables are introduced into and removed from the baseline model one by one to avoid over-specification. (We also run alternative control models with multiple control variables grouped into three categories, with our results remaining robust. See Appendix Table A3). First, we provide results for race-adjusted life expectancy estimates (second row of Table 3). These estimates "remove the differences in life expectancy across areas and income groups that are due to differences in the racial composition of those areas."[24] Our results are robust to such differences (although, as expected, the incarceration effect is marginally reduced, from -0.467 to -0.434). This primarily suggests that the impacts of deindustrialisation and incarceration are more a function of class than race.[19]

Table 3 conveys how our predictors are robust to a range of potential confounders. The magnitudes and confidence intervals of deindustrialisation and incarceration remain largely unchanged. When we run similar models with life expectancy in the top income quartile as the outcome variable, the impacts of deindustrialisation and incarceration are negligible (see Appendix Table A4). A truly remarkable result is that living in rich states or states undergoing economic growth does not aid the poor, and may even have a negative effect. However, the same models run with life expectancy for the *top* income quartile as the outcome variable reveal that both GDP per capita and economic growth exert a substantial positive

impact (log[GDP] coefficient = 2.820, 95% CI: 0.073-5.567, p-value = 0.045; growth coefficient = 2.07×10^{-4}, 95% CI: 9.53×10^{-5}-3.19×10^{-4}, p-value = 0.0003). This reflects the inegalitarian nature of American growth, which seems to benefit the wealthy but which does little, if anything, to relieve the plight of the worst off.

Finally, we run Granger causality tests (with a lag depth of order one) on our variables of interest as a means of evaluating whether they can be said to contribute significantly to the sample variation in life expectancy (see Appendix Table A5). The tests reveal that both deindustrialisation and incarceration "Granger cause" life expectancy in the bottom income quartile, meaning the improved predictability of the latter from past values of our two independent variables is substantial. In other words, the lifespan of the poor can be better predicted from past values of life expectancy *coupled with* past values of deindustrialisation and incarceration than from past values of life expectancy alone. For deindustrialisation, the test statistic equals 13.759, with p-value = 0.0002. For incarceration, $F = 6.832$ with a p-value of 0.009. Conversely, we find that life expectancy fails to Granger cause deindustrialisation or incarceration. The tests also produce negligible results for the top income quartile.

Interpretation and discussion

Our main findings suggest that, between 2001 and 2014, the loss in life expectancy for the bottom income quartile due to deindustrialisation and incarceration was substantial. To put our results in perspective, the demographic impact of all cancers corresponds to approximately 3.2 years of life expectancy.[25] On the basis of our findings, the implied average gain, were incarceration and deindustrialisation to be

entirely eliminated, would be 2.681 years. This suggests that the adverse health effects of rapid socioeconomic dislocation and of the punitive regulation of poverty could explain virtually the entire increase in the vital gap between the top and the bottom income quartiles since 2001 (which has increased by around 2.3 years; see Figure 4). It is likely that these phenomena unleash cascading effects: the weakening of American labour has left large swathes of the population in chronic unemployment, vulnerable to economic insecurity, psychosocial stress, and unhealthy behavioural patterns, such as smoking, poor diets, drug abuse, or sedentary lifestyles.[7,8,10,11] As such, it is plausible to suggest that smoking, physical inactivity, overweight/obesity, and other proximal determinants may be viewed as *pathways* rather than confounders of the relationship between deindustrialisation and life expectancy. The political response to this form of social turbulence has been largely punitive, as evidenced by the rolling out of the penal state in recent decades coupled with the dismantling of welfare assistance,[19] further perpetuating and amplifying inequalities in life expectancy. A further consideration is that, in areas with lower life expectancy, individuals may reason that there is little point in investing in measures that would improve their economic prospects and may substitute short-term rewards, even if illegal, for uncertain longer-term benefits, consistent with a substantial body of evidence on time preferences and health-related behaviour.[26,27] Thus, deindustrialisation, incarceration, and poor health mutually interact to create a vicious downward cycle.

[*Figure 4 about here*]

This research is an example of what we call the Political Economy of Public Health, an emergent research stream that seeks to understand the distal political and economic causes of population health in ways that break with the conventional assumptions of (neoclassical) health economics and political economy. It draws on but differs from the pure social determinants of health framework in that it moves even further "upstream" by examining *the social determinants of the social determinants* of health (see Figure A3 in the Appendix). In the current study, we believe the ripple effects of deindustrialisation and incarceration shape other social determinants of health, such as neighbourhood contexts, social networks, poverty, or labour market prospects. Other examples include studies of the effects of radical privatisation policies in driving the post-communist mortality crisis,[28] the impact of austerity policies on mental health in Europe,[29] and the role of corporations in shaping unhealthy behaviour like smoking and unhealthy food and drink consumption.[30] This approach is a return to the origins of public health, captured by Rudolph Virchow's famous dictum: "Medicine is a social science, and politics is nothing more than medicine on a grand scale."

We acknowledge the limitations of this study. The spatiotemporal dimensionality of our data imposes restrictions on the statistical power of our models. Significant portions of variance are suppressed in a state level analysis, which most likely conceals deeper inequalities and more salient effects located at the county or city levels. The time period in question (2001 to 2014) comes well after massive industrial decline and the explosion of incarceration that started in the mid-1970s – although there was an acceleration in employment decline in manufacturing beginning in 2000. As such, our analysis undoubtedly fails to capture the full magnitude of the effects of interest. However, we believe that access to more and further disaggregated

data will reveal much larger effect sizes for both predictors and explain a far greater portion of the variation, both within and between income groups across the nation.

The data from the HIP report lower mortality rates than those registered by the SSA. For methodological reasons, Chetty et al. restrict their sample to individual residents with positive earnings (any income subject to filed tax returns). As they point out in their web appendix, the 9% of the population who are thus excluded from their analysis account for no less than 38% of total deaths. This means that the average mortality rate in this fraction of the population is at least four times larger than the mean mortality rate of individuals with positive earnings. As such, our analysis does not capture the impacts of deindustrialisation and incarceration on those who fall below the positive income threshold. We may surmise that both factors, but incarceration in particular, exert a substantial deleterious effect on the life chances of these individuals. Another limitation is that life expectancy data by income have only been released at age 40, thereby excluding deaths at younger ages, for example from drugs and violence, that may be especially important in this population.

