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State Level Differences in Life Expectancy and Lifespan Inequality: Is It a Matter of Socioeconomic Inequalities?

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Abstract

Lifespan inequality refers to the variation in the age at which people die or the uncertainty surrounding the time of their death. This study investigates the patterns of lifespan inequality at the state level in the United States over 55 years, utilising Theil's entropy index. We also explore the demographic and socioeconomic factors associated with lifespan inequality using a Panel-Corrected Standard Errors (PCSE) model. We observe a strong and statistically significant negative correlation between life expectancy and inequality in lifespan at the state level overall and for both males and females. In terms of demographic and socioeconomic factors, the percentage of individuals who have completed high school and college education, the percentage of the Hispanic population, the number of physicians, the percentage of individuals under 65 with insurance, and population growth are all negatively associated with lifespan inequality. Moreover, there is a positive association between lifespan inequality and the rates of violent crime, CO_2 emissions per capita, cigarette smoking, and income inequality. Our results reiterate that policies aimed at tackling disparities in socioeconomic position could also serve as useful strategies for addressing health disparities.

Keywords

Lifespan inequality

Theil index

Socioeconomic inequality

United States

JEL Classification

I14

I18

J19

1. Introduction

Life expectancy at birth, long regarded as a cornerstone indicator in public health, demography, and epidemiology, serves as a key metric for assessing the overall health and well-being of populations. Despite its wide application, life expectancy bears inherent limitations. First and foremost, it neglects the present health status of individuals, offering a mere average that overlooks the diverse health experiences within a population. Furthermore, it does not consider the distribution of life expectancy within a population and thus fails to capture the dynamic variations inherent in a population's longevity. In response to these shortcomings, scholars and policymakers are increasingly turning their attention to the concept of lifespan inequality (Smits & Monden, 2009; Van Raalte et al., 2018), which goes beyond the conventional emphasis on life expectancy. Lifespan inequality illustrates variations in age at death and the uncertainties surrounding the timing of mortality, painting a more comprehensive picture of a population's health profile.

According to Van Raalte et al. (2018), lifespan inequality has significant implications at the individual and population levels. On an individual level, it offers insights into the diverse health trajectories of individuals, influencing decisions related to education, career choices and retirement planning (Edwards & Tuljapurkar, 2005; van Raalte et al., 2018). At the population level, it shapes mortality projections, influences the dynamics of insurance and annuity markets, and contributes to disparities within public pension systems. For instance, individuals with a longer lifespan are more inclined to acquire insurance policies to mitigate potential financial losses. On the other hand, insurance companies adjust premiums based on uncertainty and variation in lifespan. When examining public pension systems, it is important to note that individuals who die at a younger age have made smaller contributions to the system. In contrast, individuals who live longer will overall receive greater benefits from the public pension system. This creates socioeconomic inequalities that are worsened by the fact that poor individuals are at a disadvantage when it comes to survival (Edwards & Tuljapurkar, 2005).

Few studies have undertaken a comprehensive examination of lifespan inequality across countries, with such studies limited to Shkolnikov et al. (2003) in Russia, van Raalte et al. (2011) in ten European countries, van Raalte et al. (2014) in Finland, Sasson (2016b) in the United States, Brønnum-Hansen (2017) in Denmark, Permanyer et al. (2018) in Spain, and Seaman et al., (2019) in Scotland. These studies have contributed valuable insights to our understanding of lifespan inequality. In particular, van Raalte et al. (2011) discovered that individuals with the lowest level of education saw a higher degree of lifespan inequality compared to those with the highest level of education. Furthermore, van Raalte et al., (2014) found that manual occupational groups had a higher degree of lifespan inequality compared to non-manual occupational groups in Finland. However, while life expectancy in Denmark has been rising, the most disadvantaged groups have seen little to no improvement in lifespan inequality, while the least disadvantaged groups have shown a decrease in lifespan inequality (Brønnum-Hansen, 2017).

Turning to the US, despite investing up to four times as much as other nations in health (OECDSTAT, 2017), the US had a life expectancy ranking of 34th globally in 2016, placing it below most other high-income countries and many middle-income countries (WHO ,2018). It has therefore often been identified as an outlier among high-income nations with similar overall life expectancies, and exhibits remarkable variations in both life expectancy and lifespan inequality (Aburto et al., 2020; Crimmins et al., 2010; van Raalte et al., 2018; Rogers et al., 2021; Vaupel et al.,2011). Furthermore, life expectancy in the US exhibits significant variation based on geographical location and socioeconomic status. Chetty et al. (2016), Meara et al. (2008), Case and Deaton (2015), (2017), and Brown et al. (2012) have each observed that the least educated populations in the United States have lower life expectancy. Sasson (2016b) also examined the United States from 1990 to 2010 and found that among low-educated whites, adult life expectancy has declined for both males and females. Meanwhile, lifespan inequality has increased for high school-educated whites, significantly contributing to overall lifespan inequality. In contrast, college-educated whites have experienced rising life expectancy and a decrease in the variability of age at death. For blacks, adult life expectancy has generally increased, with lifespan inequality levelling off or decreasing across most educational groups.

On the other hand, a comparison of mortality rates between the US and peer countries such as Australia, Canada, Norway, the UK, and Finland, reveals a persistent trend of higher mortality rates in the US, and this disparity has significantly intensified since the year 2000 (Harris et al., 2021**).** Furthermore, since the 1970s the US has consistently exhibited higher probabilities of death across age groups from 15 to 65 years when compared to its peer countries (Harris et al., 2021). Moreover, the ratio of mortality rates at these ages in the US to those observed in the peer countries experienced significant growth between 2000 and 2010, and again from 2010 to 2016. Post 2000, there was a notable surge in the relative risk of death among late adolescents and young adults (below the age of 40) in the US, surpassing the increase observed in any other age cohort. However, there was a more consistent and gradual rise in the relative mortality risk observed among older age cohorts from the 1970s through 2016 (Harris et al., 2021).

