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Differences in Health and Health Care between Rural and Urban America

by

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Submitted in Partial Fulfillment of the Requirements for the M.D. Degree with Honors in a Special Field at Harvard Medical School

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I have reviewed this thesis. It represents work done by the author under my supervision and guidance.

Faculty Supervisor's Signature

Abstract

Background: Social and economic disparities in the United States have occupied significant media and political attention since the election of 2016. In particular, the country has focused on the lack of understanding of the struggles of Americans who live outside its predominantly liberal cities. In the academic literature, there remains little objective data on the differences between urban and rural Americans, and how these differences have changed over time. The rural-urban divide within health and health care is especially poorly understood. Filling in this knowledge gap would bring evidence-based data to our political discourse, and also potentially better target policy and public health interventions. This study has three aims: a) to describe the demographic and social differences of rural and urban counties; b) to understand differences in health between rural and urban counties along major causes of death; and c) to explore differences in health care access and health delivery systems between urban and rural counties.

Methods: This study uses the U.S. Census classification of all 3,142 counties as either urban or rural (defined as mostly rural or all-rural). Data from several sources were gathered to compare demographic characteristics of urban and rural counties, including the racial composition and socioeconomic status. Data from the Institute of Health Metrics and Evaluation was gathered to compare the mortality rates from all-cause mortality, cardiovascular disease, neoplasms, chronic respiratory disease, substance use disorder, and self-harm/interpersonal violence over the period of 1980-2014. Regression analysis was used to assess for differences in outcomes between rural and urban counties, adjusted for observed covariates. Data from the Area Health Resource file was used to investigate measures of access including physician density, hospital bed density, and insurance access. Two-tailed *t* tests were used to assess the significance of differences.

Results: Rural counties on average were less diverse and poorer than their urban counterparts. In unadjusted analysis of mortality data, rural counties had higher mortality rates both overall and in most disease categories; these differences generally widened over the study period. In adjusted analyses, differences in mortality between rural and urban counties were statistically significant in overall mortality and every cause of death measured except for substance use disorder/mental health. Moreover, significant differences were found between urban and rural counties across all measures of physician density (Total physicians, primary care physicians, subspecialists, and psychiatrists) with rural counties consistently having fewer providers per capita.

Conclusion: This study found differences across the various dimensions of health and health care between urban and rural counties. In the case of mortality, disparities widened over time and regression analyses demonstrated continued increasing mortality over time in all causes of death. The potential causes of this apparent disparity are unclear and likely multifactorial, ranging from socioeconomic characteristics to issues of access. The data on lower physician density in rural areas provides some understanding of the lack of availability and access to the delivery system in

rural areas. Further work should be conducted to better understand these differences and policy/public health interventions should be tailored to address these health disparities if further validated.

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None of my work would be possible without the support of my friends and family.

This work and all efforts in my career are dedicated to my mother and late father, to whom I owe everything, who for their entire careers cared for patients who came from rural and urban America and spanned the spectrum of what America looks like in Oklahoma City, Oklahoma.

A. **Introduction**:

Since the 2016 Presidential election, there has been increasing political and media attention on "middle America" and a suspected rejection of progressive policies by rural America.[1] Despite the advancement of a more progressive health system through the Affordable Care Act (ACA), there has been a heightened discussion of "Two Americas" and a lack of understanding of a "rural class" and the rural poor, both in terms of variation in health care status, but also across numerous dimensions of socioeconomic status.[2] There has also been further attention to the ways in which these differences have manifested themselves politically, with polling data indicating that rural Americans are more likely to identify as Republican, while urban voters are more likely to identify as Democrat, particularly since 2008.[3]

The recent U.S. midterm elections of 2018 produced substantial discussion on the growing differences between rural and urban voters, as well as the continued role this difference will play in future elections and policy implementation.[45] Beyond political analysis, public consumption of the purported differences among rural and urban has further spread into various types of media as is readily apparent through the popularity of bestselling books such as "Hillbilly Elegy" by J.D. Vance and "The Politics of Resentment" by Katherine Cramer, which provide personal narratives of the lives of rural America.[6,7] This heightened attention on "forgotten" portions of America—and Americans themselves—has been further magnified since Case and Deaton's landmark study in 2015, which demonstrated that mortality among lower-educated white males has increased for the first time in decades (while mortality among other segments of the U.S. population has decreased at the same time), explained by "deaths of despair" attributable to suicides, alcohol, substance use, and the sequelae of such pathologies.[8] The study triggered a flurry of research on the health of the "heartland" as public attention shifted to rural America. The *American Journal of Public Health* published a special issue in October 2017 entitled "Despair in the American Heartland? A focus on Rural Health," with several articles on rural health care and its intersections with politics, including the rise of rural suicides in Maryland and the ways in which counties left out of broader life expectancy gains abandoned the Democratic Party.[9,10,11] However, while focus might have shifted to a question of rural and urban status, the Case and Deaton study and follow-up research efforts have not truly

addressed differences in the health and health care system of rural and urban America, or the evolution of those differences in recent decades.

The impact of geography and community on health has been explored in the academic literature. Research has shown significant inequalities in life-expectancy in the U.S.[12,13] The concept of "Eight Americas" by Murray et al., which dissected the U.S. into different sections based on race and geography, highlighted apparent differences across geography and race.[14] Yet, while the literature has contemplated the role of race and socioeconomic variables on health and health care, little is known about differences in health or health care outcomes related to whether a county is rural or urban. That is, rural areas or urban areas might differ widely among each other with regards to racial and economic factors, but might share underlying similarities with regards to other factors that influence health.

Despite the media and policy attention on this rural and urban divide, there is little objective data that describes the differences in health and health care outcomes between rural and urban America. Approximately 60 million people, or about 19% of the United States (US) population, live in rural areas.[15] The overall health status and health care access of rural populations has not been well described in the literature, nor the differences between rural and urban communities.

This study provides a comparative analysis of the differences between rural and urban communities within the U.S. along numerous dimensions, social demographics, health outcomes and health access.

To date, there have been few studies that seek to better understand the differences in health between rural and urban settings at large. Furthermore, there have been even fewer large-scale studies that analyzed delivery system differences between rural and urban areas at the county level. A large literature has examined health outcomes alone. One study looked at the differences and disparity in all-cause mortality between rural and urban settings.[16] However, this study was comparing metropolitan statistical areas to non-metropolitan areas, and did not analyze along the binary dimension of rural or urban. Given that metropolitan statistical areas are not confined within county boundaries (metropolitan statistical areas cross county boundaries), it presents a different experiment than analyses of counties. Analysis of the larger delivery system has been constrained to investigating different care measures, such as substance use interventions, specialist access, or disease prevalence such as obesity, but often these studies are

limited to specific regions and narrowed within a specific specialty.[17, 18] Recently, there have been more comprehensive studies that provided some descriptive analysis of the entire U.S. population at a rural-urban comparison. One of these studies used the Robert Wood Johnson Foundation's County Health Rankings as dependent variables in comparing rural and urban counties.[19] This study was limited in that while the County Health Rankings provides a large breadth of data for comparison (demographic data, under-75 mortality, number of primary care physicians, and physical/social environmental conditions), the study did not analyze specific health outcomes or access/delivery system across a more robust set of measures. Furthermore, the data presented did not quantify the actual differences between rural and urban counties, but rather developed a quartile ranking system and segmented rural and urban counties based on where they fell in the rankings.

Most recently, Christopher Murray's group at the Institute for Health Metrics and Evaluation (IHME) at the University of Washington has published in JAMA the first large-scale descriptive analyses of county-level changes mortality rates for major causes of death in the U.S. over a 34-year period beginning in 1980.[20] The study was focused on analyzing county level trends, between county differences, and geographic variation of mortality rates for specific disease types. This analysis, however, did not look at differences between rural and urban settings. Follow-up analyses in JAMA further studied county-level differences and changes in mortality rates across cardiovascular pathologies, respiratory disease, malignancies, and substance use/mental health mortality rates.[21 22 23] However, while these studies have provided likely the most accurate estimates of county mortality rates over time, there was no analysis to study the overall differences between rural and urban settings—a distinction that may be more policy relevant at the federal level.

One area where there is a significant dearth in the literature is the differences in the delivery of health care between rural and urban areas. Workforce disparities have shown to contribute to poor health outcomes.[24] Recent studies have quantified differences among specialist providers between rural and urban counties, including dermatologists and colorectal surgery.[25,26] However, to our knowledge there has been no study comparing rural and urban physician density across numerous fields including generalists and specialists to better assess workforce and geographic disparities.

There is a significant need to better understand the differences between rural and urban communities. In this study, we plan to study these differences in several ways. The county serves as our primary geographic unit as it is the smallest geographic unit with document health care data, and additionally each county has a U.S. Census documentation of either rural or urban status. This binary status allows the U.S. to create a clear binary of distinction across the entire U.S. and the ability to both describe the ways rural and urban counties might differ, but also to think about "rurality" as a possible independent effect on a population, just as one might treat another socioeconomic dimension.

This study was centered on several specific aims. First, we examined the overall demographic differences between rural and urban counties, using variation in age, racial make-up, and socioeconomic differences to better understand the make-up of rural and urban communities at baseline. Second, we assessed the differences in health outcomes between rural and urban counties in the U.S. over time. Our primary measure of health outcomes was age-adjusted mortality data for all counties in the U.S. with rural-urban status as the dependent variable. The health outcomes we will study include mortality rates from main causes of death in the US, including cardiovascular disease, neoplasms, chronic respiratory disease, neoplasms, mental health/substance-use disorder, and self-harm/inter-personal violence. Second, we seek to better understand the delivery system differences between rural and urban counties by a measure of health access to different healthcare providers. Our primary measure of health access will be physician density per capita across a variety of specialties over time. The main measures of physician density we will study include MDs, primary care practitioners, medicine subspecialists, psychiatrists, and surgical specialists. We will also study health access through infrastructure measures including hospital bed per capita, nursing facility beds per capita, and skilled nursing facility beds per capita.

As evidenced by the lack of literature, there is a substantial need to better understand the differences between rural and urban America for both academia and policymakers. Significant differences in health outcomes and health outcomes could inform the ways in which we consider new health interventions and the way we think of delivery system reforms including insurance coverage and provider distribution within states and across counties. Furthermore, the use of a rural-urban binary will further prove more useful than more specific previous descriptions as it could more easily translate to broad scale policy and public health shifts.

B. Methods

The project centers on a descriptive analysis of the differences in current demographics, health outcomes over time, and access to health care in rural and urban counties in the U.S. Rural and urban status was designated for each county based on the U.S. Census definition which classifies every county as either all rural, mostly rural, or mostly urban. These classifications use a variety of criteria to make these distinctions including absolute population, population density, land use, and distance of urbanized clusters. For the purpose of this study, we have combined the categories of mostly rural and all rural counties under the umbrella of rural to provide a binary analysis.

Data:

The data for the overall demographic differences for 2016 between rural and urban counties were taken from the Robert Wood Johnson Foundation (RWJF) County Health Rankings (CHR) for data on population, racial breakdown, children in poverty, unemployment rate and education status, which sourced the data from the American Community Survey and the Bureau of Labor Statistics. Median household income and percentage of population in poverty were taken from Small Area Poverty Estimates.

