Factors Influencing the Spatial Distribution of Lung Cancer Mortality in the United States, 2000 - 2002

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ABSTRACT

Smoking is the single most important cause of preventable mortality, contributing to between one-fifth and one-quarter of all deaths in the U.S. (Rogers et al. 2005; Peto and Lopez 2005). Given the contribution of smoking to mortality patterns, the prevalence of smoking and the structure of mortality across states may have important repercussions in terms of health expenditures across states. This paper examines the factors influencing the distribution of mortality across states. Specifically, it examines interstate differences in lung cancer mortality in the United States among persons aged 45 and over. The results presented here suggest the importance of behavioral and selected demographic factors in explaining state variations in lung cancer mortality for both men and women. Further, my results support the strong causal link between smoking prevalence and all-cause mortality across states, especially for men.

INTRODUCTION

Smoking is the single most important cause of preventable mortality, contributing to between one-fifth and one-quarter of all deaths in the U.S. (Rogers et al. 2005; Peto and Lopez 2005). An estimated 91 percent of lung cancer deaths in 2000 for males ages 35 and over and 86 percent of lung cancer deaths in 2000 for females ages 35 and over in the U.S. can be attributed to smoking. (Peto and Lopez 2005). Given the contribution of smoking to mortality patterns, the prevalence of smoking and the structure of mortality across states may have important repercussions in terms of health expenditures across states. Moreover, given the high correlation between smoking, race and poverty status, interstate variation in lung cancer mortality and mortality is particularly relevant to considerations of the distribution of public health expenditures across states.

This paper examines the factors influencing the distribution of mortality across states. Specifically, it examines interstate differences in lung cancer mortality in the United States among persons aged 45 and over. Among men age 45 and over, age-adjusted lung cancer rates varied from 98.5 per 100,000 in Utah to 327.2 per 100,000 in Kentucky; among women these rates ranged from 46.8 per 100,000 in Utah to 153.4 per 100,000 in Kentucky. In this paper, the following questions are addressed:

1) Are there specific spatial patterns of lung cancer mortality across states? Do these spatial patterns differ among men and women?
2) What factors influence geographic patterns in lung cancer mortality among men and women?
3) How are geographic patterns of lung cancer mortality related to geographic patterns in all-cause mortality? To what extent do geographic patterns in lung cancer mortality contribute to geographic patterns in all cause mortality?

Ecological studies have impacted public health knowledge since John Snow's maps of cholera highlighted the waterborne transmission of the bacteria in 1855 (Snow, 1855). Devesa, et al. (1999) identified variations in lung cancer mortality rates across Census Divisions and State Economic Areas in the U.S. by race and sex and documented changes over in these patterns throughout the latter half of the 20th century. Further, they found that the changes in geographic patterns of lung cancer mortality since the 1950s coincided with regional trends in cigarette smoking, which has been causally linked to lung cancer (*Health Consequences of Smoking*, 2004).

Additional research has identified several risk factors for lung cancer morbidity and mortality, including smoking, industrial/occupational and environmental risks. Both correlation and case-control methods have been used to associate these risk factors with lung cancer mortality. For example, in their community-level study of long-term exposure to air pollution on lung cancer mortality, Pless-Mulloli et al. (1998) identified a gradient between proximity to industrial air pollution and lung cancer mortality rates for British females under age 75. However, results were less conclusive for men. In a prospective mortality study, Pope et al. (2002) linked self-reported risk factors -- including smoking, alcohol consumption, diet and occupational exposures -- with air pollution data and cause of death information. They found that fine-particulate air pollution was associated with an elevated risk of lung cancer mortality and cardiopulmonary mortality. Other case-control studies identified an increase in lung cancer risk associated with occupations and industries in which workers were exposed to chemicals or asbestos, such as shipyards (Devesa et al. 1999; Blot and Fraumeni 1976).

Cancer mortality maps produced by the National Cancer Institute reflect mortality data through 1994 (The National Cancer Institute's Cancer Mortality Maps and Graphs can be accessed online at http://cancercontrolplanet.cancer.gov/atlas/index.jsp). This study focuses specifically on lung cancer mortality across states among adults 45 and older in 2000 – 2002.

First, I age-adjusted state lung cancer mortality rates using the U.S. projected 2000 population, the standard population for age adjusting mortality statistics (Klein and Schoenborn 2001). Next, I generated quintile maps for men and for women in order to visually assess whether there are spatial patterns of lung cancer mortality and how these differ by sex.