To have a comprehensive understanding of the various dimensions of life expectancy and lifespan inequality in the United States, it is imperative to navigate the intricate sociodemographic diversity of the country at the subnational level. The role of Federalism is an integral component of the U.S. government system, granting significant autonomy to each State in formulating and implementing policies and procedures leading to distinct social and economic challenges, healthcare infrastructures, and cultural disparities that are the key determinates of lifespan inequality (Edwards and Tuljapurkar 2005; Brown et al. 2012; Sasson 2016a). Therefore, tracking lifespan inequality at the state level over time permits a deeper understanding of lifespan inequality and its fundamental causes and acts as a tool for assessing progress toward the goal of more equitable health outcomes, as enshrined in the Healthy People 2030 objective: "Eliminate health disparities, achieve health equity, and attain health literacy to improve the health and well-being of all" (Office of Disease Prevention and Health Promotion, n.d.). Furthermore, state-level data on health outcomes is critical for efficiently allocating resources and designing and implementing national health and social welfare policies. Furthermore, monitoring subnational trends in life expectancy and lifespan inequality can shed light on future mortality for both privileged and disadvantaged groups. However, to the best of our knowledge, ours is the first study that examines the long-term trends in lifespan inequality and assesses the association between lifespan inequality and various demographic and socioeconomic variables at the state level. Only a few cross-sectional studies, the majority of which used older data sets, have examined socio-economic and demographic dimensions of lifespan inequality, including Aburto and van Raalte (2018) in Central and Eastern Europe, Edwards and Tuljapurkar (2005) in industrialized countries, Gillespie et al. (2014) in Sweden, Japan, Canada, and the United States, Neumayer and Plumper (2016) in western developed countries, Permanyer and Scholl (2019) and Smits and Monden (2009) in the global context, and Tuljapurkar (2010) in Sweden.

In this paper, we address the following research questions:

1. What are the state-level differences in life expectancy at birth and lifespan inequality in the U.S.?
2. What is the association between socioeconomic, demographic, and health factors and state-level lifespan inequality?

The rest of the paper is organized as follows. Section 2 describes the data and provides a brief explanation of the methodology. Section 3 presents the results and analysis of the econometric model. The final section concludes.

2. Data and Methods

Our primary source of data for the measurement of lifespan inequality is the United States Mortality Database (USMDB),[1] which provides complete life tables by sex for all 50 states and the District of Columbia for each year from 1959 to 2018, with age-specific mortality values up to the age of 110. However, after initial analysis, the District of Columbia was identified as an outlier since its mortality pattern, and socioeconomic, demographic, and health characteristics differ significantly from those of other states. The District of Columbia is therefore excluded from our study.

For the analysis of the determinants of lifespan inequality, the data for the independent variables come from various sources. First, we included key socioeconomic predictors of health (Bayati et al., 2013). Income data were obtained from the Federal Reserve Bank of St. Louis FRED database, and the state-level Gini coefficient from the U.S. State-Level Income Inequality database. We use the percentage of the population who are high school graduates and the percentage of the population who are college graduates from the database developed by Frank (2009) as a measure of population-level educational attainment. Data on the percentage of employees in manufacturing by state was obtained from the Bureau of Labor Statistics(n.d). As measures of health resources, we include the number of physicians per 10,000 population, and personal health care expenditures (calculated as a percentage of state Gross Domestic Product). These data were obtained from the United States Census Bureau (U.S. Census Bureau, n.d.). Data on cigarette pack sales per capita were obtained from the Centers for Disease Control and Prevention. Descriptive statistics for the independent variables are given in Table 1. This panel data consists of annual observations for 50 states over the period 1987-2014.

[1]https://usa.mortality.org/

Table 1: Descriptive Statistics for the sample

	N	Mean	Std. Dev.	Median	Min	Max
Theil index	1400	3.08	0.45	3.06	2.17	4.41
% of high school graduates	1400	0.61	0.05	0.62	0.45	0.74
% of college graduate	1400	0.17	0.05	0.16	0.07	0.46
Gini index	1400	0.58	0.04	0.58	0.49	0.71
Violent Crime rate(10000 per population)	1400	44.5	22.38	411.6	5.68	124.43
Cigarette Consumption (Pack Sales Per Capita)	1400	81.65	31.62	81.70	15.40	195.10
Total Personal Health care (% GDP)	1400	13.00	2.82	12.70	4.40	22.30
Physician (10000 per population)	1400	23.89	6.04	23.00	12.20	47.40
% Insurance prevalence under 65	1400	84.44	4.51	85.00	70.60	96.20
Population growth	1400	0.96	0.94	0.80	-5.99	6.24
% Black population	1400	10.21	9.44	7.32	0.25	37.51
% Hispanic population	1400	7.95	9.06	4.77	0.00	47.67
Co_2 per Capita	1400	23.31	19.24	18.22	0.05	139.54
Population density	1400	69.90	95.02	34.75	0.36	465.54
Unemployment rate(%)	1400	5.69	1.87	5.40	2.30	13.70
% Employees in manufacturing	1400	8.95	4.37	8.82	0.04	19.83
Log Real Per Capita income	1400	4.55	0.09	4.55	4.29	4.81

Source: Authors' calculations

Lifespan inequality measures

Kannisto (2000), Shkolnikov et al. (2003), Vaupel et al. (2011), Wilmoth and Horiuchi (1999), and van Raalte and Caswell (2013) have all analyzed features of the indicators of lifespan inequality and revealed strong correlations between various measures. We employ the Theil Index in our analysis as the measure of lifespan inequality, because it is more sensitive than other measures to differences across the full range of the age-at-death distribution, whereas alternatives such as the Gini Index attach lesser weight to high values, which are important in the context of measuring lifespan. We quantify lifespan inequality for the entire population, male and female populations (or other subsets such as regions).

The Theil index for lifespan inequality, which is denoted as T_a, can be calculated as follows:

$$T_a = \frac{1}{l_a} \sum_{x=a}^{\omega} d_x \left(\frac{\alpha_x}{\mu_a}\right) log \left(\frac{\alpha_x}{\mu_a}\right) \quad (1)$$

where a and ω are the youngest and oldest age intervals taken from a given life table, l_a is the radix of the population,[22], μ_a is the average age at death of the population, and d_x and α_x are the life table number of deaths and the average age at death in the age interval x to $x+5$, respectively.

Panel Corrected Standard Errors (PCSE) model

The basic econometric specification of the panel regression model is as follows.

$$Y_{it} = \beta_0 + \beta_K X_{Kit} + \cdots \beta_k X_{kit} + U_{it} \quad (2)$$

where Y_{it} is lifespan inequality for state *i* in period *t*, X_{kit} is a vector of independent variables, β_k is a vector of coefficients for the independent variable, and U_{it} is the error term and is assumed to be i.i.d. We estimated separate models for total lifespan inequality, male lifespan inequality, and female lifespan inequality as dependent variables.

First, pooled OLS regression was employed, and the decision between random effect and fixed effect models was determined based on the results of the Hausman Test. Based on this test, we identified the fixed effects model for all models of lifespan inequality as being the appropriate specification (total $p<0.001$; male $p<0.001$; and female $p<0.001$). Therefore, we next estimated fixed effects regressions and checked for the heteroscedasticity and auto-correlation using the Wald test and serial correlation test respectively. These tests revealed evidence of autocorrelation and heteroscedasticity in the panel data (see Appendix 1, Table A1). Next, we checked for cross-sectional dependence among the sample states by employing Pesaran et al.'s (2004) cross-sectional dependence (CD) and scaled Lagrange Multiplier (LM) tests, as well as the Breusch-Pagan LM test (Breusch and Pagan, 1980). The results of these tests clearly reject the null hypothesis of no cross-sectional dependence (see Appendix 1, Table A2).