The data for health outcomes from 1980-2014 were gathered from the IHME at the University of Washington. IHME collected raw data from the Center for Disease Control (CDC) National Center for Health Statistics and the Human Mortality database and adjusted these data by sociodemographic variables. Additionally, population data over the time period of 1980-2014 for the adjusted analysis with linear regressions was obtained from the National Bureau of Economic Research's open source files on county populations of age, race, and sex. Median household income data and percentage of population of poverty in poverty over the time period of 1980-2014 were taken from the Small Area Poverty Estimates.

The data for health access was gathered from the Area Health Resources File (AHRF) and population estimates from the U.S. Census. The AHRF is compiled by the Health Resources and Services Administration (HRSA). It consists of data on the number of physicians and medical providers across numerous specialties per county across a relatively recent period as well as other health structures within counties such as hospitals and nursing facilities, and measures of access including percent insured and uninsured within counties.

All data was de-identified and taken from public data sets. Therefore, this study did not require Institutional Review Board approval at Harvard Medical School. All statistical analyses were conducted using STATA statistical software.

Variables:

For patient demographics, the primary variables included average population, age, percentage of racial breakdown, household income, unemployment rate, and percentage of high school and college educated.

For health outcomes, the primary variables included data from 1980-2014. These included mortality rates in U.S. counties for all-cause mortality, cardiovascular disease mortality, neoplasm mortality, chronic respiratory disease mortality, chronic respiratory disease mortality, mental illness and substance use disorder mortality, and self-harm and interpersonal violence.

For health access, the primary variables included total MDs per capita, primary care providers per capita, cardiologists per capita, medicine sub-specialists per capita, psychiatrists per capita, and surgical subspecialists per capita. Additionally,

Statistical Methods:

I. Unadjusted Analyses

Demographics of rural counties along the multiple variables mentioned above (Population, age, percentage of racial background, average household income, unemployment rate, percentage with high school and college education, and percentage uninsured) were compared to urban counties. Differences were examined between rural and urban counties using the two-tailed *t*-test.

Health outcomes variable were gathered from the IHME mortality data set. Christopher Murray and colleagues at IHME have published in the last year a series of papers in which they utilize a new method of more precisely and accurately for estimating cause-specific county level mortality rates particularly in areas with small population levels and low mortality counts. As part of previous studies on the Global Burden of Disease, *ICD-9* and *ICD-10* codes have been translated to attribute all deaths to one cause. However, previous work has elucidated that many registered deaths have been assigned "garbage codes" that provided a non-specific intermediate or immediate cause of death, rather than an underlying cause of death. The IHME data took into

account this issue by redistributing "garbage codes' using algorithms to biologically plausible target causes.

The IHME mortality data also utilized small area models to better estimate mortality rates using Bayesian spatially explicit mixed-effect regression models. The variables included in their model were: proportion of adults who graduated high school, proportion of population that is Hispanic, proportion of population that is black, proportion of population that is a racer other than black or white, proportion of county that is contained within a state or federal Native American reservation; the median household income; and the population density. The data was further scaled along multiple dimensions to ensure that sums across all causes equaled all-cause mortality rate for each county and weighted averages of county-specific mortality equaled state and national averages. These small areas estimate models were validated by the IHME group through previous methods of evaluation.

Health access variables were calculated by creating a "per capita" variable from the raw data across the numerous variables. Each variable per county-year was divided by the population of the county at the given time point and then multiplied by 100000 to generate data easiest to interpret. This was done to mitigate the impact of population on increased or decreased absolute provider number. Differences were examined between rural and urban counties using the *t*-test.

II. Adjusted Analyses

The adjustments of the IHME data-set provided us with a more accurate and rigorous data set of different causes of mortality over time relative to the draw CDC data. However, given that we were largely interested in the way that rural and urban areas differ in health outcomes over time, we further adjusted the IHME data using a linear multivariable regression. In order to approach the question of how rural and urban counties differed in mortality outcomes over time and the impact of rural or urban status on mortality, we controlled for observable covariates. The variables controlled for were chosen for their known relationships to health status, including race and age. In the regression testing the effect of rurality on the different mortality measures from 1980-2014, covariates included percentage of white males, percentage of white females, percentage of black males, percentage of black female, and median age of each county.

The regression model was in the form of:

$$Y = \beta_0 + B_1 X_{1t} + u_i + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \in$$

Where Y is change in mortality rates over time, X_1 is rural or urban status and t is change in year, u_i is a county fixed effect, X_3 is the percentage of white males in a county population, X_4 is the percentage of white females in a county population, X_5 is the percentage of black males in a county population, X_6 is the percentage of black females in a county population, and X_7 is the median age of a county. The regression was further adjusted to weight population at the individual level. Errors were clustered to correct for heteroscedasticity. Linear combinations of the rural-year interaction in 11 and 12 year increments of the 1980-2014 time were taken to best estimate the adjusted mortality difference between rural and urban counties across time. All analyses were conducted using STATA software, version 15SE.

Results:

I. Study Population and Demographics.

The study population included 3142 counties where 1895 were rural and 1247 were urban. When specific county data was not available, those counties were excluded from descriptive and statistical analysis. **Table 1** describes the demographic differences between urban and rural counties at the fixed time point of 2015. All demographic differences between rural and urban counties were statistically significant though absolute differences varied. Urban counties were found to be younger, with a greater proportion of population under 18 and a lower proportion of population older than 65. Rural counties on average had a higher percentage of white residents than urban counties (78.2% vs. 69.0%) while urban counties had a higher percentage of black residents (9.8% vs. 8.2%). Urban counties were found to have statistically significantly higher percentages of Hispanic (13.9% vs. 6.0%) and Asian residents (2.7% vs. 0.7%) when compared to rural counties. Rural counties had a higher proportion of Native Americans (2.4% vs. 1.4%) and Hawaiian/Pacific Islanders (3.5% vs. 1.8%) compared to urban counties. **Figure 1 and Figure 2** demonstrate the trends of white male and black male populations over the time point of 1980 - 2014 in rural and urban counties. White male percentage in rural counties increased and then began to decrease. White males in urban counties demonstrated a consistent decrease across the study period.

In 2015, rural counties had significantly lower median household income across all race groups when compared to urban counties ($54,348 vs. $45,238). **Figures 3 and Figure 4** demonstrate changes over time from 2004 to 2014 in terms of percent of population living in poverty and median household income. Rural counties saw an average increase in median household income of $9,989 from 2003 to 2014. Urban counties saw an average increase in median household income of $10,616 over the same time period. In 2003, the difference in median household income between urban and rural counties was $7,167 while the difference in 2014 was $7,795.

In 2015, more rural residents on average had a high school education than their rural counterparts (87.7% vs. 84.8). Urban residents were more likely to have some form of college education compared to rural residents (61.3% vs. 53.7%).

II. Health Outcomes

Descriptive Analysis:

Unadjusted mortality rates (deaths per 100,000) were plotted over time (1980-2014) with rural or urban status as an independent variable. Both rural and urban counties had overall decreases in mortality over time for mortality by all-causes, cardiovascular diseases and neoplasms in the time period. Mortality rates increased for both rural and urban counties for chronic respiratory disease and mental health and substance use disorders. Mortality rates decreased for urban counties for self-harm/interpersonal violence but increased for rural counties.

a. All-Cause Mortality

The average all-cause mortality rate in urban counties in 1980 was 1092.83 deaths per 100,000 and 835.79 deaths per 100,000 in 2014, demonstrating a net change of -257.04 deaths over the time period. In rural counties, the average all-cause mortality rates in 1980 were 1100.93 deaths per 100,000 and 897.24 deaths per 100,000 in 2014 for a net change of -203.93 deaths per 100,000. The difference between urban and rural counties in average all-cause mortality rates in 1980 was -8.1 deaths per 100,000. The difference in 2014 was -61.45 deaths per 100,000. **Figure 5** shows the trends of all-cause mortality in rural and urban counties over time.

b. Cardiovascular Disease Mortality

The average cardiovascular disease mortality rate in urban counties in 1980 was 492.22 deaths per 100,000 and 263.82 deaths per 100,000 in 2014, demonstrating a net change of -228.40 deaths per 100,000 over the time period. In rural counties, average cardiovascular mortality rates in 1980 were 502.35 deaths per 100,000 and 287.19 deaths per 100,000 in 2014 for a net change of -215.06 deaths per 100,000. The average difference between urban and rural counties in cardiovascular disease mortality rates in 1980 was -10.10 deaths per 100,000. The average difference in 2014 was -23.37 deaths per 100,000. **Figure 6** shows the trends of cardiovascular mortality in rural and urban counties over time.

c. Neoplasm Mortality

The average neoplasm mortality rate in urban counties in 1980 was 230.84 deaths per 100,000 and 199.34 deaths per 100,00 in 2014, demonstrating a net change of -31.4 deaths per 100,000 over the time period. In rural counties, neoplasm mortality rates in 1980 were 226.33 deaths per 100,000 and 211.02 deaths per 100,000 in 2014 for a net change of -15.31 deaths per 100,000. The difference between urban and rural counties in neoplasm mortality rates in 1980

was -4.10 deaths per 100,000. The difference in 2014 was -11.68 deaths per 100,000. **Figure 7** shows the trends of neoplasm mortality in rural and urban counties over time. Neoplasm mortality rates increased from the years 1992-1995 in both rural and urban counties which was not seen in all-cause or cardiovascular disease mortality but ultimately had no more years of consecutive increased rates after this period.

d. Chronic Respiratory Disease Mortality

The chronic respiratory disease mortality rate in urban counties in 1980 was 42.71 deaths per 100,000 and 60.27 deaths per 100,00 in 2014, demonstrating a net change of +17.56 deaths per 100,000 over the time period. In rural counties, chronic respiratory disease mortality rates in 1980 were 41.85 deaths per 100,000 and 66.11 deaths per 100,000 in 2014 for a net change of +24.26 deaths per 100,000. The difference between urban and rural counties in chronic respiratory disease mortality rates in 1980 was +0.87 deaths. The difference in 2014 was -5.84 deaths per 100,000. **Figure 8** shows the trends of chronic respiratory disease mortality in rural and urban counties over time. Chronic respiratory disease mortality rates steadily increased from the years 1982-2014 in both rural and urban counties.

e. Mental Health and Substance Use Disorder Mortality

The mental health and substance use disorder mortality rate in urban counties in 1980 was 3.80 deaths per 100,00 and 13.43 deaths per 100,000 in 2014, demonstrating a net change of +9.60 deaths per 100,000 over the time period. In rural counties, mental health and substance use disorder mortality rates in 1980 were 3.65 and 13.08 in 2014 for a net change of +9.43 deaths per 100,00. The difference between urban and rural counties in mental health and substance use disorder mortality rates in 1980 was +0.15 deaths per 100,000. The difference in 2014 was +.35 deaths per 100,000. **Figure 9** shows the trends of mental health and substance use disorder mortality over time. Mortality rates increased throughout the time period surveyed. It also was the only outcome measure studied where urban mortality rate were found to be higher than rural rates in the descriptive analysis.

f. Self-Harm and Interpersonal Violence

The self-harm and interpersonal violence mortality rate in urban counties in 1980 was 22.55 deaths per 100,00 and 20.89 deaths per 100,000 in 2014, demonstrating a net change of -1.66 deaths per 100,000 over the time period. In rural counties, self-harm and interpersonal violence mortality rates in 1980 were 22.63 deaths per 100,000 and 22.78 deaths per 100,000 in

2014 for a net change of +.15 deaths per 100,00. The difference between urban and rural counties in self-harm and interpersonal violence mortality rates in 1980 was -.08 deaths per 100,000. The difference in 2014 was +1.89 deaths per 100,000. **Figure 10** shows the trends of self-harm and interpersonal violence mortality over time. Mortality rates increased throughout the time period surveyed for rural counties but decreased in urban counties. Both saw a decrease from 1980 – 1983, but saw increases in mortality from 1983 to 1987 and continued to decrease from 1987 to 2000. Average mortality rates have steadily climbed since 2000 in both urban and rural counties.