Finally, it is important to emphasise that prison incarceration, which is the measure utilised in this article, constitutes only a small fraction of the operations of the American penal apparatus. Alternative imprisonment measures (notably pre-trial and shorter-term jail, as opposed to prison, incarceration) are not readily available. Future research should seek to integrate such data in order to evaluate the true impact of punitive social policy across various social and spatial divides.

Conclusions and public health implications

Between 2001 and 2014, deindustrialisation and incarceration constituted major determinants of the life expectancy of the poor, generating deeply consequential health deficits for states adopting punitive responses to economic stagnation. The historical legacies of rapid industrial decline and slavery are likely to exert substantial long-term effects on vital inequality. Therefore, for a full understanding of health inequalities in the U.S., researchers must remain conscious of the upstream political and economic determinants of public health. If public policy responses to growing health inequalities are to be effective, they must consider industrial policy as well as ending hyper-incarceration of society's most vulnerable.

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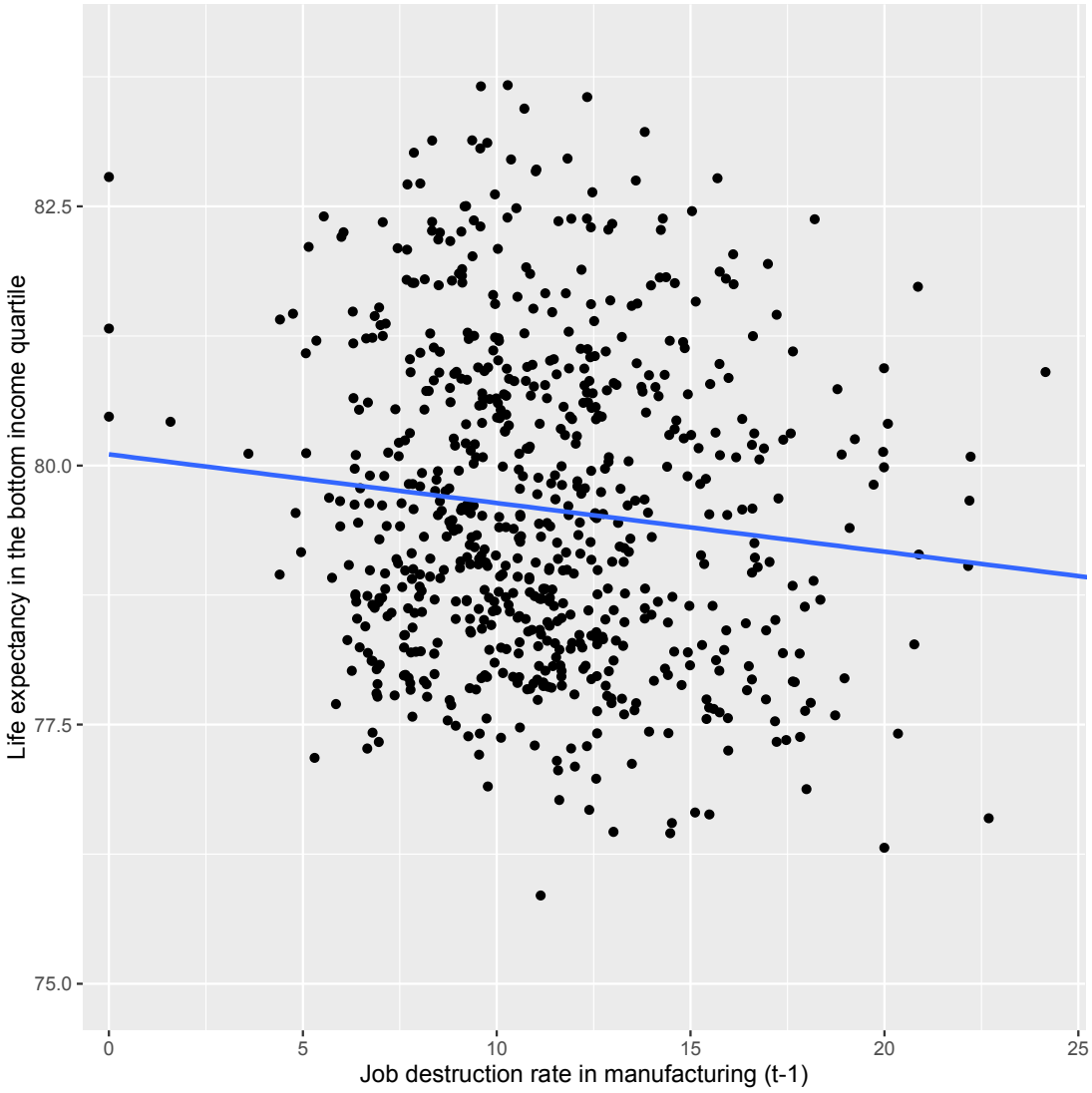

Figure 1: Life expectancy in the bottom income quartile vs. job destruction rate in manufacturing lagged one year. *Notes*: 700 state-year observations of life expectancy and the share of manufacturing employment lost to establishment contraction or closure, 2001-2014. Bivariate linear estimate with 95% confidence interval shaded in grey. *Source*: Life expectancy in the bottom income quartile from the Health Inequality Project; job destruction rate in manufacturing from U.S. Bureau of the Census.