The stationarity of target variables was checked before model estimation. First-generation unit root tests may yield biased outcomes in the presence of heterogeneity and cross-sectional dependence (Pesaran, 2007). Thus, following Pesaran (2007), we employed second-generation panel unit root tests: the cross-sectional ADF (CADF) and cross-sectionally augmented IPS (CIPS). The results of CADF showed that total personal health care, percentage of Black population, and percentage of Hispanic population were stationary

[2] Of the starting number of newborns in the life table, usually set at 100,000.

in first differences, while other variables were stationary in both levels and first differences (see Appendix 1, Table A3).

The CIPS results indicate that the Gini index, total personal health care (as a percentage of GDP), percentage of Black population, percentage of Hispanic population, population density and real per capita income each have a unit root but become stationary when the first difference is taken. In conclusion, based on the CIPS test, we used first differences in our PCSE models for the Gini index, total personal health care (as a percentage of GDP), percentage of Black population, percentage of the Hispanic population, population density and real per capita income, while the remaining variables are measured in levels.

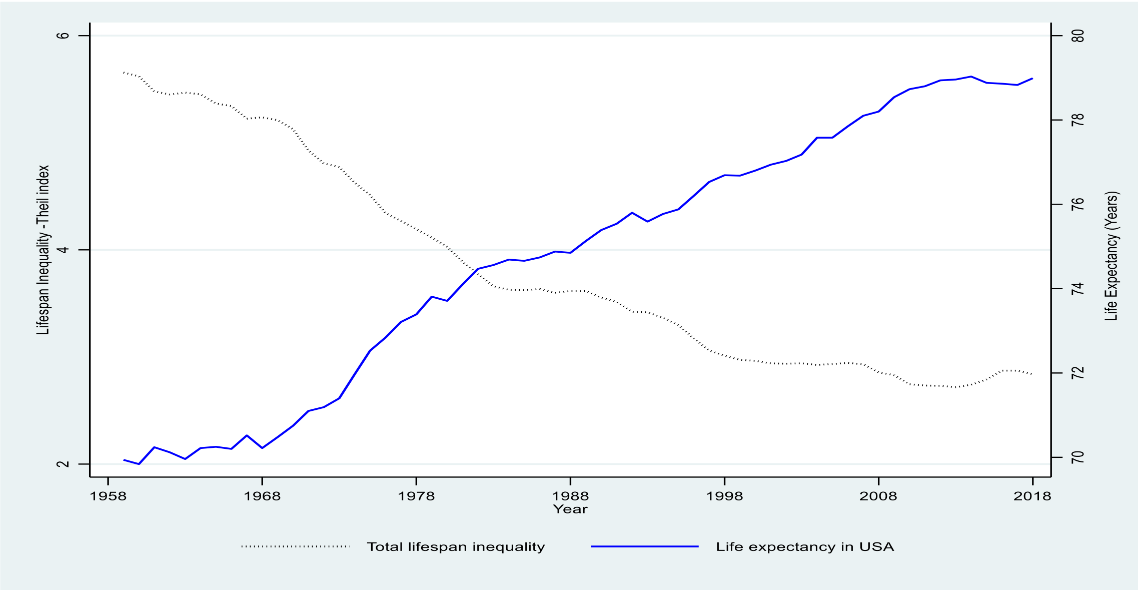
To address the econometric issues present in our data, including heteroscedasticity, serial correlation, and cross-sectional dependence, a suitable approach is to utilize the Feasible Generalized Least Squares (FGLS) method. This method, along with the conventional Error Correction technique, can effectively resolve the concerns, as suggested by Wooldridge (2010). However, Beck and Katz (1995) suggested that researchers employ OLS with heteroscedastic panels of corrected standard errors (OLS-PCSE) for analysing cross-sectional time-series data. This is because the standard errors of the estimated coefficients using FGLS may potentially underestimate the sampling variability. The OLS-PCSE method outperforms the FGLS method in accurately estimating standard errors, as demonstrated in their Monte Carlo analyses. Moreover, the Feasible Generalized Least Squares (FGLS) estimator is most suitable for panels with a larger number of periods (T) compared to the number of cross-sectional units (N). Conversely, panels with a smaller number of periods compared to the number of cross-sectional units are better suited to the Panel Corrected Standard Errors (PCSE) estimator We note that our sample has small T (27) and large N (50). An additional advantage of utilizing the OLS-PCSE approach is that it allows for the simultaneous correction of homoscedastic disturbances across cross-sections (Reed and Webb, 2010). Bailey and Katz (2011)assert that the PCSE estimates are resistant to variations in unit heteroscedasticity and possibly simultaneous correlation among units. Based on these factors, we apply PCSE as the most suitable estimator for analysing the panel data.

3. Results and Discussion

Trends in Life Expectancy and Lifespan Disparity

Life expectancy at birth in the United States increased by almost 9.05 years between 1959 and 2018, from 69.94 years in 1959 to 78.99 years in 2018, as shown in Figure 1. The highest decadal rise in life expectancy occurred between 1970 and 1980, with a 2.96-year increase from 70.75 to 73.71 years. The rise in life expectancy was not, however, continuous or universal. For example, life expectancy decreased in 1993, was stable in 2005, and has been relatively constant in recent years. Life expectancy in the United States in 2010 was 78.7 years, the same as in 2018. Until recently, the last time the United States saw a sustained drop in life expectancy for selected years was in 1918, during the First World War and the outbreak of Spanish influenza.

Figure 1: Life expectancy and lifespan inequality in the US: 1959-2018

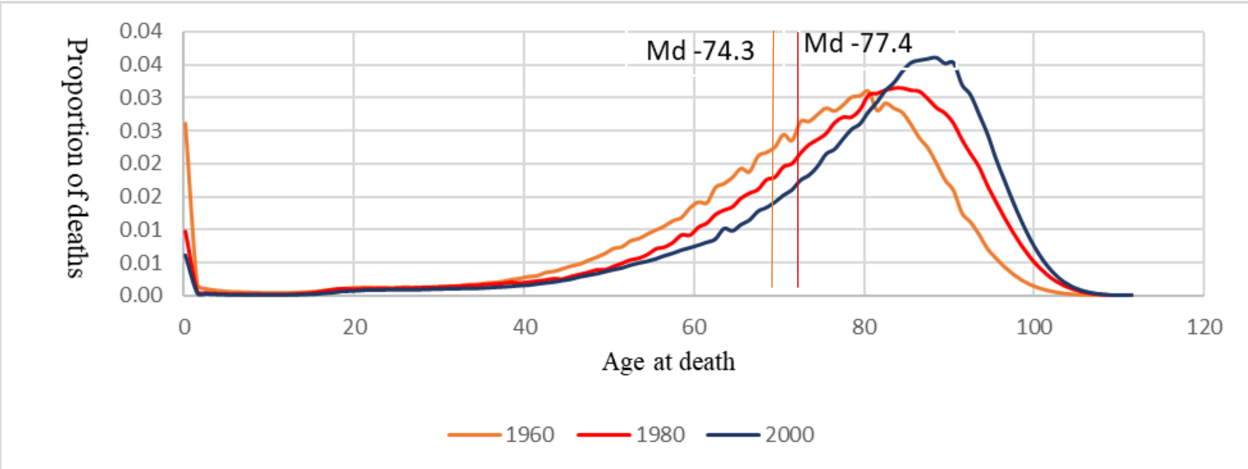


Source: Authors' calculations based on the United States Human Mortality Database