Statistical Analysis:

Regression analyses were conducted from the years 1980-2014 to test the effect of rurality on the different causes of mortality over time. Point estimates across the year increments of 1981- 1992, 1993 – 2004, and 2004 - 2014 were made to better assess the adjusted difference rural status may confer on mortality on rural counties in comparison to urban counties. **Table 2** shows the overall effect of rural status across the time year increments on the different mortality measures from 1981 – 2014.

a. All-Cause Mortality

We found there was a statistically significant increase in all-cause mortality between urban and rural counties across all years from 1980-2014 using our adjusted analysis. For the years 1981-1992, we found a statistically significant increase of 23.5 (95% CI: 20.2 – 26.8) deaths per 100,000 in rural counties. From 1993-2004, there was a statistically significant increase of 74.7 (66.5 – 82.9) deaths per 100,000. From 2004-2014, there was a statistically significant increased difference of 124.2 deaths (110.6 – 137.8) per 100,000. Within this regression, the variables of white male populations percentage, white female population percentage, black male population, black female population, and median age were controlled for.

b. Cardiovascular Disease Mortality

We found there was a statistically significant increase in cardiovascular disease mortality between rural and urban counties across all years from 1980-2014 using our adjusted analysis. For the years 1981-1992, we found a statistically significant increase of 7.32 (95% CI: 5.07 – 9.58) deaths per 100,000 in rural counties. From 1993-2004, there was a statistically significant increased difference of 24.0 (19.0 – 28.9) deaths per 100,000. From 2004-2014, there was a statistically significant increased difference of 32.8 (25.0 – 40.6) deaths per 100,000. Within this

regression, the variables of white male populations percentage, white female population percentage, black male population, black female population, and median age were controlled for.

c. Neoplasm Mortality

We found there was a statistically significant overall increase in neoplasm mortality between rural and urban counties across all years from 1980-2014 using our adjusted analysis. For the years 1981-1992, we found a statistically significant increase of 6.85 (95% CI: 6.06 – 7.64) deaths per 100,000 in rural counties compared to urban counties. From 1993-2004, there was a statistically significant increased difference of 24.0 (18.8 – 22.8) deaths per 100,000. From 2004-2014, there was a statistically significant increased difference of 31.5 (28.5 – 34.5) deaths per 100,000. Within this regression, the variables of white male populations percentage, white female population percentage, black male population, black female population, and median age were controlled for.

d. Chronic Respiratory Disease

We found there was a statistically significant overall increase in chronic respiratory disease mortality between rural and urban counties across all years from 1980-2014 using our adjusted analysis. For the years 1981-1992, we found a statistically significant increase of 1.52 (95% CI: 1.21 – 1.83) deaths per 100,000 in rural counties compared to urban counties. From 1993-2004, there was a statistically significant increased difference of 5.59 (4.79 – 6.38) deaths per 100,000. From 2004-2014, there was a statistically significant increased difference of 11.3 (9.97 – 12.7) deaths per 100,000. Within this regression, the variables of white male populations percentage, white female population percentage, black male population, black female population, and median age were controlled for.

e. Mental Health and Substance Use Disorder Mortality

For mental health and substance use disorder mortality, from the years of 1981-1992, we found that rural counties had an adjusted difference of an overall decrease in mortality compared to urban counties of -0.01 (95% CI: -0.21 – 0.18) deaths per 100,000 though this decrease was not statistically significant. From 1993-2004, rural counties were found to have an increase in mortality of 0.18 (-0.13 – 0.50) deaths per 100,000, though this increase was also not statistically significant. From 2004-2014, there was a statistically significant increased difference of 1.49 (0.71 – 2.27) deaths per 100,000 between rural and urban counties. Within this regression, the

variables of white male populations percentage, white female population percentage, black male population, black female population, and median age were controlled for.

f. Self-Harm and Interpersonal Violence

We found there was a statistically significant increase in mortality from self-harm and interpersonal violence between rural and urban counties across all years from 1980-2014 using our adjusted analysis. For the years 1981-1992, we found a statistically significant increase of 1.5 (95% CI: 1.34 – 2.35) deaths per 100,000 in rural counties compared to urban counties. From 1993-2004, there was a statistically significant adjusted difference of 5.59 (3.21 – 5.20) deaths per 100,000. From 2004-2014, there was a statistically significant adjusted difference of 6.12 (4.67 – 7.56) deaths per 100,000. Within this regression, the variables of white male populations percentage, white female population percentage, black male population, black female population, and median age were controlled for.

III. Health Care Access

Physician Density:

Across all measures of physician density, there were statistically significant differences between rural and urban counties. Years surveyed were 2005, 2010, and 2015 for Total MDs, medicine subspecialists, surgical subspecialists, and psychiatrists. Data was available for primary care providers for 2011-2015. **Table 3** shows the data for average physician density across the different subspecialties. Urban counties had consistently higher physician density across all provider specialties over the years of data available. Two-tailed *t* tests demonstrated that all differences were statistically significant with non-overlapping confidence intervals. Additionally, there was little variation across time within a rural categorization or urban categorization. The average number of total MDs per capita in rural counties from 2005-2015 was 74.32 while the average in urban counties was 205.80. The average percent difference in total MDs per capita between urban and rural counties was 176% across this time period. From 2011-2016, the average number of primary care providers per capita in rural counties was 43.71 compared to 69.06 providers per capita in urban counties. The average percent difference in primary care providers per capita between urban and rural counties was 58% across this time period. From 2005-2015, the average number of medicine subspecialists per capita in rural counties was 16.60 compared to 64.7 providers per capita in urban counties. The average percent

difference in medicine subspecialists per capita between urban and rural counties was 289% across this time period. From 2005-2015, the average number of surgeon per capita in rural counties was 11.41 compared to 41.19 surgeons per capita in urban counties. The average percent difference in surgeons per capita between urban and rural counties was 261% across this time period. The average number of psychiatrists from 2005-2015 in rural counties 1.82 and 8.106 psychiatrists per capita in urban counties. The average percent difference in psychiatrists per capita between urban and rural counties was 345% across this time period.

Infrastructure:

Table 4 demonstrates the differences between urban and rural counties across the variables of total hospital beds per capita, total nursing facility beds per capita, and total skilled nursing facilty beds per capita for year 2014. The average number of total hospital beds per capita in 2014 in urban counties was found to be 290 (95% Confidence Interval: 269-312) while there were an average of 329 (306-352) beds per capita in urban counties. Two-tailed *t* tests demonstrated that this was not a statistically significant difference given the overlapping of 95% confidence intervals. The average number of nursing facilities per capita in 2014 in rural counties was found to be 73.1 (56.8 – 89.5) and was a statistically significant difference from 23.2 (16.0 – 30.5) beds per capita in urban counties. There was an average of 875 (844 – 906) skilled nursing facility beds per capita in rural counties which was a statistically significant increase from the average of 672 skilled nursing facility beds per capita in urban counties.

Insurance:

Figure 11 shows the average percentage of uninsured people under age 65 in urban and rural counties from 2010-2015. There was an overall decrease in the average uninsured percentage of the population in both urban and rural counties over time. The average percentage the under 65 population that was uninsured in 2010 was 19.2% (95% CI: 18.9 – 19.4) in rural counties and decreased to an average of 12.6% (12.3 – 12.8). The decrease from 2010 to 2015 was -6.8% In urban counties, the average percentage of the under 65 population that is uninsured was 17.5% (17.1 – 17.8) in 2010 and was 11.2% (10.9 – 11.5) in 2015. The overall decrease over time was -6.4%. The difference in uninsured percentage between urban and rural counties in 2010 was 1.7% and in 2015 was 1.5%.

Discussion:

This study sought to better understand the differences in health and health care between rural and urban America across several key dimensions of health outcomes and delivery system capacity. We have found that rural counties have worse health outcomes than urban counties, and that these inequalities have widened over time even after adjustment for some observable demographic characteristics.

The results of unadjusted analysis showed a generally widening gap of disparity in age-adjusted mortality in nearly all of the major causes of death in the U.S. (cardiovascular, neoplasms, respiratory diseases, and self-harm/interpersonal violence). Cardiovascular disease mortality demonstrated a near continuous decline in mortality for both rural and urban counties over the time, but with a widening difference between urban and rural counties (in favor of the urban). Cancer mortality actually demonstrated increases at certain time points from 1982 – 1988 and 1992 – 1995, with cancer mortality increasing higher than 1980 levels in 1995, but both rural and urban counties eventually saw their cancer mortality diminish over time from 1980 mortality rates. Chronic respiratory disease mortality and substance use/mental health mortality both saw increases over the study period in rural and urban counties. Chronic respiratory disease mortality saw a widening gap between urban and rural counties beginning in 2000. Substance use mortality increased by over 300% for both rural and urban counties from 1980 to 2014 in both urban and rural counties and was the only cause of death in our descriptive analysis where urban counties had a higher mortality than rural counties in 2014. On self-harm and interpersonal violence, both rural and urban counties saw periods decreased mortality as well as a period of increase that has continued since 2000. One new finding, which to our knowledge, has not been documented either in the Murray analysis or elsewhere in the literature, was the overall increase self-harm in rural counties over the period 1980 – 2014. Rates of self-harm/interpersonal violence in all counties in aggregate in the U.S. have decreased; thus the increase in rural mortality is a notable finding.

Previous work, including the Murray et al. analyses have not discussed the overall widening disparities between rural and urban counties in nearly all causes of death (besides substance use/mental health) to such an extent. To examine whether the differences in mortality between urban and rural counties exist in spite of differences in observable characteristics of the two groups, we conducted adjusted analyses that control for variables that might affect mortality,

including white and black male and female race percentages and median age of a county.[27, 28] After adjustment for age and race, we found that rural counties had a statistically significant differential increase in all-cause mortality compared urban counties over the 3 time segments of the study (1981-1991, 1992-2003, 2004-2014). This statistically significant increase in mortality was observed for all causes of death by the time point 2004-2014. All causes of death showed an increase in the adjusted mortality difference in rural counties relative to urban counties across time. Though substance use/mental health mortality did not have a statistically significant difference from 1981-2003, there was a significant increased difference from 2004-2014 of 1.49 deaths per 100,000. This represents a nearly 1000% increase from the 1992-2003 point estimate of 0.18. This is notable, as our descriptive analysis on substance use disorders/mental health showed urban counties as having a higher mortality rate throughout the time period. This increase is consistent with the current evidence on the rise of the opioid epidemic in the last two decades as well as the work of Case and Deaton suggesting "deaths of despair."