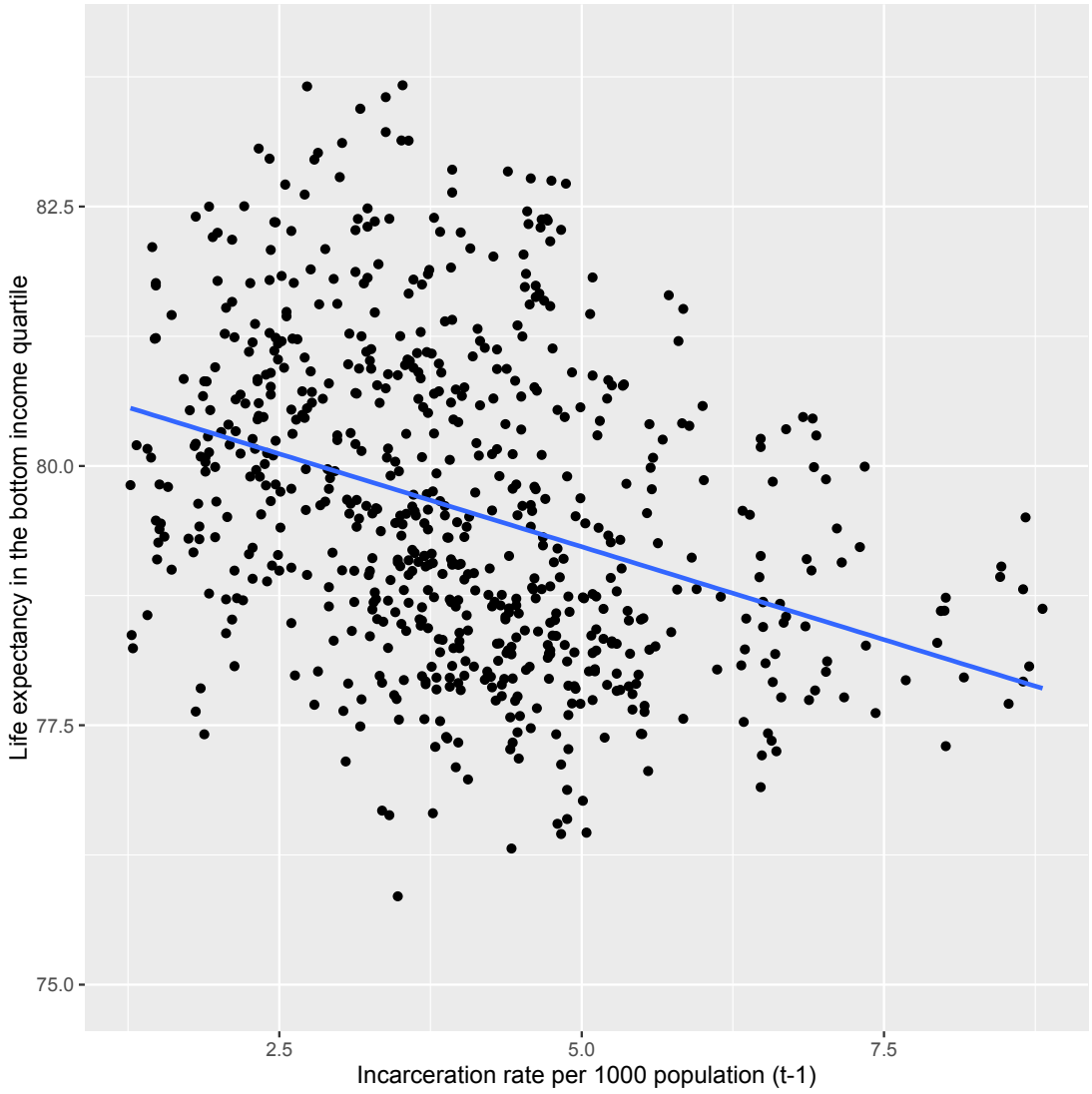

Figure 2: Life expectancy in the bottom income quartile as a function of incarceration rate per 1000 population, lagged one year. *Notes*: 698 state-year observations of life expectancy and the number of prisoners serving state sentences of more than 1 year per 1000 state residents, 2001-2014. Bivariate linear estimate with 95% confidence interval shaded in grey. *Source*: Life expectancy in the bottom income quartile from the Health Inequality Project; incarceration rate from U.S. Bureau of Justice Statistics.

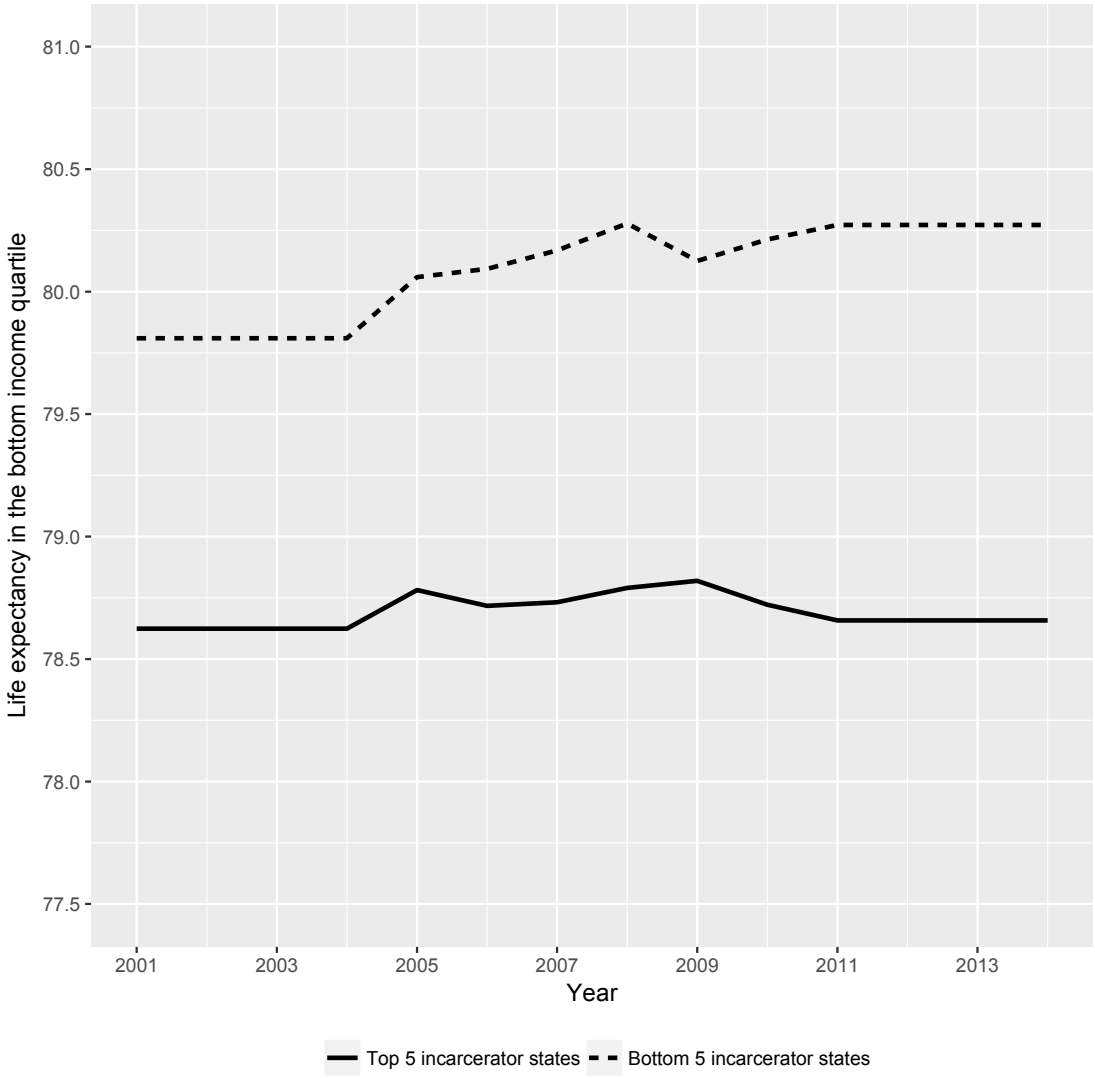

Figure 3: Average life expectancy in the bottom income quartile in the top-five and bottom-five incarcerator states, 2001-2014. *Notes*: mean incarceration rate in top five = 6.946 prisoners per 1000 residents; mean incarceration rate in bottom five = 1.852 prisoners per 1000 residents. *Source*: Life expectancy in the bottom income quartile from the Health Inequality Project; incarceration rate from U.S. Bureau of Justice Statistics.