Other studies of mortality differences across states have relied on correlation analysis. For example, while not specifically examining lung cancer mortality, Kaplan et al. (1996) and Kawachi et al. (1997) examine how income inequality and social capital are associated with mortality rates and trends in mortality across states. Kaplan et al. find that income inequality has a positive and significant association to a variety of health outcomes, including age-adjusted mortality rates, even after controlling for state median incomes. Kawachi et al. derive state estimates of social capital from the General Social Survey and find that lower social capital (as measured by social mistrust, perceived lack of fairness, perceived lack of helpfulness) is associated with higher rates of mortality, even after controlling for state poverty rates. However, in this study, a set of factors associated with variations in lung cancer mortality across states was examined by estimating a multivariate regression model. I then conducted a Moran's I test for spatial autocorrelation using the residuals from the adjusted models for males and females. Finally, I also used multivariate regression to examine the association between lung cancer mortality and all-cause mortality across states.

DATA AND METHODS

Mortality Data

I obtained lung cancer mortality and all-cause mortality data for the years 2000 through 2002 for males and females ages 45 and over for the 50 states and the District of Columbia from the Center for Disease Control's Compressed Mortality Database accessed at (http://wonder.cdc.gov/mortICD10J.html). Again, I age-adjusted state lung cancer mortality rates using the U.S. projected 2000 population, the standard population for age adjusting mortality statistics (Klein and Schoenborn 2001). I pooled three years of data in order to control for annual fluctuations in mortality within states. The paper focuses on persons 45 and over because lung cancer is not a prominent cause of death for persons younger than 45. For example, the age-adjusted death rate for persons less than 45 years of age is 1.5 per 100,000 for females in the U.S. and 1.8 per 100,000 for males in the U.S. and is 115.7 per 100,000 for females and 211.8 per 100,000 for males 45 and over. Even among young adults aged 25 to 44, age-adjusted lung cancer mortality rates are low – 3.3 per 100,000 for females and 3.8 per 100,000 for males.

1. EXAMINING SPATIAL PATTERNS OF LUNG CANCER MORTALITY FOR MEN AND WOMEN, 45 AND OLDER

In order to examine spatial patterns of lung cancer mortality across states, I mapped age-adjusted state lung cancer mortality rates for men and for women 45 years and older using ArcGIS. Map 1 (see Appendix) shows a chloropleth map of lung cancer mortality rates for men. I divided these rates into quintiles, with the darkest shaded areas indicating the 20 percent of states with the highest age-adjusted lung cancer mortality rates and the lightest areas indicating the 20 percent of states with the lowest age-adjusted lung cancer mortality rates among men 45 and older. As seen in Map 1, high rates of male lung cancer mortality are clustered in the Appalachia and the South, in the former "black belt," with the exception of Indiana. For males, lowest rates of lung cancer mortality appear clustered in the mountain states of Colorado, Idaho, Wyoming and Utah, Arizona and New Mexico, in addition to California, Connecticut, Michigan and North Dakota.

However, as seen in Map 2 (See Appendix), the spatial patterns of lung cancer mortality for women look substantially different than those for men. While southern Appalachia (West Virginia and Kentucky) appear in the highest quintile, lung cancer mortality for women 45 and older is also high in the Pacific Northwest (specifically Washington and Oregon). The high rates of lung cancer mortality among women in the Northwest cannot be attributed to current smoking prevalence. According to Devesa, et al. (1999), these high mortality rates are consistent with high smoking prevalence in the West in the 1950s. Also included in the highest quintile of female lung cancer mortality are such geographically dispersed states as Delaware, Indiana, Maine, Oklahoma, and Nevada. Therefore, spatial clustering of high lung cancer mortality is not as evident among women 45 and older as among men 45 and older. For women, the lowest state lung cancer mortality rates were found in the mountain states (Colorado, Idaho, New Mexico, Utah) and in the Great Plains (Iowa, Minnesota, Nebraska, North Dakota, South Dakota and Wisconsin).

In order to determine whether the spatial clustering apparent on the map suggests spatial autocorrelation, I generated a Moran's I statistic using rook contiguity weights based on mortality rates in contiguous states. Spatial autocorrelation would imply that lung cancer mortality rate in a particular state are dependent on (or significantly similar to) the rates in surrounding states. Because sample size was relatively small (n=51), the resulting Moran's I statistic could be sensitive to the specification of the weights. Therefore, I also tested for spatial autocorrelations with alternative weights based on rook contiguity and nearest neighbors (defining one and four nearest neighbors for each state). However, these alternative specifications of weights yielded similar results.