Our adjustment of the substance use disorders/mental health mortality and self-harm/interpersonal violence mortality data is notable as it further supports the recent literature on the opioid epidemic as well as Case and Deaton's explanation of "deaths of despair" comprising suicides and opioid overdose of white males. However, our adjusted analysis of the substance use/mental health mortality data demonstrated a notable difference from our descriptive analysis. Within the descriptive analysis, urban mortality was higher across the time period surveyed, however upon adjustment there was an increasing mortality difference in rural counties from 2004-2014. Furthermore, the Murray et al. study analyzing self-harm/interpersonal violence demonstrated an overall decrease in both self-harm and interpersonal violence over the same time period of 1980 in U.S. counties, whereas our data indicates that in fact this does not hold true when we study rural counties on their own. Their work does highlight the increase in self-harm since 2000, but not an overall increase since 1980. This increase in self-harm/interpersonal violence is critically important as it could signal that our concern over "deaths of despair" within this population is not only warranted, but likely deserves more attention among rural communities.

Our adjusted analyses demonstrate that after controlling for some observable differences between rural and urban counties, there remains difference in mortality between these counties. This disparity has worsened throughout time in all causes of death. In considering why rural

status might confer a difference in mortality and an increasing difference over time relative to urban counties, numerous factors could contribute an explanation. Although we controlled for demographic variables that have known associations with mortality (race and age), we were not able to control for a host of unobserved longitudinal variables that might be different between rural and urban counties and contribute to mortality differences during the study period.

Perhaps the most significant variable that might explain some of these differences is the effect of socioeconomic status of a county on its health outcomes. Poverty has been well studied and has a negative association with health status.[29] Rural populations were found to be poorer than urban populations, both in terms of median household income and the percentage of poverty at the county level. However, the differences between urban and rural median household income over the last decade did not change dramatically, a difference of $7,167 in 2003 while the difference in 2014 was $7,795 in favor of urban counties. However, even though we were unable to control for these economic variables. Our descriptive analyses of the available data only shows a slight change in the differences between median household income and percentage of population in poverty across 2003-2014, which seems out of proportion to the continued increasing disparity between urban and rural counties across the entire time period. However, at this moment we are unable to adequately understand the effect of this relationship.

Lower levels of college education are also associated with worsening health status and unhealthy behaviors.[30,31] Our descriptive analysis found that rural counties on average have a lower percentage of the population with college education. We were unable to control for this variation in education and this difference in education status could also explain part of the poorer health outcomes between urban and rural counties.

In addition to socioeconomic status, there are other factors that could also explain the continued and increasing adjusted differences between rural and urban counties across the different causes of mortality. Differences in behaviorally linked determinants could also explain some of these differences across numerous causes of death. Smoking confers a greater risk of cardiovascular disease, numerous malignancies, and is a known cause of respiratory disease.[32] Previous studies have shown that smoking is more prevalent in rural counties than urban counties which could have contributed to this adjusted mortality difference that we have observed.[33] Furthermore, comorbidities that are associated with increased risk of disease as well as mortality could also be influencing this mortality difference. Obesity and diabetes, both risk factors of

cardiovascular disease and malignancies, have been shown to have higher prevalence in rural counties than urban counties.[34,35] Along with these comorbidities, food security and issues of nutritional status have been shown to influence survival and mortality in several chronic conditions including heart failure, coronary artery disease, and numerous malignancies.[36] Food security has been found to be a greater issue among the rural poor than urban poor with in the US.[37] In summary, our mortality differences could be partly explained by the current evidence we have from observational studies that suggest rural areas are at baseline unhealthier than urban areas. However, few studies have examined whether the relevant differences in prevalence of these comorbid conditions or disparity in socially determined factors have changed over time—and if they have changed to the extent that mortality differences have.

One major contributor to mortality that was not controlled for in our regression was the overall access to the health care system. Evidence in the literature has shown that overall access to health care in terms of financial resources through health insurance as well as proximity and availability of resources and providers influence outcomes.[38,39] Our descriptive analysis of physician density, health infrastructure, and insurance, attempted to address part of this question. Across all measures of physician density, rural counties had significantly lower numbers of providers per capita. To our knowledge, these results demonstrating lower physician density across several different types of providers have not been shown previously in the literature. The greatest percent difference between urban and rural counties was between psychiatrists per capita (>300% difference) while the smallest percent difference was between primary care providers per capita (57% average difference). The reasons for these shortages of providers in rural areas relative to urban are themselves multifactorial. This could be potentially explained by differences in compensation between urban and rural areas, greater economic opportunity, higher private payer mix, quality of life differences, as well as availability of clinics or hospital to practice. The larger differences between specialists and surgeons suggests that there could be a lack of infrastructure to support surgical or medicine subspecialists. Urban counties also likely benefit from higher likelihood of proximity to academic medical centers, which would attract a greater number of specialist providers.

While the explanation of the lack of providers is still largely speculative, perhaps the more significant question is whether and how this unequal provider availability might contribute to the increased differences in mortality that we observe with our adjustment. The potential

impact could be explained in several ways. First, the literature is sparse on the optimal physician per capita goal for improved health, let alone the optimal estimate across a variety of specialties. However, some literature does indicate higher physician to population ratios, particularly within primary care providers, do have a positive association with improved health status as well as on several specific measures. Low physician density not only could create increased barriers to care (e.g. longer wait times to see a provider within an area), but also time and distance barriers to travel out of one's county to receive care that might not be readily available nearby. Availability and access to physicians certainly could influence care with regards to several of the chronic conditions we studied. Access to new and innovative therapies, for example, immunotherapy in specific malignancies, would more likely be associated with proximity to academic centers which are more likely to be found in urban counties. Similarly, access to the newest technology and interventions available could be influenced by the density of providers within a region. Lifesaving intervention such as cardiac catheterization for coronary artery disease or left ventricular assist devices for heart failure require not only referrals to physicians with expertise in these areas, but also the infrastructure to provides these interventions. Unfortunately, our infrastructure access data did not have such granularity to further interrogate these system level factors. This physician density issue could play an even more important role in light of the opioid epidemic and our findings on increased rates of self-harm and substance use/mental health, particularly for psychiatrists and medication-assisted treatment (MAT) providers. Distance traveled and crossing state lines for MAT has been shown to lead to poor outcomes for patients who are opioid dependent. Furthermore, a lack of MAT providers can lead to waitlist for methadone maintenances, which has been shown to confer an increase in mortality and relapse.[40] Similarly, as we found that mortality from self-harm/interpersonal violence has increased since 1980 in rural counties, the availability of psychiatrists and mental health providers might play a crucial role in these worsening mortality rates.[41] There has been some mixed research on the associations of increased psychiatry care on suicidality both in the US and abroad, with some evidence showing an association between increased providers in the outpatient setting and decreased suicide attempts.[42, 43] Nevertheless, some experts theorize that 80% of outcomes are attributable to socioeconomic factors, rather than the health care delivery system itself.[44]

In summary, our findings demonstrate that rural American are dying at a higher rate than their urban counterparts across every cause of death studied. Social and behavioral determinants

could be influencing this finding, as well as access to health care. What seems clear is that there are real disparities between rural and urban America in health and health care that continue to worsen, and these certainly warrant further study and intervention to address the root causes.

Limitations:

There are several important limitations to this type of study. One is the measurement error that comes from our sources of data. We have accrued data from several different sources to make comparisons across various outcomes; in the cases of our adjusted analyses, we have different data sets playing a role within the same statistical analysis. One possible source of error could come from our race and demographics data as we appended data sets from the four decades. As noted in Figures 1 and 2, there is a notable change in both data in the year 2000 with both black and white populations. This change is most likely due to changes in Census classification of race in the year 2000—expanding the Hispanic population definition rendered both black Hispanic and white Hispanic population proportions a similar change. Our primary mortality data set is a public dataset from IHME which has already undergone adjustments to provide the best possible estimates. These adjustments carry their own set of standard errors for all of the mortality data points. This data set has already been validated and provides some level of reassurance that significant measurement errors are unlikely.

Our descriptive analyses centered on understanding the data of rural and urban counties in aggregate. We did not study intra-rural or intra-urban variation. Furthermore, our analysis did not take into account spatial or geographic variation to investigate whether certain rural mortality trends were clustered within geographic areas or the way in which proximity to an urban county might influence the health of a rural county.

One issue with our data on physician density and other delivery measures is that density might not actually be reflective of a county's needs or the overall spatial make up of rural and urban counties in the U.S. For example, residents who live in a rural county but near the border of an urban county might find it easier to travel to an urban county and thus the need for providers in rural counties would be lessened. Similarly, the need for nursing facilities or hospital beds in a rural county would be decreased if nearby urban counties were resource-rich and thus there was no need for this type of infrastructure. Future study could focus on rural and urban counties that are located adjacent to one another.

Finally, as previously noted, we were unable to control for numerous relevant unobserved covariates within our regression model. Regressions that included economic status, a measure of education, and proximity to urban centers for rural counties could further strengthen the validity of any adjusted differences in mortality between rural and urban counties.

Considerations for Future Work and Policy Implications:

Our work has shown that rural and urban counties differ from each other across various dimensions of demography, health, and health care. Future research should aim to better refine these differences, particularly through assessing how outcomes change as additional observable factors are accounted for. Our mortality findings should stimulate more research interrogating the health and wellbeing between rural and urban counties that could lead to such stark differences. More specific data on the available of specialty services, their availability across time, and utilization could provide greater insight into how better access could be quantified. There are numerous policy and public health implications for this work. Federal and State governments both often use broad categories of geography—notably urban and rural designations—to implement and legislate new policies (e.g. policies towards rural hospitals in the Medicare program). Thus, understanding the rural-urban dichotomy provides utility as polices are not levied at an individual county level, but more often at the level of urban and rural designations. Efforts to improve health care systems in rural geographies will require tackling both issues of social determinants, improving behavioral interventions, and encouraging greater access in resource poor settings.

Summary:

The divisions between rural and urban America have received great political and public attention in the last few years. We used longitudinal descriptive and statistical analyses over time to better quantify the differences along this binary dimension, including analysis of demographic factors in rural and urban counties, mortality rates due to major causes of death, and measures of health care access, including physician density. Along with differences along socioeconomic lines which showed rural counties were on average less diverse and poorer than urban counties, we found differences in mortality between urban and rural counties that demonstrate widening disparities across nearly all causes of death including cardiovascular disease, neoplasms, chronic respiratory disease, and self- harm/interpersonal violence. Regression analysis showed that these differences remained statistically significant even when controlling for some inherent differences between urban and rural counties. Regression analysis of substance use and mental health mortality demonstrated an adjusted worsening mortality rate among rural counties from 2000-2014 where descriptive analysis had not. Furthermore, rural counties showed an increased rate of self-harm and inter-personal violence since 1980 in rural counties, where previous literature had not. The reasons for these continued and widening disparity along multiple variables of mortality are unclear and likely multifactorial, including uncontrolled inherent differences in social determinants, the general health of rural vs. urban counties, and health care access. Data on physician density data found statistically significant differences which suggested rural counties lacked access to physicians, particularly specialists. Further work must be conducted to continue to investigate these differences in outcomes and access, their causes, and how policy can be utilized to address these disparities.