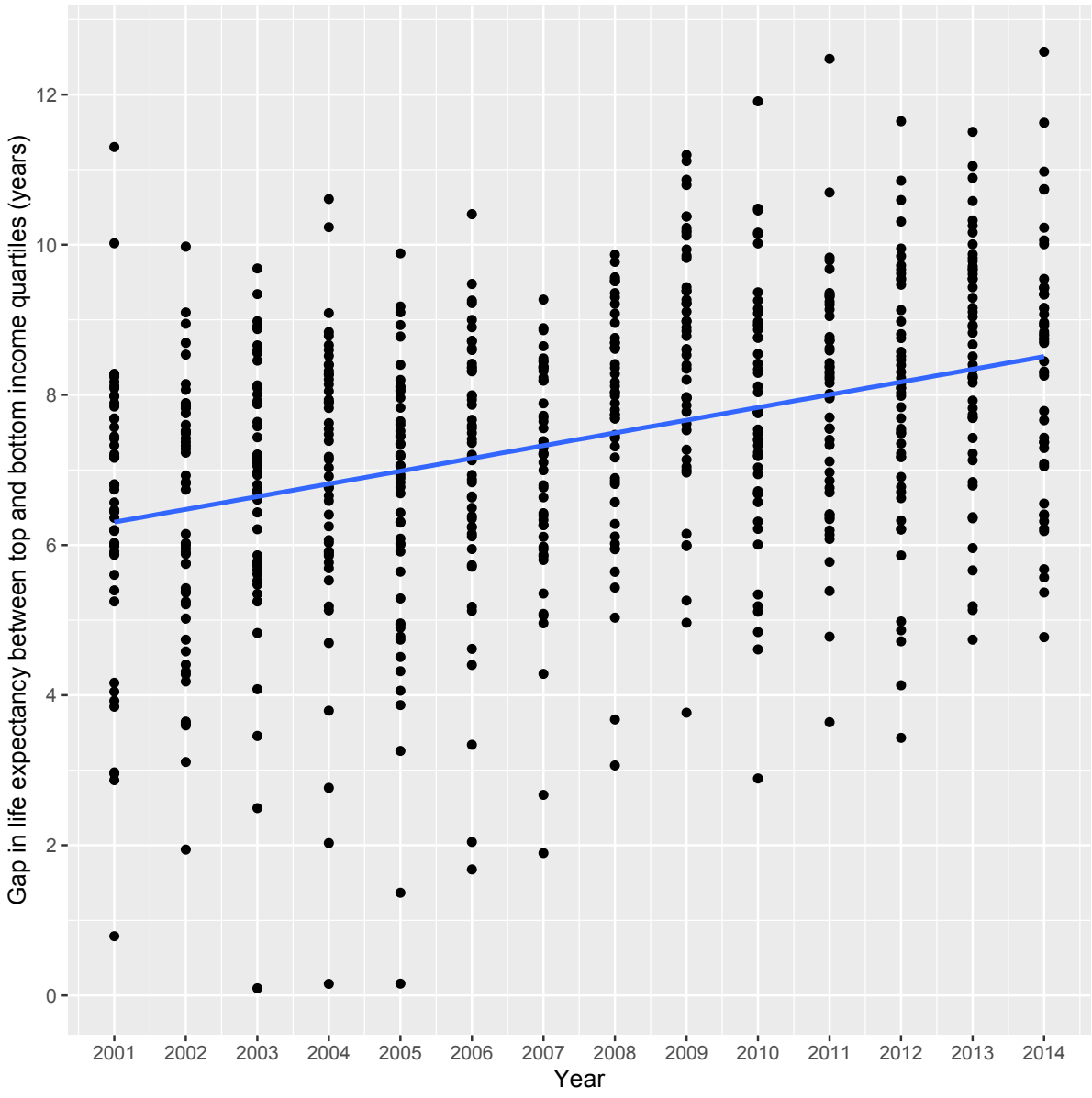

Figure 4: Linear trend in the gap in life expectancy between the top and the bottom income quartiles between 2001 and 2014. *Notes*: 700 state-year observations of life expectancy, 2001-2014. Bivariate linear estimate with 95% confidence interval shaded in grey. *Source*: Life expectancy in the bottom income quartile from the Health Inequality Project.

Table 1: Descriptive statistics

	N	*Mean*	*St. Dev.*	*Min*	*Max*
Life expectancy [LE]	700	79.6	1.5	73.9	83.7
Deindustrialization [DI]	700	11.2	3.5	0.0	27.5
Incarceration rate [IR]	697	4.0	1.5	1.3	8.8
State social spending	700	695	323	156	1833
State health spending	700	186	98.9	40.8	530
State welfare spending	700	1324	444	403	2949
Fraction uninsured	694	0.2	0.1	0.1	0.4
Fraction smokers	699	0.3	0.04	0.2	0.4
Fraction physically inactive	694	0.4	0.1	0.2	0.5
Fraction overweight/obese	699	0.6	0.04	0.4	0.7
Overdose mortality rate	700	18.4	7.7	2.6	54.7
Homicide rate	700	4.5	2.3	0.8	14.6
GDP per capita	700	46019	8644	28856	73464
GDP growth	700	344	1245	-4512	11009
Labour force participation rate	700	66.1	4.2	53.3	76.1
Relative size of manufacturing	650	11.3	4.4	2.4	23.2

Notes: State-year data, 2001-2014. Life expectancy in the bottom income quartile estimated by the Health Inequality Project from Personal Income Tax income data and Social Security Administration death data. Full sources listed in Appendix Table A3.