Figure 1 demonstrates a negative relationship between inequality in lifespan and life expectancy at the national level. Life expectancy has increased over time while lifespan inequality has decreased. This is because increases in life expectancy are frequently the result of decreases in infant mortality and premature death (Shkolnikov et al., 2011). This is further supported by Figure 2, which demonstrates that infant mortality has declined dramatically, with the distribution of ages at death steadily shifting to the right and fatalities increasingly concentrating just above the median age at death. On the other hand, according to Case and

Deaton (2015) the United States is the only developed nation in which midlife mortality has been increasing. A growing number of prime-age people (aged 20 to 49) are dying from 'despair' (Acciai & Firebaugh, 2017; Muennig et al., 2018), with the opioid epidemic, suicide, and alcohol-related mortality being attributed as causes (Muennig et al., 2018). This effect is not noticeable in Figure 2, where the data stops in 2000, but it has halted both the increase in life expectancy in recent years, as well as the reduction in lifespan inequality, as shown in Figure 1.

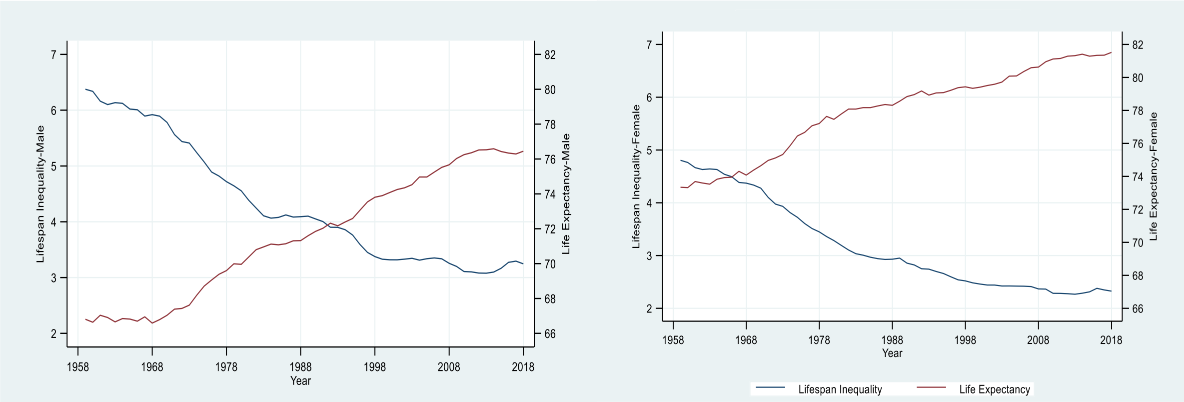
Figure 2: Age distribution of deaths in the US, 1960-2000



Source: Authors' calculations based on the United States Human Mortality Database

When gender differences in life expectancy and lifespan inequality are examined, females have greater life expectancy; nevertheless, in the US their gains in life expectancy over time have been less than those of males, as shown in Figure 3. In 1959, the average life expectancy for a male was 66.81 years, while the average life expectancy for a female was 73.34 years (a difference of 6.53 years). The average male life expectancy increased by 9.64 years to 76.45 years between 1959 and 2018. The life expectancy of women grew by 8.18 years, reaching 81.52 years. The male-female disparity in life expectancy decreased from 6.53 years in 1959 to 5.07 years in 2018. Figure 3 also illustrates the relationship between lifespan inequality and life expectancy at birth for men and women. The data suggest a substantial negative correlation between life expectancy and lifespan inequality (male r = -0.97 and female r = -0.99). As life expectancy has increased over time, lifespan inequality has decreased for both sexes (Figure 3).

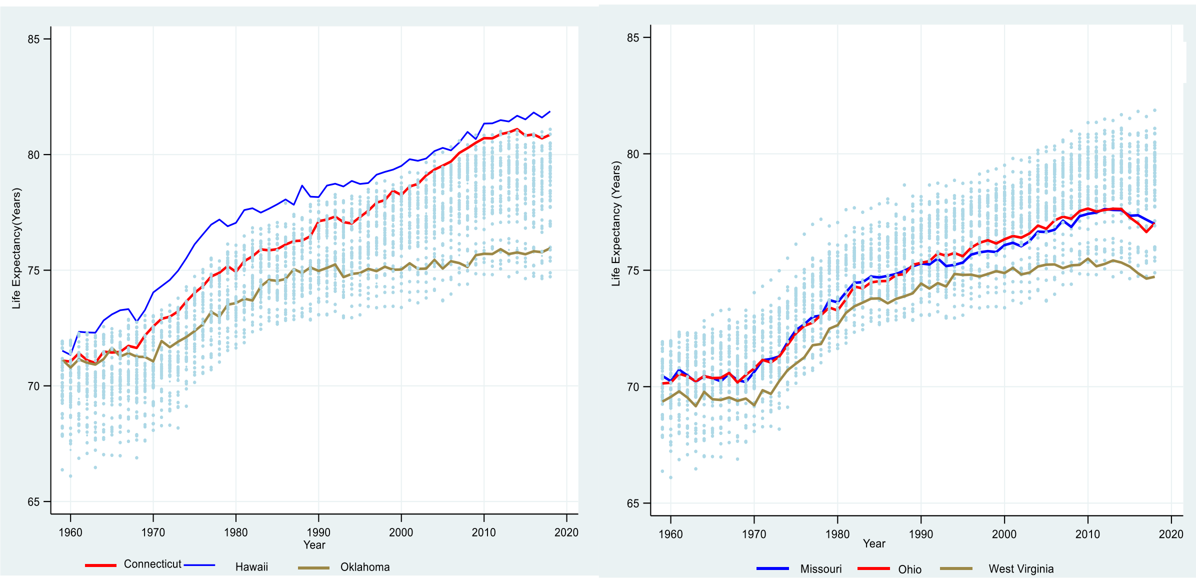
Figure 3: Lifespan inequality by gender in the US, 1959-2018



Source: Authors' calculations based on the United States Human Mortality Database

As shown in Figure, 4, life expectancy grew in all States between 1950 and 2020. However, not all states performed the same. For example, even though life expectancy was similar in Connecticut and Oklahoma in 1959, Connecticut's life expectancy has risen substantially more, and the life expectancy gap between those two states has widened (Figure 4, Panel (a)). Moreover, life expectancy has plateaued or even declined in recent years in some states, such as Ohio, Missouri, and West Virginia (Figure 4, Panel (b)).