Tables and Figures:

Table 1. Demographic Characteristics of Rural and Urban Counties in 2016

	Rural Counties (n=1,864)	Urban Counties (n=1,247)	P value
Population	21,418	219,818	<0.001
Age			
Less than 18 (%)	26.2	38.8	0.002
65 and older (%)	18.8	15.5	<0.001
Female (%)	49.7	50.2	<0.001
Race (%)			
White	78.2	69.0	<0.001
Black	8.2	9.8	0.002
Hispanic	6.0	13.9	<0.001
Asian	0.7	2.7	<0.001
Native American	2.4	1.4	<0.001
Hawaiian/Pacific Islander	3.5	1.8	0.002
Household income ($)	45,238	53,348	<0.001
White	45,703	54,584	<0.001
Black	31,535	37,522	<0.001
Hispanic	40,184	42,023	<0.001
Children in poverty (%)	24.8	21.1	<0.001
Unemployment (%)	5.6	5.3	<0.001
Education (%)			
High school	87.7	84.8	<0.001
Some college	53.7	61.3	<0.001

Figure 1: Percentage of White Males in Population in Rural and Urban Counties

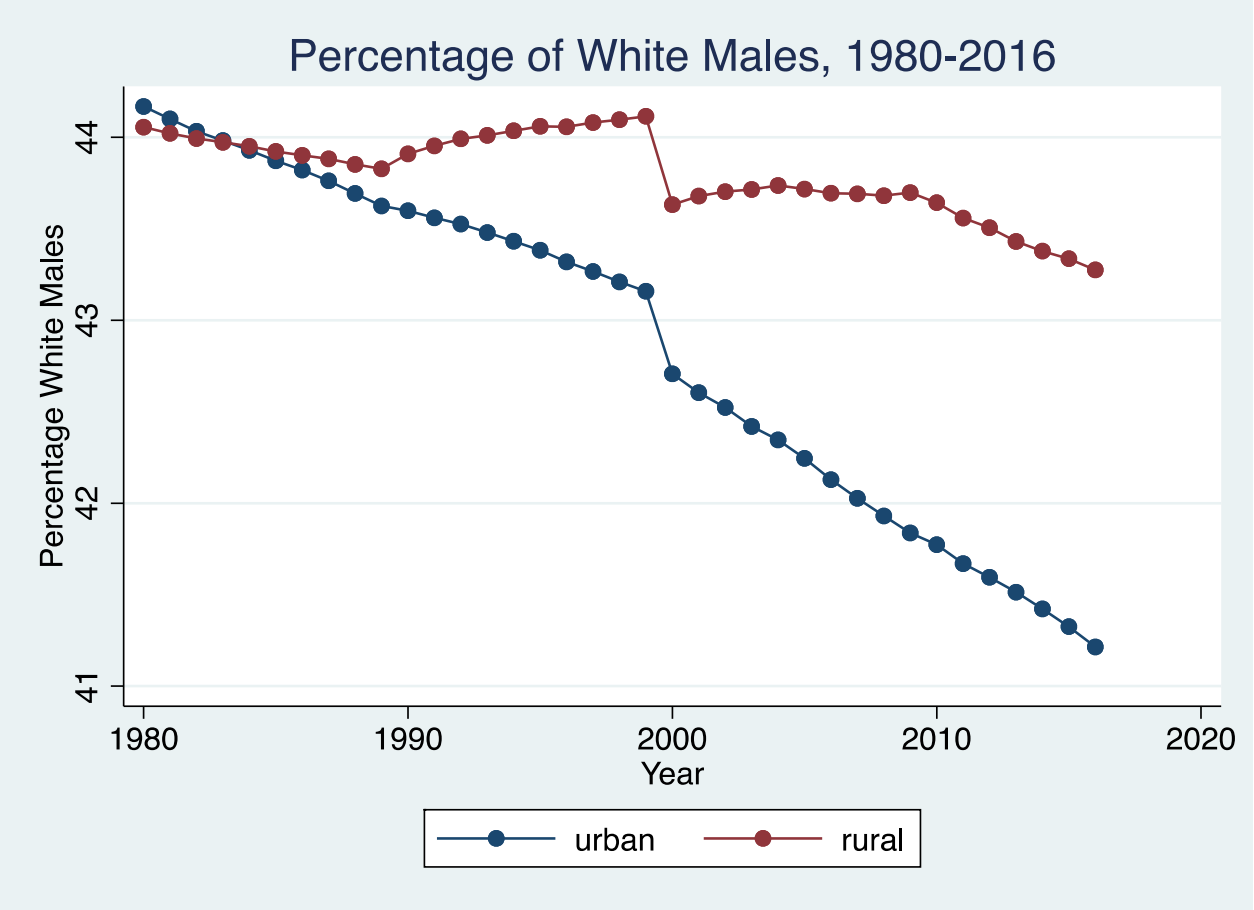

Figure 2: Percentage of Black Males in Population in Rural and Urban Counties

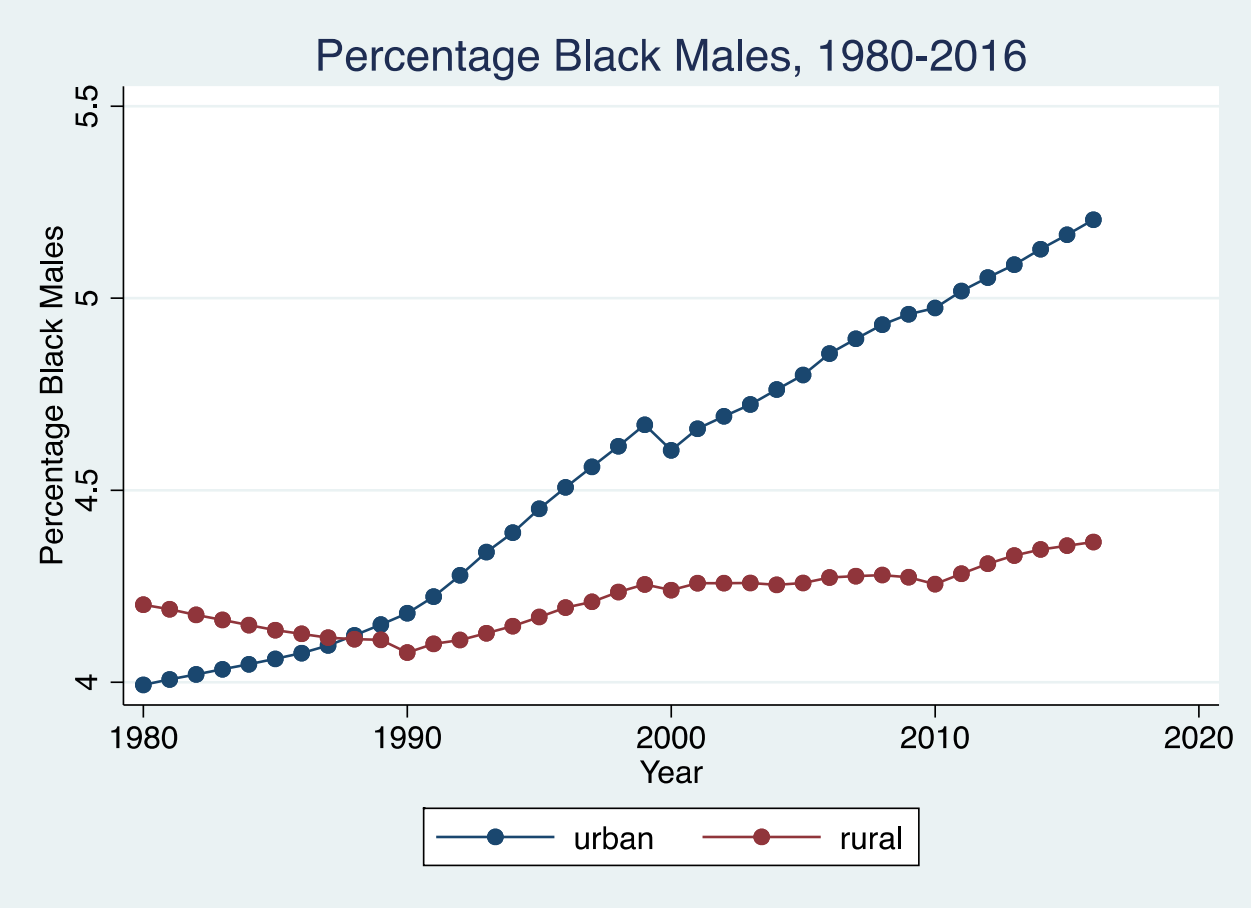