Table 2: Variable definitions and sources

Variable name	*Definition*	*Source*
Life expectancy	"The expected length of life for a hypothetical individual who experiences mortality rates at each subsequent age that match those in the cross-section during a given year"	The Health Inequality Project: Data URL: https://healthinequality.org/data/
Race-adjusted life expectancy	"Race-and-ethnicity adjusted estimates remove the differences in life expectancy across areas and income groups that are due to differences in the racial composition of those areas"	The Health Inequality Project: Data URL: https://healthinequality.org/data/ URL: https://healthinequality.org/faq/
Deindustrialisation	Annual rate of job destruction in manufacturing (NAICS sector 31-33)	U.S. Census Bureau: Statistics of U.S. Businesses URL: http://www.census.gov/programs-surveys/susb.html
Incarceration rate	Total number of prisoners serving to more than 1 year per 1000 U.S. residents	Bureau of Justice Statistics: National Prisoner Statistics URL: https://www.bjs.gov/index.cfm?ty=dcdetail&iid=269
State social spending	Amount spent by state government in each fiscal year on workers' insurance trusts	U.S. Census Bureau: State Government Finances URL: https://www.census.gov/govs/state/
State health spending	Amount spent by state government in each fiscal year on healthcare	U.S. Census Bureau: State Government Finances URL: https://www.census.gov/govs/state/
State welfare spending	Amount spent by state government in each fiscal year on public welfare	U.S. Census Bureau: State Government Finances URL: https://www.census.gov/govs/state/
Fraction uninsured	Fraction of individuals earning less than $25,000 p.a./more than $75,000 p.a. without any form of medical insurance	Centers for Disease Control and Prevention: Behavioral Risk Factor Surveillance System URL: https://www.cdc.gov/brfss/annual_data/annual_data.htm
Fraction smokers	Fraction of individuals earning	Centers for Disease Control and Prevention: Behavioral Risk Factor Surveillance System

	less than $25,000 p.a./more than $75,000 p.a. who are current smokers	URL: https://www.cdc.gov/brfss/annual_data/annual_data.htm
Fraction inactive	Fraction of individuals earning less than $25,000 p.a./more than $75,000 p.a. who have not engaged in physical exercise in the past 30 days	Centers for Disease Control and Prevention: Behavioral Risk Factor Surveillance System URL: https://www.cdc.gov/brfss/annual_data/annual_data.htm
Fraction overweight/obese	Fraction of individuals earning less than $25,000 p.a./more than $75,000 p.a. who are either overweight or obese	Centers for Disease Control and Prevention: Behavioral Risk Factor Surveillance System URL: https://www.cdc.gov/brfss/annual_data/annual_data.htm
Overdose mortality rate	Number of state level deaths per 100 000 state residents amongst individuals aged 20-64 years	Centers for Disease Control and Prevention: Compressed Mortality database (codes X40-44, X60-64, X85, Y10-14) URL: https://wonder.cdc.gov/controller/datarequest/D132
Homicide rate	Total number of murders committed per 100,000 state residents	Federal Bureau of Investigation: Uniform Crime Reporting Statistics URL: https://www.ucrdatatool.gov/Search/Crime/Crime.cfm
GDP per capita	State real gross domestic product in thousands of U.S. dollars divided by state population estimate	Bureau of Economic Analysis: Regional Economic Accounts URL. https://www.bea.gov/regional/index.htm
GDP per capita growth	Annual change in state real gross domestic product in thousands of U.S. dollars divided by state population estimate	Bureau of Economic Analysis: Regional Economic Accounts URL. https://www.bea.gov/regional/index.htm
Labour force participation rate	Civilian labour force as percentage of total state population	Bureau of Labor Statistics: Local Areas Unemployment Statistics URL. https://www.bls.gov/lau/
Relative size of manufacturing sector	Total state employment in manufacturing sector at the start of each year divided by total employment across all sectors	U.S. Census Bureau: Statistics of U.S. Businesses URL: http://www.census.gov/programs-surveys/susb.html
Rust Belt	Dummy variable indicating whether a state is considered part of the region known for undergoing heavy industrial decline in the latter half of the 20th century, known	–

	as the Rust Belt: Illinois, Indiana, Michigan, Ohio, Pennsylvania	
Former slave state	Dummy variable indicating whether a state is a former slave state or not: Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, Virginia	–

Table 3: Fixed effects baseline and single-variable control models

	Life expectancy in the bottom income quartile		
	Control	*DI (t-1)*	*IR (t-1)*
Baseline model	–	**-0.073** (-0.119, -0.026), *p* = 0.002	**-0.468** (-0.723, -0.213), *p* = 0.0003
Race-adjusted baseline model	–	**-0.072** (-0.119, -0.026), *p* = 0.002	**-0.434** (-0.691, -0.177), *p* = 0.0009
State social spending	0.0006 (-0.0003, 0.002), *p* = 0.208	**-0.075** (-0.122, -0.029), *p* = 0.001	**-0.424** (-0.681, -0.168), *p* = 0.001
State health spending	-0.0005 (-0.002, 0.001), *p* = 0.600	**-0.072** (-0.118, -0.026), *p* = 0.002	**-0.467** (-0.727, -0.207), *p* = 0.0004
State welfare spending	0.0004 (-0.0003, 0.001), *p* = 0.297	**-0.074** (-0.121, -0.028), *p* = 0.002	**-0.451** (-0.696, -0.206), *p* = 0.0003
Fraction uninsured	-0.327 (-2.452, 1.798), *p* = 0.763	**-0.073** (-0.119, -0.026), *p* = 0.002	**-0.459** (-0.725, -0.194), *p* = 0.0007
Fraction smokers	**-4.365** (-7.93, -0.798) *p* = 0.017	**-0.075** (-0.123, -0.028) *p* = 0.002	**-0.429** (-0.682, -0.175) *p* = 0.0009
Fraction physically inactive	-2.410 (-4.961, 0.141) *p* = 0.064	**-0.072** (-0.118, -0.025) *p* = 0.002	**-0.441** (-0.698, -0.183) *p* = 0.0008
Fraction overweight/obese	0.918 (-3.636, 5.472) *p* = 0.693	**-0.073** (-0.120, -0.026) *p* = 0.002	**-0.466** (-0.722, -0.210) *p* = 0.0004
Overdose mortality rate	-0.003 (-0.026, 0.020) *p* = 0.819	**-0.073** (-0.120, -0.026) *p* = 0.003	**-0.461** (-0.714, -0.208) *p* = 0.0004
Homicide rate	-0.026 (-0.132, 0.079) *p* = 0.623	**-0.073** (-0.119, -0.026) *p* = 0.002	**-0.466** (-0.724, -0.208) *p* = 0.0004
Log of GDP per capita	**-2.115** (-3.65, -0.58) *p* = 0.007	**-0.070** (-0.118, -0.023) *p* = 0.004	**-0.444** (-0.694, -0.185) *p* = 0.0007
GDP growth	-3.15×10^{-5} $(-9.68\times10^{-5}, 3.39\times10^{-5})$ *p* = 0.346	**-0.073** (-0.120, -0.026) *p* = 0.002	**-0.468** (-0.724, -0.212) *p* = 0.0003
Labour force participation rate	-0.020 (-0.100, 0.059) *p* = 0.613	**-0.072** (-0.119, -0.025) *p* = 0.003	**-0.465** (-0.715, -0.215) *p* = 0.0003
Relative size of manufacturing	-0.115 (-0.291, 0.062) *p* = 0.203	**-0.070** (-0.115, -0.025) *p* = 0.003	**-0.438** (-0.710, -0.166) *p* = 0.002