Figure 4: Overall trends in Life expectancy by State and highlights



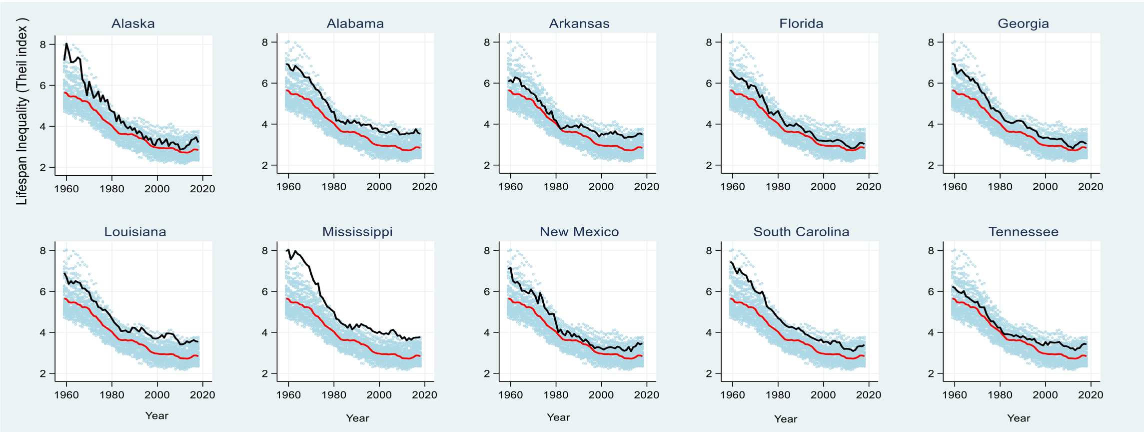
(a) (b)

Source: Authors' calculations based on the United States Human Mortality Database

Comparing national-level lifespan inequality with state-level lifespan inequality, different patterns of lifespan disparity can be observed, as shown in Figure 5.

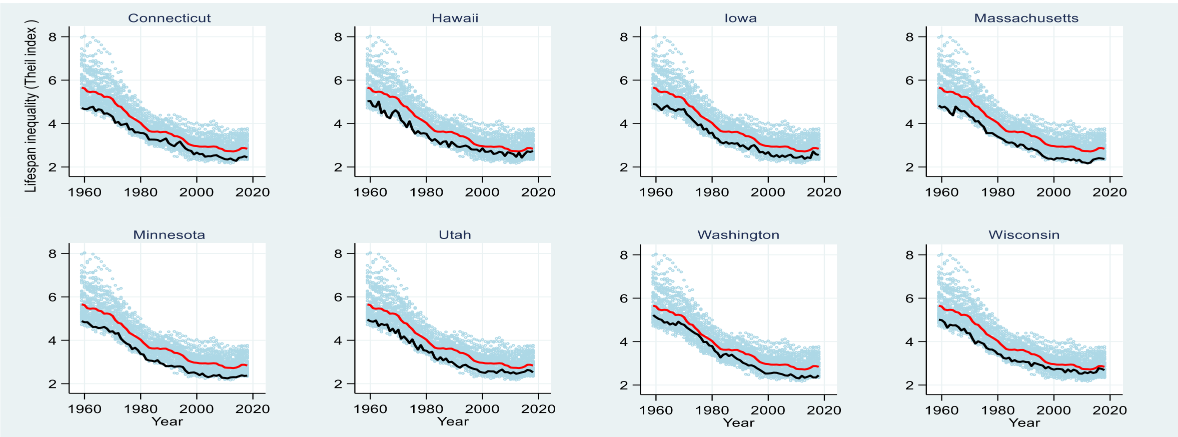
Figure 5a highlights states that recorded higher lifespan inequality than the national level over the entire period, while Figure 5b highlights states that recorded lower lifespan inequality than the national level over the entire period. Among the states, Mississippi has consistently had the highest lifespan inequality (Figure 5a), while Massachusetts and Minnesota have consistently had the lowest lifespan inequality (Figure 5b).

Figure 5a: Overall trends in Lifespan inequality by State and highlights for selected States



Source: Authors' calculations based on the United States Human Mortality Database

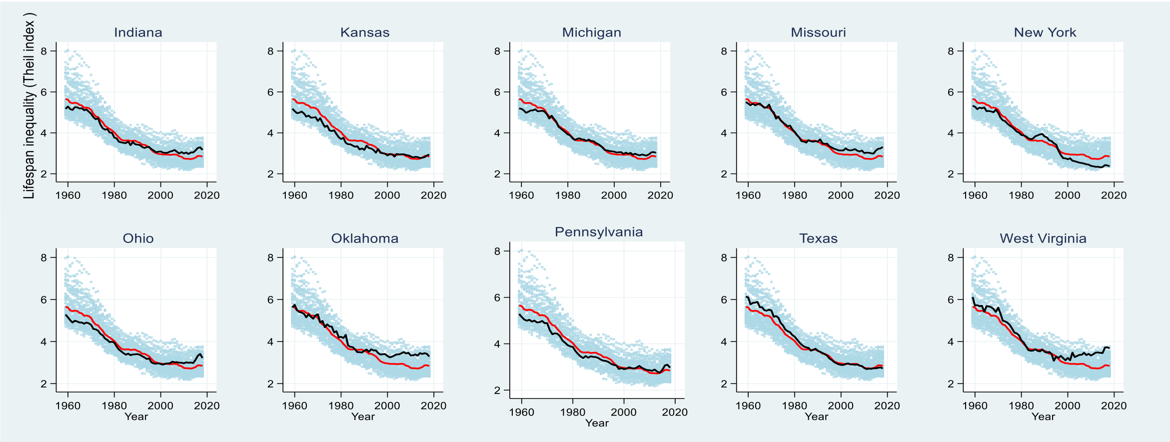
Figure 5b: Overall trends in Lifespan inequality by State and highlights for selected States



Source: Authors' calculations based on the United States Human Mortality Database

As depicted in Figure 5c, some states (Indiana, Missouri, Michigan, and Ohio) had below-average lifespan inequality at the beginning of the period under review, but above-average lifespan inequality after the 1990s. In particular, Indiana and Ohio experienced a substantial increase in lifespan inequality after 2010 (Figure 5c), as well as significant decreases in life expectancy and increases in mortality.