Figure 3: Percentage of Population in Poverty in Rural and Urban Counties

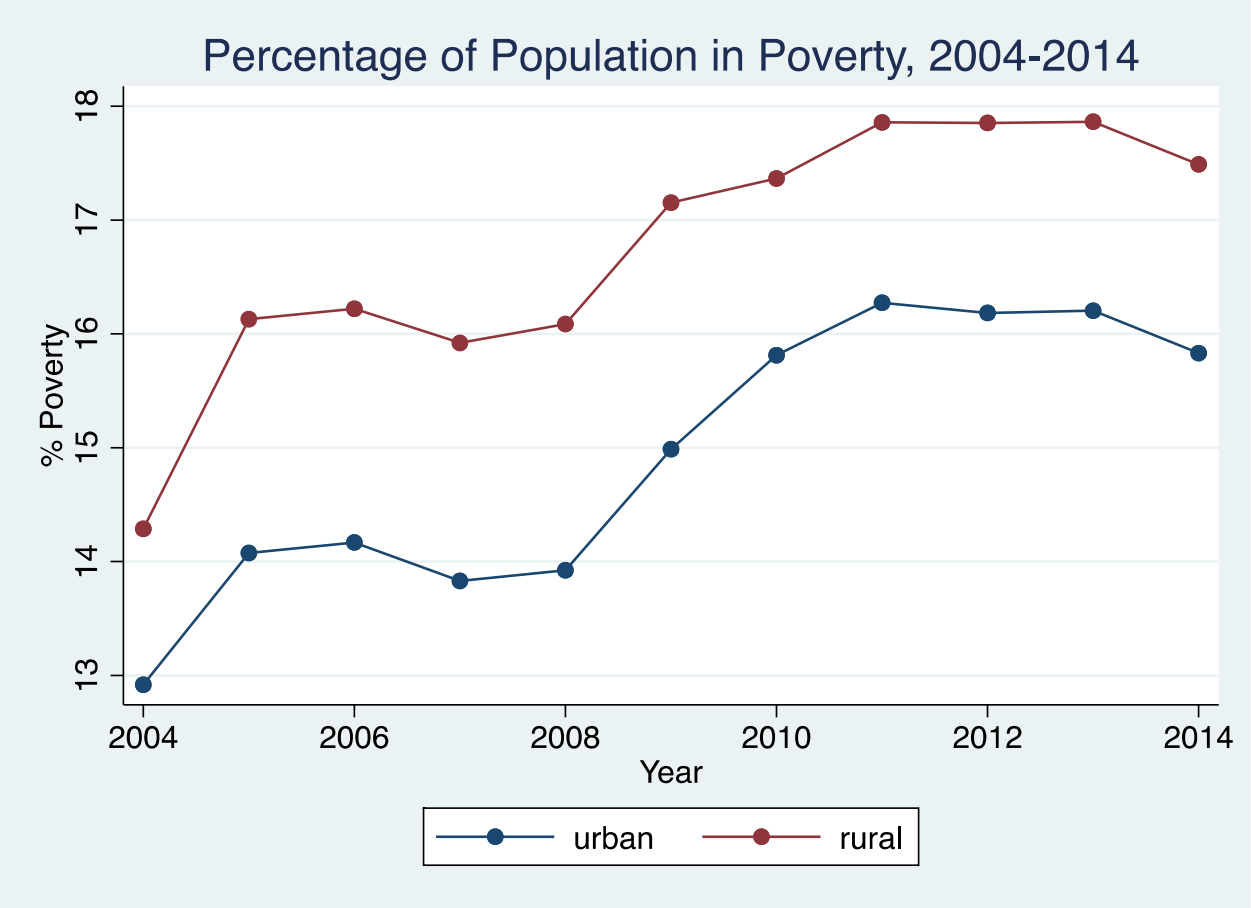

Figure 4: Median Household Income in Rural and Urban Counties

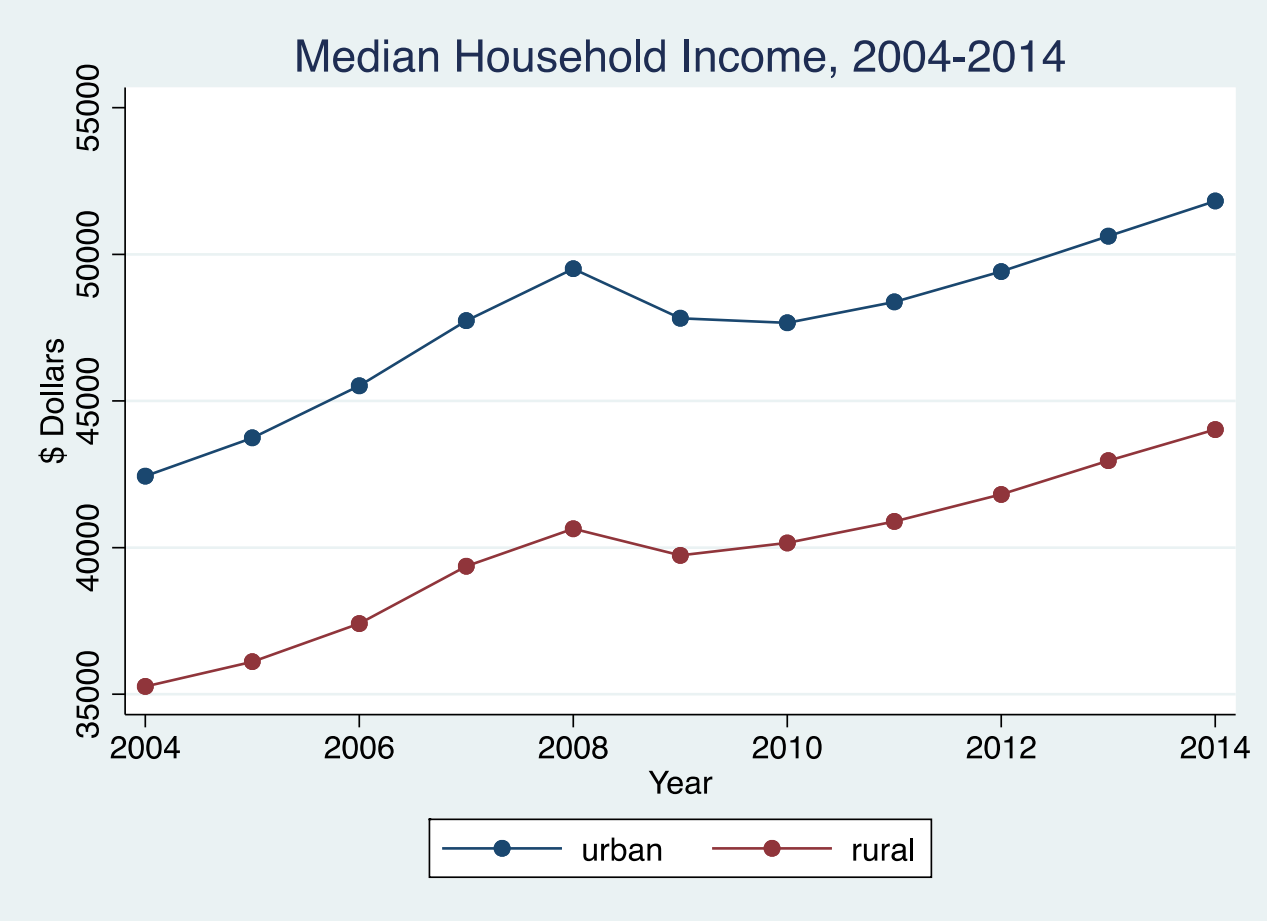

Figure 5: All-Cause Mortality Rates in Rural and Urban Counties

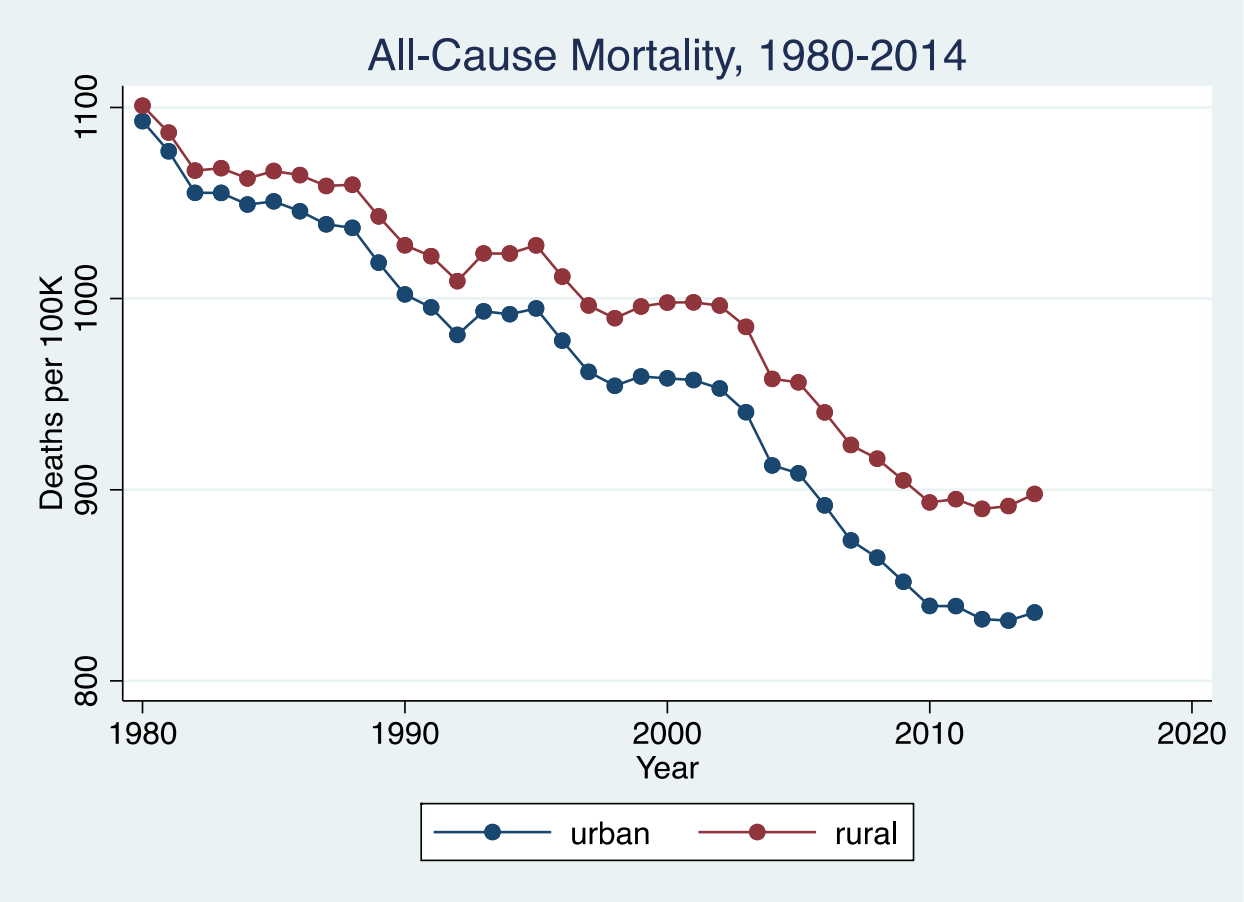

Figure 6: Cardiovascular Disease Mortality Rates in Rural and Urban Counties

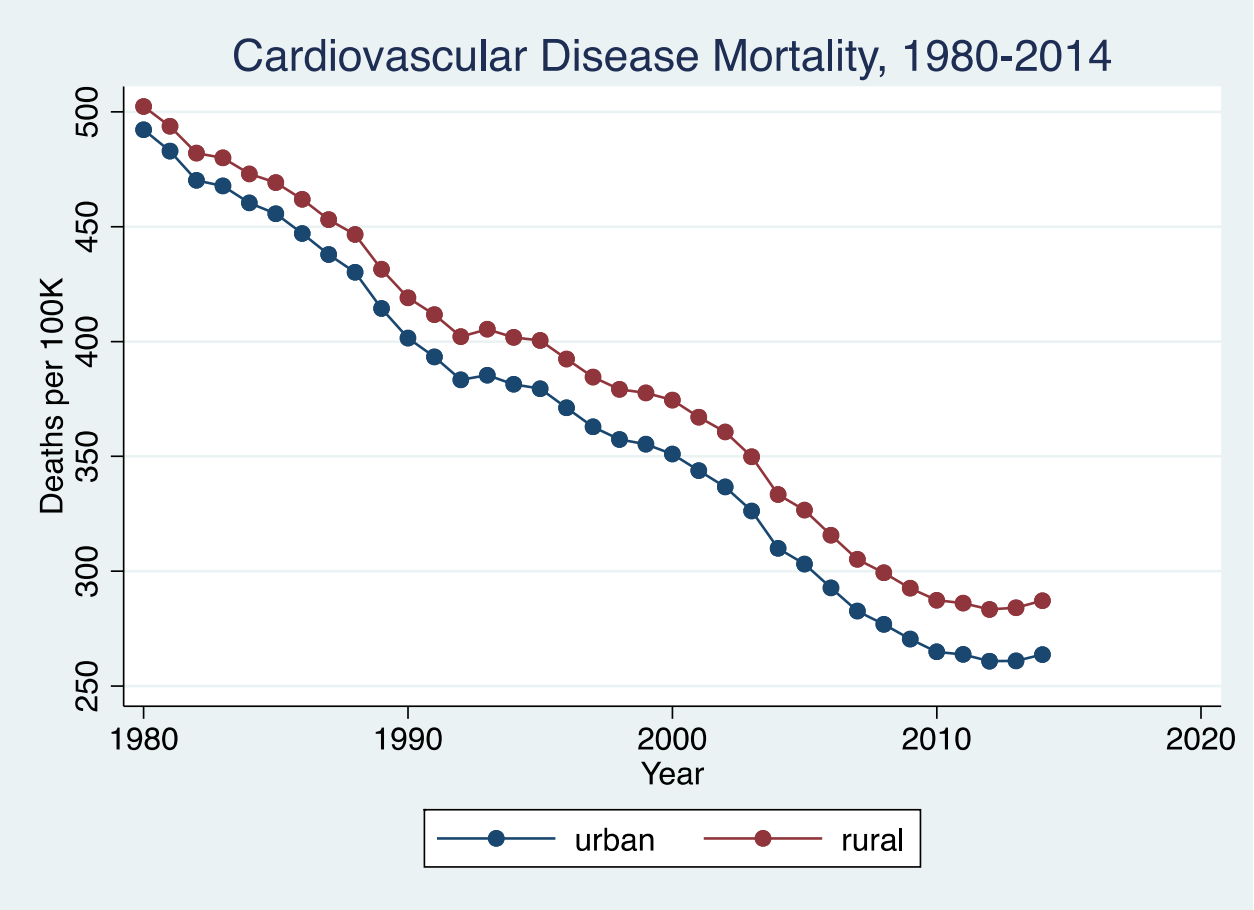

Figure 7: Neoplasm Mortality

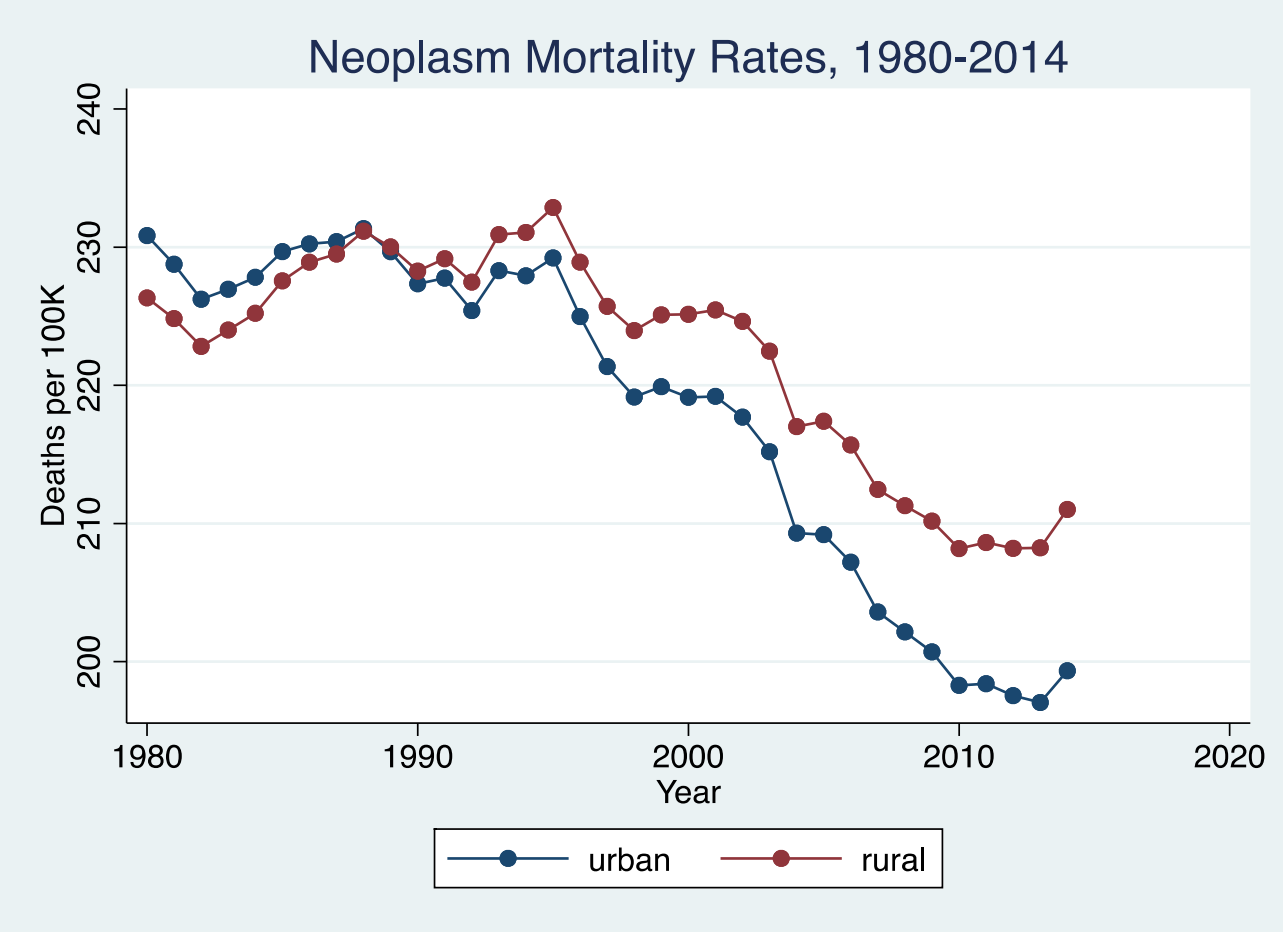

Figure 8: Chronic Respiratory Disease Mortality

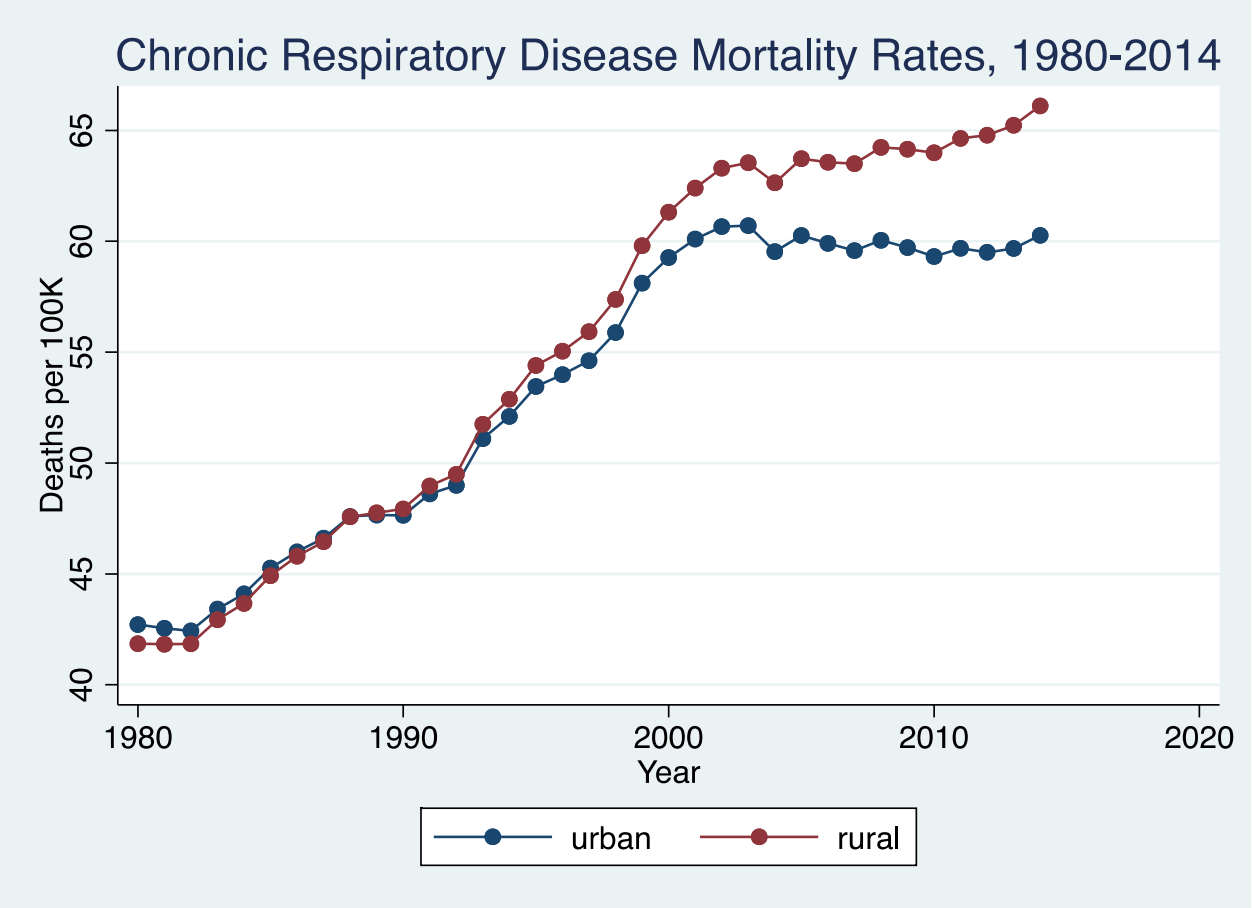

Figure 9: Mental Health and Substance Use

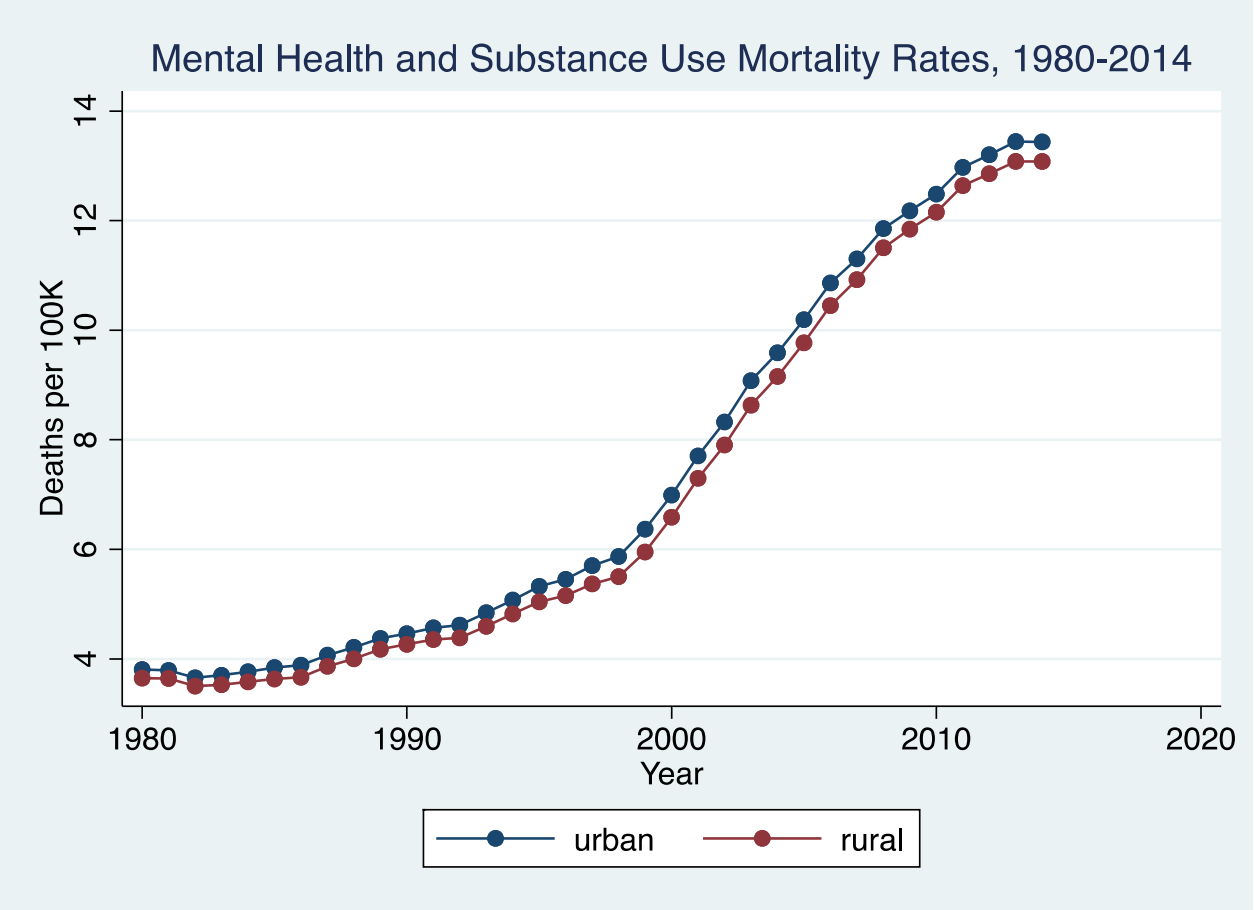

Figure 10: Self-Harm and Interpersonal Violence

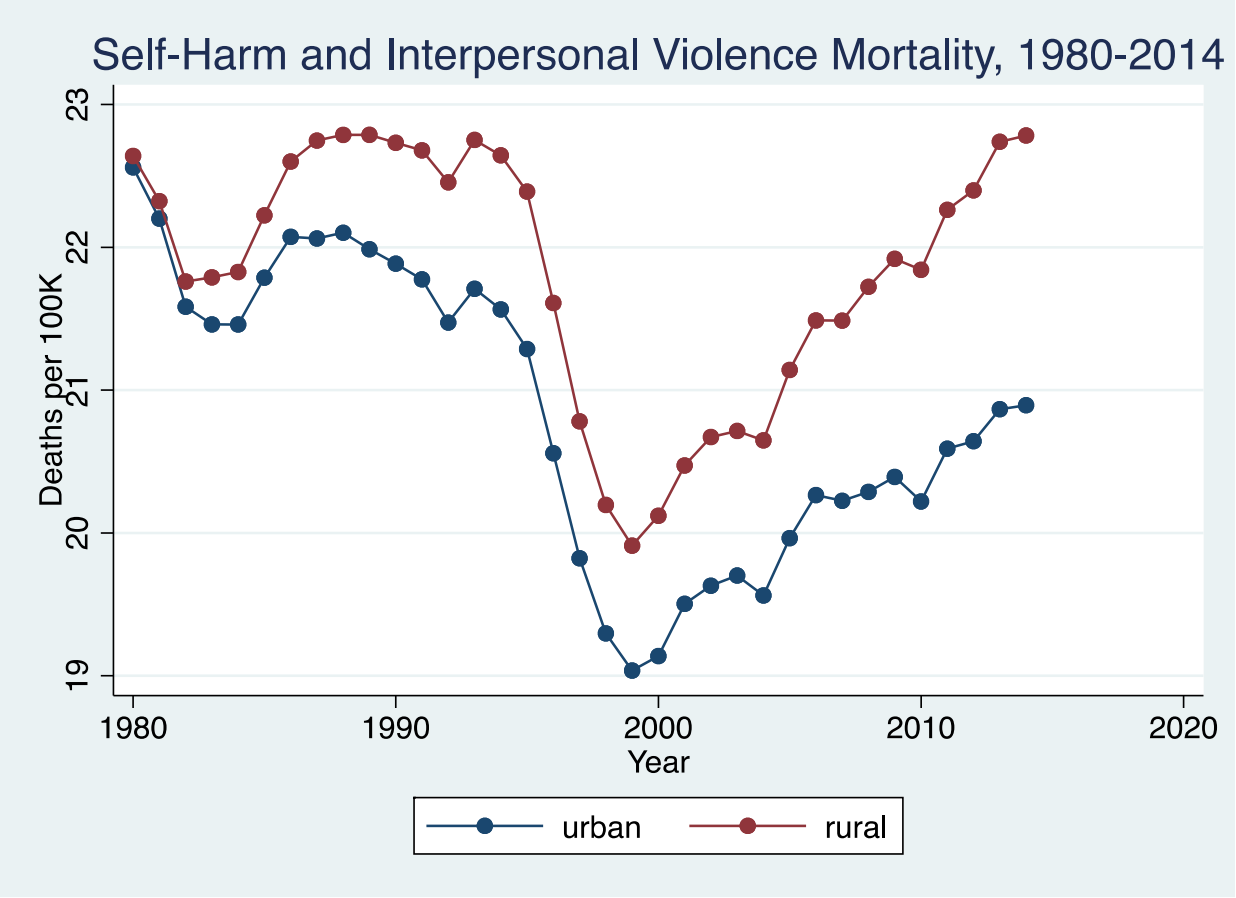

Figure 11: Uninsured Adults in Rural and Urban Counties

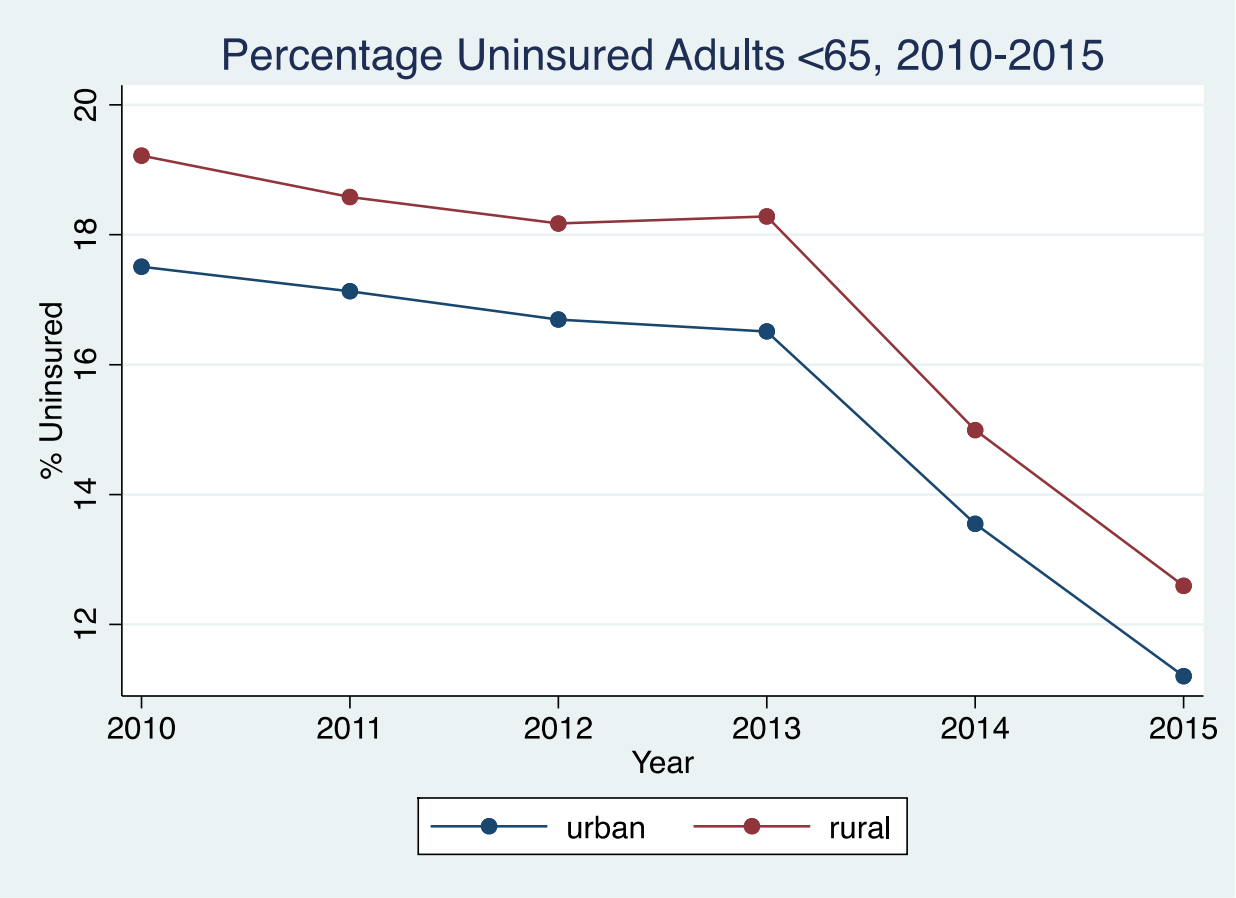

Table 2: Adjusted Mortality Differences

	1981-1992	**1992-2003**	**202.03-2014**