Note: 95% confidence intervals using robust standard errors in parentheses, followed by *p*-values

APPENDIX

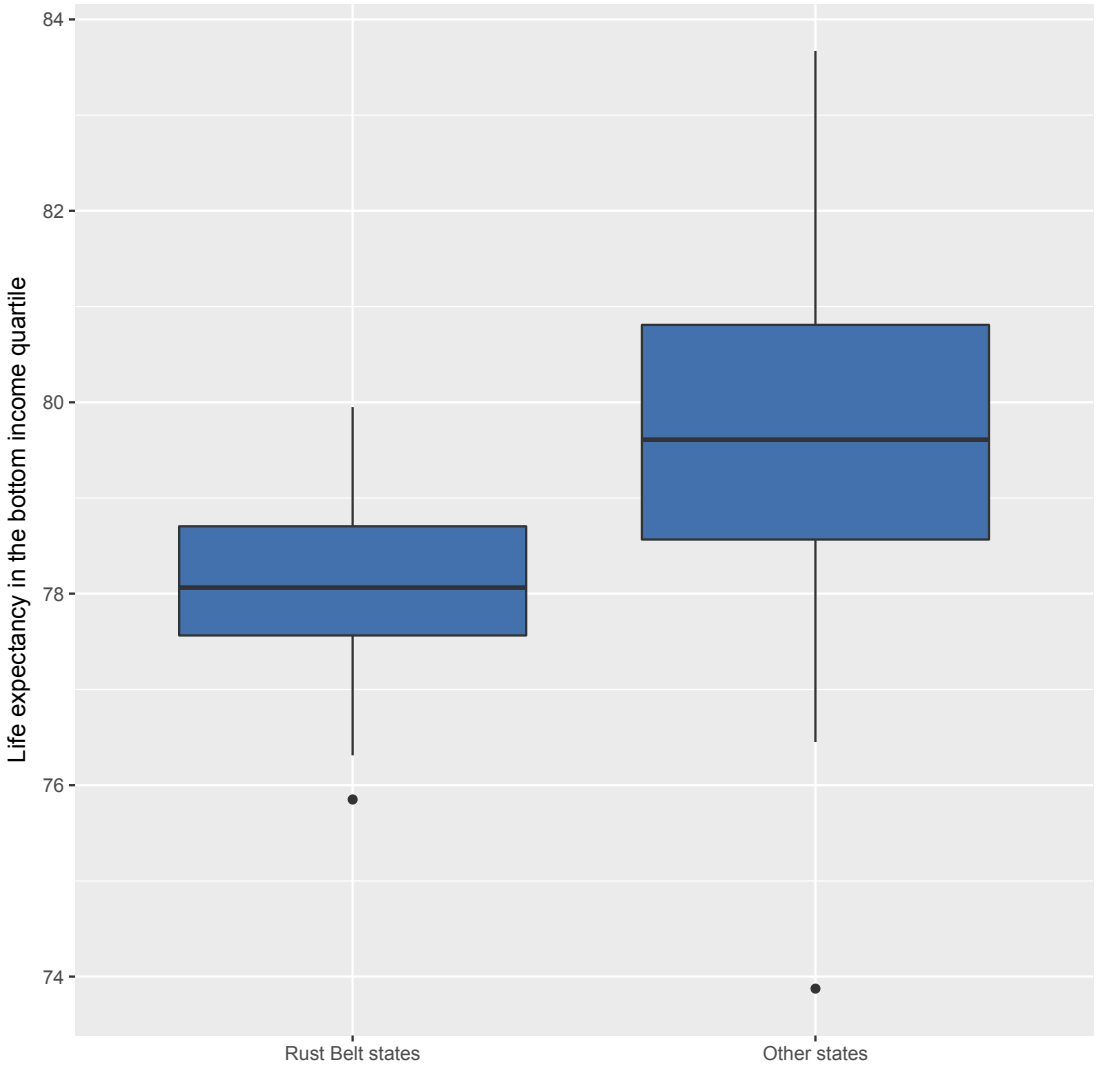

Figure A1: Life expectancy in the bottom income quartile 2001-2014 in Rust Belt states versus other states. *Source*: Life expectancy in the bottom income quartile from the Health Inequality Project.