Figure 5c: Overall trends in Lifespan inequality by State and highlights for selected States



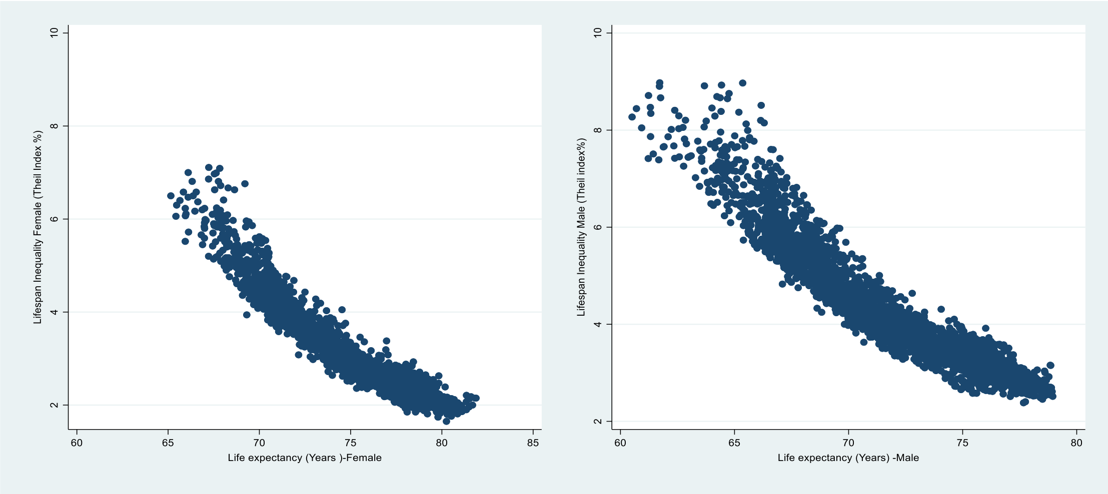
Source: Authors' calculations based on the United States Human Mortality Database

Moreover, some States, such as New York, maintained a low level of lifespan inequality until the 1980s; since then, it has increased, but it has remained below the national average since 2000 (Figure 5c). On the other hand, other states, including West Virginia and Oklahoma showed a decreasing trend, experiencing substantial increases in lifespan inequality after the 1990s and have remained above the US average lifespan inequality (Figure 5c).

Sex Differences in Life Expectancy and Lifespan Inequality by State

As shown in Figure 6, the relationship between lifespan inequality and life expectancy becomes even more apparent when life expectancy is plotted against the lifespan inequality for all state-year combinations. Both males (right panel of Figure 6, r = -0.94) and females (left panel of Figure 6, r = -0.95) exhibit a very substantial negative correlation between life expectancy and lifespan inequality. In addition, the figure illustrates that at each level of life expectancy, there exists a range of levels of lifespan inequality across states.

Figure 6: State-level lifespan inequality by life expectancy for females and males



Source: Authors' calculations based on the United States Human Mortality Database

Regression Results

Table 4 presents the results of the PCSE estimations, with total lifespan inequality (Model 1), lifespan inequality for females (Model 2), and lifespan inequality for males (Model 3) as dependent variables. The sample size is reduced to 1350, as some variables are measured in the first differences. However, all three models have relatively high *R*-squared values, demonstrating that they explain a large proportion of the variation in lifespan inequality.

Table 4: Panels Corrected Standard Error Model Results (PCSEs)

	Model 1 **Lifespan inequality - Total**	**Model 2** **Lifespan inequality - Female**	**Model 3** **Lifespan inequality – Male**
	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)
% high school graduates	-1.100 (<0.001)***	-1.087 (<0.001)***	-1.211 (<0.001)***
% college graduates	-1.140 (<0.001)***	-0.879 (0.002)***	-1.420 (<0.001)***
Gini index	0.750 (0.077)*	0.771 (0.089)*	0.797 (0.151)
Violent Crime rate (per 10000 population)	0.008 (<0.001)***	0.006 (<0.001)***	0.010 (<0.001)***
Cigarette consumption (Pack Sales Per Capita)	0.003 (<0.001)***	0.002 (<0.001)***	0.003 (<0.001)***
Total Personal Health care (% GDP)	0.016 (0.151)	0.008 (0.523)	0.025 (0.085)*
Physicians (per 10000 population)	-0.015 (<0.001)***	-0.012 (<0.001)***	-0.018 (<0.001)***
% insurance prevalence under 65	-0.004 (0.061)*	-0.004 (0.061)*	-0.005 (0.075)*
Population growth	-0.027 (0.007)***	-0.031 (0.003)***	-0.038 (0.003)***
% Black population	-0.026 (0.490)	-0.042 (0.313)	-0.010 (0.832)
% Hispanic population	-0.014 (0.076)*	-0.015 (0.115)	-0.020 (0.104)
CO_2 emissions per capita	0.001 (0.032)**	0.001 (0.175)	0.001 (0.234)
Population density	-0.003 (0.426)	-0.005 (0.184)	0.0001 (0.975)
Unemployment	-0.002 (0.717)	0.0003 (0.955)	0.0004 (0.959)

% of employees in manufacturing	0.001 (0.678)	0.001 (0.722)	-0.004 (0.228)
Real per capita income (Log)	0.413 (0.469)	0.763 (0.214)	0.185 (0.811)
Constant	4.113 (<0.001)***	3.553 (<0.001)***	4.669 (<0.001)***
R-squared	0.885	0.808	0.848
Sample Size	1350	1350	1350

Notes:
Standard errors are reported in parentheses. *Variable names in italics indicate that they are measured in first differences.*
***, ** ,* indicate significance at the 1%, 5% and 10% levels respectively.

Education is one of the important predictors in our model. One standard deviation (0.05) increase in the percentage of high school graduates is associated with a 0.054 unit decrease in total lifespan inequality (compared with a mean value of 3.08), and 0.053 unit and 0.06-unit lower lifespan inequality for females and males, respectively. Similar sized effects are demonstrated for the percentage of college graduates. Individuals with a higher level of education generally have greater access to material and nonmaterial resources, facilitating access to healthcare as well as being associated with healthier lifestyles and environments (Link & Phelan, 1995). This suggests that populations with a greater capacity to optimize health over the life course have a more uniform distribution of age at death (Brown et al., 2012). Moreover, the importance of education in explaining state-level differences in lifespan inequality is consistent with previous research that shows, on average, Americans with a college education live longer and exhibit a greater compression of mortality, with fatalities narrowly concentrated at the upper tail of the age distribution, a pattern that is also observed in many European countries (van Raalte et al., 2011). Our results in terms of the importance of education are also consistent with the extant literature on lifespan inequality. Edwards and Tuljapurkar (2005) observed that income or education accounted for a 10 to 15% of the difference in lifespan variation (for those aged 10+ years) in the US. Brown et al. (2012) examined old age mortality compression along socioeconomic dimensions in the United States, revealing a positive association between education and mortality compression. Mortality was more compressed among women within each educational group than males. Additionally, Shkolnikov et al. (2003) identified larger lifespan inequality among less educated Russians (ages 20 to 65), with differences by educational group widening between 1979 and 1989.