Mortality	Rural Urban Difference [CI]	Rural Urban Difference [CI]	Rural Urban Difference [CI]
All-Cause	23.5 (20.2 – 26.8)	74.7 (66.5 – 82.9)	124. 2 (110.6 – 137.8)
Cardiovascular	7.32 (5.07 – 9.58)	24.0 (19.0 – 28.9)	32.8 (25.0 – 40.6)
Neoplasm	6.85 (6.06 – 7.64)	20.8 (18.8 – 22.8)	31.5 (28.5 – 34.5)
Chronic Respiratory	1.52 (1.21 – 1.83)	5.59 (4.79 – 6.38)	11.3 (9.97 – 12.7)
Substance Use and Mental Health	-0.01 (-0.21 – 0.18)	0.18 (-0.13 – 0.50)	1.49 (0.71 – 2.27)
Self-Harm and Interpersonal Violence	1.84 (1.34 – 2.35)	4.20 (3.21 – 5.20)	6.12 (4.67 – 7.56)

Table 3. Physician Density in Rural and Urban Counties

	Rural Counties (n=1,887)	Urban Counties (n=1,253)	P value	% Difference
Total MDs per capita				
Total MDs 2005	74.1	203.7	<0.001	174.9%
Total MDs 2010	74.4	206.5	<0.001	177.6%
Totals MDs 2015	73.3	207.0	<0.001	182.4%
Primary Care Physicians per capita				
PCPs 2010	40.4	69.0	<0.001	70.8%
PCPs 2011	44.4	68.6	<0.001	54.5%
PCPs 2012	44.5	68.9	<0.001	54.8%