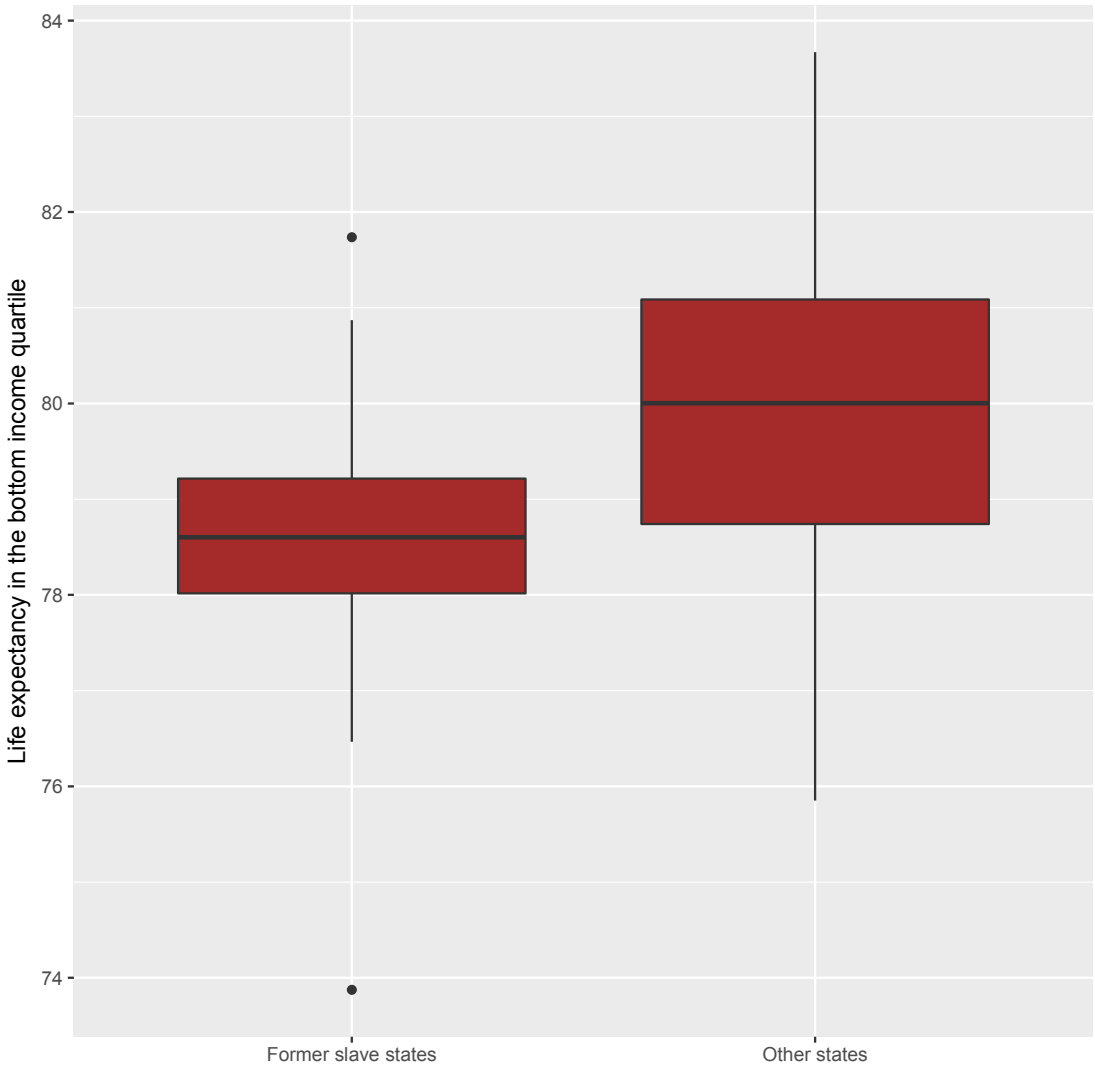

Figure A2: Life expectancy in the bottom income quartile 2001-2014 in former slave states versus other states. *Source*: Life expectancy in the bottom income quartile from the Health Inequality Project.

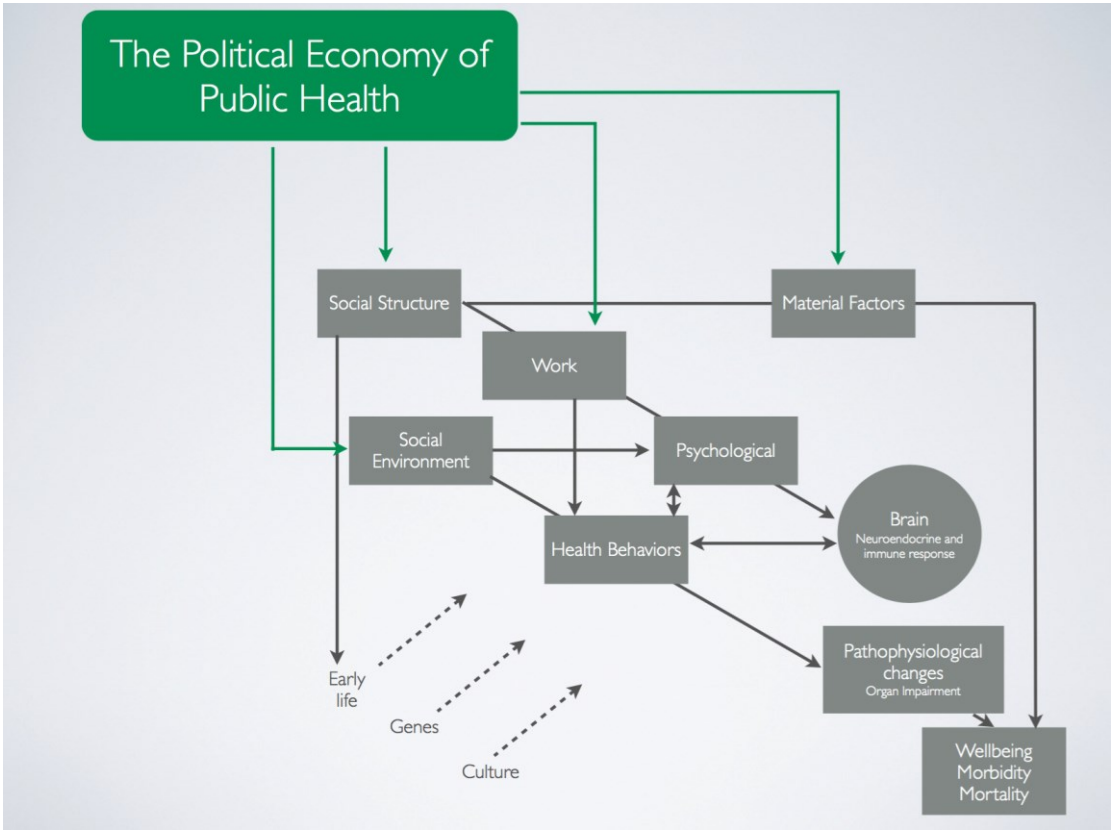

Figure A3: The Political Economy of Public Health.