There is less evidence that income matters in our analysis, after controlling for other state-level factors, with GDP per capita statistically insignificant for all three models. However, income inequality, as measured by the Gini index, is a weak predictor of lifespan inequality in total and for females (significant at the 10 percent level). A one standard deviation (0.04 point) increase in the Gini index is associated with total and female lifespan inequality that are 0.027 and 0.028 units higher, respectively. High income inequality has been associated with increased health risk behaviors like smoking, obesity, and exercise (Chetty, 2016). Furthermore, higher income inequality is significantly associated with rates of low birth weight, homicide, violent crime, low expenditures on medical care and access, all of which led to higher mortality (Kennedy et al, 1996). Thus, higher income inequality is likely to be associated with greater disparities in mortality rates, leading to greater lifespan inequality.

One standard deviation (22.38 per 10,000 population) increase in the violent crime rate is associated with a 0.18-unit higher total lifespan inequality, while one standard deviation (31.62 packs per capita-year) increase in cigarette consumption is associated with 0.095 units higher total lifespan inequality. Our findings on violence are in accord with earlier research showing a positive association between lifespan inequality and the violent crime rate in Venezuela (Garcia and Aburto, 2019) and in Mexico (Aburto and Beltrán-Sánchez, 2019). Even though smoking prevalence has declined in the US, trends in smoking prevalence are highly differentiated geographically and smoking rates have been identified as a significant contributor to the divergence in mortality across US regions (Fenelon, 2013). Peak smoking-attributable mortality trails behind peak smoking consumption by about 30 years at the population level (Lopez et al., 1994), meaning that in spite of decreasing rates of smoking, smoking-related mortality will continue to affect life expectancy and lifespan inequality for many years. According to a long-running prospective British cohort study of medical doctors (Doll et al., 2005), lifelong smokers die on average ten years earlier than nonsmokers. According to Peto et al. (2006), smoking contributed to 29% of male deaths and 27% of female deaths in the US between the ages of 35 and 69 in 2000. Preston et al. (2010) reported comparable statistics across many countries and demonstrated that, among twenty developed nations in 2003, the US had the highest deaths attributable to smoking among females and the sixth highest proportion among males.

Although personal healthcare expenditure is not statistically significant (except for in the model for male lifespan inequality at the 10 percent level), other healthcare variables are significantly related to lifespan inequality. The negative relationship between lifespan inequality and physician density is consistent with negative relationships between physician supply and mortality rates reported for the United States (Kindig et al.,2002), as well as between mortality rates and the supply of primary care physicians (Starfield et al., 2005). Health insurance prevalence is also associated with lower lifespan inequality. Health insurance facilitates access to health care services and provides financial protection against the high costs of illness. Insured Americans are more likely to obtain recommended screening and treatment for chronic conditions (Ayanian et al., 2000), and are less likely to suffer from undiagnosed chronic conditions (Ayanian et al., 2003) or to receive substandard medical care, compared to those without health insurance (Committee on the Consequences of Uninsurance, 2002). Furthermore, lack of health insurance increases the likelihood of mortality from certain diseases (Franks et al.1993; McWilliams et al.,2004 and Wilper et al.,2009). For example, more than twice as many Americans aged 25 to 64 died due to lack of health insurance in 2006 than were murdered (Tanne, 2008). There is significant geographic variation in health insurance coverage (Stone et al., 2015). Moreover, medical insurers offer various schemes with different terms and conditions, which can lead to unequal benefits distribution among beneficiaries, and consequently variation in lifespan inequality.

Population growth is negatively associated with lifespan inequality in all three models. Short term population growth depends on migration, and migrants tend to be younger than the native-born population, as well as healthier – a phenomenon known as the 'healthy migrant' effect (Razum et al., 2000; Newbold, 2006). A healthier population on average, as a result of migration, will also exhibit lower lifespan inequality.

4. Conclusion

In this study, we investigated trends over the last 55 years in life expectancy and lifespan inequality in the US, as well as the factors associated with state-level lifespan inequality. The analyses demonstrate compression of mortality over time, in which the distribution of deaths has shifted rightward toward older ages and become increasingly compressed around a rising late-life modal age at death. This is manifested in decreasing lifespan inequality over time. However, the general trend masks substantial heterogeneity in the experiences of different states, particularly in recent years where increases in life expectancy, and decreases in lifespan inequality, have ceased in some Midwest states. Moreover, some states, such as Mississippi, Massachusetts, and Minnesota, exhibit noteworthy departures from the national level of lifespan inequality. Mississippi has continuously had the greatest lifespan inequality, while Massachusetts and Minnesota have consistently had among the lowest levels of lifespan inequality.

Investigating the factors associated with lifespan inequality at the state level, we found that lifespan inequality is correlated with a number of socioeconomic, demographic, and health-related variables, in particular education, income inequality, violent crime, cigarette consumption, and the population growth rate. While not necessarily causal, the relationships we identify may have significant policy ramifications. In particular, risk factor-focused policies and initiatives (such as tobacco taxation, state laws on gun ownership, and health resources allocation) can potentially reduce geographic disparities by enhancing health and safety in all areas, particularly among those currently most disadvantaged. This is not to say that policies that focus on the socioeconomic factors that cause disparities would not be successful; instead, it is to suggest various pathways to more equitable health outcomes for federal, state, and local policymakers should be considered. Moreover, experts now understand that socioeconomic status and health links reflect causal pathways in both directions (Bloom & Canning, 2000). Therefore, policies that address health inequalities may, over time, also be effective means of addressing inequalities in socioeconomic status.

Education was the socio-economic factor that had the greatest relationship with lifespan inequality in our analysis. Health insurance provision was also found to be an important factor associated with lifespan inequality. Disparities in public health insurance provision may be among the most significant policy differences between states. The two age categories whose mortality rates have continued to decrease in the US have been those with complete public health care coverage: the elderly and the very young (Cha & Cohen,2022). While millions have gained health insurance after the passage of the Affordable Care Act in 2010, these gains have since been eroded due to changes to the Medicaid program (which covers low-income Americans) that have made it increasingly difficult for people to enrol and maintain coverage (Ayanian et al, 2000; Wilper et al., 2009). Increasing insurance coverage and removing barriers to access the insurance may contribute to reducing lifespan inequality by improving health among the young and mid-life populations.