PCPs 2013	44.9	69.5	<0.001	54.1%
PCPs 2014	44.1	69.3	<0.001	57.1%
PCPs 2015	43.7	68.9	<0.001	57.7%
Surgeons per capita				
Surgeons 2005	11.7	42.8	<0.001	265.8%
Surgeons 2010	11.4	40.7	<0.001	257.0%
Surgeons 2015	11.1	39.9	<0.001	259.5%
Medicine Subspecialists per capita				
Medicine Subspecialists 2005	17.0	63.1	<0.001	271.2%
Medicine Subspecialists 2010	16.0	64.0	<0.001	300.0%
Medicine Subspecialists 2015	16.6	67.0	<0.001	303.6%
Psychiatrists per capita				
Psychiatrists 2005	1.95	8.80	<0.001	351.3%
Psychiatrists 2010	1.73	7.98	<0.001	361.3%
Psychiatrists 2015	1.77	7.54	<0.001	326.0%

Table 4: Infrastructure Access in Rural and Urban Counties

	Rural Counties	**Urban Counties**	***p***
Hospitals Beds per Capita	290 (269 – 312)	329 (306 – 352)	0.02
Nursing Facility Beds per Capita	73.1 (56.8 – 89.5)	23.2 (16.0 – 30.5)	<0.001
Skilled Nursing Facility Beds	875 (844 – 906)	672 (646 – 698)	<.001

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