Table A1: Approaches to the study of health inequality

Type of literature	Cause(s) of inequality	Example
Descriptive	None specified	Chetty R, Stepner M, Abraham S, Lin S, Scuderi B, Turner N, Bergeron A, Cutler D. The association between income and life expectancy in the United States, 2001-2014. ***JAMA*** 2016;315(16):1750–1766.
Conventional epidemiology	Lifestyle (smoking, drinking, diet, physical exercise)	Micha R, Peñalvo JL, Cudhea F, Imamura F, Rehm CD, Mozaffarian D. Association Between Dietary Factors and Mortality From Heart Disease, Stroke, and Type 2 Diabetes in the United States. ***JAMA*** 2017;317(9):912–924. DOI:10.1001/jama.2017.0947
Emerging economics literature	"Creative destruction" and "despair"	Case A, Deaton A. Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. ***PNAS*** 2015;112(49): 15078–15083.
Social determinants of health	Discrimination, social policy, ecological factors	Marmot M. Social determinants of health inequalities. ***Lancet*** 2005;365(9464):1099–1104.
Political economy of public health	Macro-level social, political, and economic forces	Stuckler D, McKee M, King L. Mass privatisation and the post-communist mortality crisis: a cross-national analysis. ***Lancet*** 2009; 373(9661):399–407.

Table A2: Correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
1. Life expectancy	1																	
2. Deindustrialisation	-0.05	1																
3. Deindustrialisation (t-1)	-0.11	0.40	1															
4. Incarceration rate	-0.35	0.09	0.09	1														
5. Incarceration rate (t-1)	-0.34	0.08	0.09	0.99	1													
6. Overdose mortality rate	0.03	-0.05	-0.08	0.10	0.10	1												
7. Homicide rate	-0.36	0.17	0.15	0.71	0.71	0.15	1											
8. GDP per capita	0.20	-0.06	-0.09	-0.24	-0.22	-0.08	-0.16	1										
9. GDP growth	0.08	-0.28	-0.20	-0.11	-0.12	-0.16	-0.09	0.11	1									
10. Fraction smokers	-0.43	0.005	-0.01	0.15	0.12	0.02	0.17	-0.15	0.05	1								
11. Fraction physically inactive	-0.50	0.11	0.10	0.42	0.42	0.08	0.48	-0.13	-0.08	0.23	1							
12. Fraction overweight/obese	-0.28	-0.25	-0.23	0.31	0.31	0.21	0.27	-0.10	-0.10	-0.02	0.49	1						
13. Fraction uninsured	-0.01	0.05	0.13	0.47	0.48	0.08	0.42	-0.17	0.03	0.20	0.04	-0.13	1					
14. Social spending	0.25	-0.24	-0.09	-0.15	-0.12	0.34	-0.15	0.41	-0.06	-0.13	-0.22	0.16	-0.08	1				
15. Health spending	0.23	-0.02	-0.02	-0.16	-0.15	0.13	-0.10	0.46	-0.07	-0.08	-0.20	-0.07	-0.23	0.30	1			
16. Welfare spending	0.26	-0.26	-0.24	-0.26	-0.25	0.30	-0.16	0.29	-0.04	-0.13	0.04	0.33	-0.40	0.60	0.43	1		
17. Labour force participation rate	0.13	-0.002	-0.02	-0.45	-0.45	-0.49	-0.45	0.37	0.13	-0.05	-0.31	-0.32	-0.15	-0.16	-0.05	-0.24	1	
18. Relative size of manufacturing	-0.47	-0.01	-0.08	0.04	0.02	-0.29	0.02	-0.44	0.004	0.21	0.30	0.21	-0.20	-0.32	-0.47	-0.14	0.01	1

Table A3: Fixed effects multivariable control models

	Life expectancy in the bottom income quartile		
	Behavioural controls	*Economic controls*	*Welfare state controls*
Deindustrialisation (t-1)	-0.073**	-0.066**	-0.075**
	(0.024)	(0.024)	(0.023)
Incarceration rate (t-1)	-0.409**	-0.413**	-0.405**
	(0.135)	(0.138)	(0.134)
Homicide rate	-0.015		
	(0.052)		
Overdose mortality rate	0.001		
	(0.011)		
Fraction smokers	-4.027*		
	(1.909)		
Fraction inactive	-2.208		
	(1.333)		
Fraction overweight/obese	0.695		
	(2.422)		
GDP per capita		-0.00005	
		(0.00003)	
GDP growth		-0.00000	
		(0.00003)	
Labour force participation rate		0.011	
		(0.045)	
Relative size of manufacturing		-0.081	
		(0.089)	
Fraction uninsured			0.001
			(1.033)
Social spending			0.001
			(0.001)
Health spending			-0.001
			(0.001)
Welfare spending			0.0003
			(0.0004)
Observations	691	647	691
Adjusted R^2	0.224	0.237	0.224
Note: robust standard errors in parentheses			*p<0.05; **p<0.01; ***p<0.001

Table A4: Fixed effects baseline and single-variable control models for the top income quartile

	Life expectancy in the top income quartile		
	Control	*DI (t-1)*	*IR (t-1)*
Baseline model	—	0.020	-0.184
		(0.045)	(0.177)
Race-adjusted baseline model	—	0.021	-0.172
		(0.046)	(0.172)
State social spending	-0.0001	0.021	-0.194
	(0.0005)	(0.046)	(0.182)
State health spending	0.0004	0.019	-0.185
	(0.001)	(0.045)	(0.177)
State welfare spending	0.0004	0.019	-0.167
	(0.0004)	(0.046)	(0.175)
Fraction smokers	3.006	0.020	-0.212
	(3.414)	(0.045)	(0.179)
Fraction inactive	-3.269	0.022	-0.180
	(3.561)	(0.044)	(0.169)
Fraction overweight/obese	2.939	0.022	-0.216
	(1.965)	(0.045)	(0.176)
Overdose mortality rate	-0.004	0.021	-0.173
	(0.011)	(0.045)	(0.182)
Homicide rate	0.081	0.019	-0.190
	(0.060)	(0.046)	(0.172)
GDP per capita	0.00006*	0.017	-0.215
	(0.00002)	(0.044)	(0.188)
GDP growth	0.0002***	0.021	-0.183
	(0.00005)	(0.041)	(0.175)

Note: robust standard errors in parentheses *p<0.05; **p<0.01; ***p<0.001

Table A5: Granger causality tests with lag depth of order one

Outcome variable	*Covariate*	*F statistic*	*p-value*
LE Q1	DI (t-1)	**13.759**	**0.0002**
LE Q1	IR (t-1)	**6.8381**	**0.009**
LE Q4	DI (t-1)	0.093	0.759
LE Q4	IR (t-1)	3.021	0.082
DI (t-1)	LE Q1	0.0204	0.886
IR (t-1)	LE Q1	0.481	0.488
DI (t-1)	LE Q4	0.020	0.886
IR (t-1)	LE Q4	0.481	0.488