It is important to recognize specific limitations in the study of health inequality. A significant limitation is the sole emphasis on mortality, without a thorough analysis of morbidity and the quality of life in terms of health (Permanyer et al., 2022). Our research has not examined the relationship between health inequality and two important aspects of health: morbidity, which refers to the occurrence of illnesses or diseases in a community, and quality of life (QoL). Future study could extend lifespan inequality to a consideration of *healthy lifespan inequality*, incorporating not only mortality but also quality of life considerations. Notwithstanding these issues, our study provides an important contribution to our understanding of lifespan inequality in the US by examining trends over a considerable period of state-level variations. This study may serve as a foundation for policymakers and assist in directing endeavors to formulate policies and treatments that aid in the objective of diminishing lifespan inequality and promoting the overall health and well-being of population groups. Lifespan inequality remains an underutilized metric of health outcomes, and this study provides important insights that, we hope, can be used to steer future research endeavors.

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Appendix

Table A1: Fixed and Random Effects Models

	Model 1 Lifespan inequality -Total (Coef.)		**Model 2 Lifespan inequality-Female (Coef.)**		**Model 3 Lifespan inequality-Male (Coef.)**	
	FE	RE	FE	RE	FE	RE
% of high school graduates	-0.168 (0.462)	-0.075 (0.744)	-0.045 (0.834)	0.012 (0.955)	-0.257 (0.383)	-0.157 (0.592)
% of college graduate	0.543 (0.08)*	-1.306 (0.001)***	-0.918 (0.002)***	-1.552 (0.001)***	-0.214 (0.593)	-1.093 (0.003)***
Gini index	0.479 (0.006)***	0.411 (0.002)**	0.039 (0.814)	-0.013 (0.935)	0.834 (0.001)***	0.757 (0.001)***
Violent Crime rate (per 10000 population)	0.0006 (0.001)***	0.0008 (0.001)***	0.004 (0.001)***	0.005 (0.001)***	0.008 (0.001)***	0.01 (0.001)***
Cigarette Consumption (Pack Sales Per Capita)	0.002 (0.001)***	0.002 (0.001)***	0.001 (0.001)***	0.001 (0.001)***	0.002 (0.001)***	0.002 (0.001)***
Total Personal Health care (% GDP)	-0.008 (0.065)*	-0.006 (0.152)	-0.004 (0.321)	0.00003 (0.994)	-0.01 (0.099)*	-0.006 (0.206)
Physicians(per 10000 population)	-0.011 (0.001)***	-0.01 (0.001)***	-0.007 (0.022)**	-0.009 (0.001)***	-0.014 (0.001)***	-0.013 (0.001)***
% of insurance prevalence under 65	0.015 (0.001)***	0.012 (0.001)***	0.011 (0.001)***	0.008 (0.001)***	0.018 (0.001)***	0.015 (0.001)***
Population growth	-0.012 (0.064)*	-0.009 (0.167)	-0.015 (0.012)**	-0.014 (0.019)**	-0.01 (0.219)	-0.005 (0.522)
% of Black population	-0.008 (0.298)	0.016 (0.000)***	0.007 (0.297)	0.016 (0.000)***	0.009 (0.343)	0.018 (0.000)***
% of Hispanic population	-0.02 (0.001)***	-0.01 (0.001)***	-0.012 (0.001)***	-0.005 (0.002)***	-0.026 (0.001)***	-0.011 (0.001)***
Co_2 per capita	-0.0003 (0.723)	0.0001 (0.248)	0.0001 (0.923)	0.001 (0.168)	-0.001 (0.597)	0.001 (0.290)
Population density	-0.004 (0.001)***	-0.001 (0.001)***	-0.004 (0.001)***	-0.001 (0.005)***	-0.004 (0.001)***	-0.001 (0.010)***
Unemployment rate	0.0077 (0.014)***	0.004 (0.180)	0.003 (0.305)	-0.001 (0.829)	0.01 (0.012)**	0.006 (0.143)
% of employees in manufacturing	-0.004 (0.270)	-0.005 0.162	-0.002 (0.548)	-0.002 (0.456)	-0.008 (0.085)*	-0.009 (0.019)**

Real Per Capita Income (Log)	-0.882 (0.001)***	-0.988 (0.001)***	-0.371 (0.019)**	-0.467 (0.001)***	-1.09 (0.001)***	-1.34 (0.001)***
Constant	5.839 (0.001)***	6.368 (0.001)***	3.777 (0.001)***	4.055 (0.001)***	7.081 (0.001)***	7.994 (0.001)***
Heteroscedasticity test		0.000		0.000		0.000
Serial correlation test		0.000		0.042		0.000
R-squared	0.789	0.768	0.683	0.768	0.745	0.746
Sample Size		1400		1400		1400
*** p<.01, ** p<.05, * p<.1						

Source: Authors’ calculations

Table A2: Cross-sectional dependence test

Test	**Statistic**	**Prob.**
Prob Breusch-Pagan’s LM	6145.062	0.000
Pesaran’s scaled LM	104.8551	0.000
Pesaran’s CD	56.69722	0.000

Source: Authors’ calculations

Table A3: Second Generation Unit root test

Variable	CADF		CIPS	
	I(0)	I(I)	I(0)	I(I)
Theil index	-2.637***	-4.643***	-3.623***	-5.931***
Male T	-2.867 ***	-4.747***	-3.842 ***	-5.915***
Female T	-3.014***	-4.975***	-4.219***	-6.030***
% of high school graduates	-2.653***	-4.449***	-2.957***	-5.579 ***
% of college graduate	-2.819***	-4.499***	-3.207***	-5.589***
Gini index	-2.023 ***	-2.954***	-1.943	-4.349 ***
Violent Crime rate(10000 per population)	-2.172***	-3.739***	-2.978***	-4.877***
Cigarette Consumption (Pack Sales Per Capita)	-2.003***	-3.808***	-2.416***	-5.166***
Total Personal Health care (% GDP)	-1.576	-3.396***	-1.463	-4.520***
Physician (10000 per population)	-1.862	-3.820***	-2.526 ***	-5.651***
% Insurance prevalence under 65	-2.292***	-4.759***	-2.900 ***	-5.821***
Population growth	-2.682***	-3.313***	-2.655***	-4.670***
% Black population	-1.126	-2.451***	-0.942	-3.039***
% Hispanic population	-1.444	-2.285***	-2.109*	-4.232***
Co_2 per Capita	-2.583***	-5.429***	-3.543 ***	-6.074***
Population density	-2.368***	-2.533***	-1.269	-2.558 ***
Unemployment rate(%)	-2.428***	-3.327***	-2.364***	-4.073***
% Employees in manufacturing	-2.186***	-2.937***	-2.222 ***	-3.878 ***
Log Real Per Capita income	-2.107***	-2.735***	-1.824	-3.958 ***

Source: Authors' calculations

*** ,* indicate significance at the 5% and 10% levels