. If spatial autocorrelation is present, the independence assumption necessary for OLS estimation is violated and estimated coefficients would be biased. In this case, spatial regression techniques would generally be more appropriate. As shown in Table 1, the Moran's I value was significant at the 0.001 level, signaling spatial autocorrelation. Male and female lung cancer mortality rates are significantly clustered across states.

TABLE 1: Moran's I for Age-Adjusted Lung Cancer Mortality Rates, 2000 – 2002 (Rook Contiguity Weights)

Gender	Moran's I
Males	0.6045**
Females	0.2103*

**$p < 0.001$; * $p < 0.01$

Although the visual examination of the quantile maps and the Moran's I values listed in Table 1 for male lung cancer mortality rates suggest spatial autocorrelation, it is not apparent why female lung cancer mortality rates do not exhibit a similar pattern.

2. EXPLAINING STATE VARIATIONS IN LUNG CANCER MORTALITY FOR MEN AND WOMEN, 45 AND OLDER

I used OLS and spatial regression techniques to predict state variations in lung cancer mortality for men and women ages 45 and older. It is hypothesized that differences in smoking behaviors across states as well as state variations in environmental factors, demographic composition, and industrial structure would influence lung cancer mortality rates across states. A description of the variables included in this analysis model are described below and listed in Table A in the Appendix. Summary statistics for the variables used in the models can be found in Table B in the Appendix.

Smoking behaviors

Smoking is considered the leading cause of lung cancer, accounting for approximately 90 percent of lung cancer deaths (Peto and Lopez 2005; See also Ries et al. 2004). Therefore, I expect that states with higher proportions of self-reported smokers will also have higher lung cancer mortality. Former, as well as current, smoking behavior may be implicated in lung cancer incidence since the physiological effects of smoking persist over time, although the risk of lung cancer steadily declines in persons who quit (Rogers, 2005; Centers for Disease Control and Prevention 2005c). However, the risk of lung cancer remains higher among former smokers than among those who have never smoked (Centers for Disease Control and Prevention 2004).

In this analysis, data on former and current smoking by state and gender for 2000-2002 for males and females aged 45-64 and 65 and over were drawn from the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS defines current smokers as individuals who reported having smoked more than 100 cigarettes during their lifetime and who currently smoked every day or some days. Former smokers were defined as those who reported having smoked more than 100 cigarettes during their lifetime and who currently did not smoke at all. These data are available online through the *National Center for Health Statistics, Data Warehouse on Trends in Health and Aging,* http://www.cdc.gov/nchs/agingact.htm. I calculated age-adjusted rates of current smoking prevalence by state and former smoking prevalence by state for males and females 45 and over using the U.S. projected population for 2000 (Klein and Schoenborn 2001). One noteworthy limitation of this data is that the BRFSS is a telephone survey and thus excludes non-telephone households. However, it does offer sufficient sample size for state and sub-state estimates, unlike the National Health Interview Survey.

Environmental Data

Environmental factors have also been cited as causes of lung cancer. For example, radon exposure is reported to be the second leading cause of lung cancer in the U.S. (National Cancer Institute, http://www.cancer.gov/cancertopics/factsheet/Risk/radon). Further, research suggests that air pollution may also be linked to lung cancer (Pless-Mulloli et al., 1998; Pope et al., 2002). Moreover, poor air quality may further compromise individuals with severe respiratory conditions. Therefore, it is hypothesized that states with high levels of potential radon exposure or poor air quality will also have higher rates of lung cancer mortality.

Potential radon exposure data were derived from the U.S. Environmental Protection Agency's Radon Zone Maps. Each of the counties in the U.S. are assigned to one of three zones (low, medium and high) based on the average short-term radon measurement expected in a building without the implementation of radon control methods. I accessed the radon zone maps at http://www.epa.gov/radon/zonemap.html. In order to obtain state-level data, I computed the proportion of the state population residing in counties with high potential radon exposure (i.e. counties having a predicted average indoor radon screening level greater than 4 pCi/L) using state population data from the 2000 U.S. Census.

In addition, data on air quality was obtained from the U.S. Environmental Protection Agency's Air Quality Index report. An Air Quality Index report for the United States by county for 2000-2002 was generated from http://www.epa.gov/air/data/reports.html. The Air Quality Index reports daily air quality and is calculated for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For this paper, the Air Quality Index for each state was measured by the median of the annual county values for the Median Air Quality Index.

Higher values of the Median Air Quality Index indicate higher levels of pollutants and lower air quality. However, a limitation of aggregating these data for states is that air quality varies substantially within states, and the median may mask this variation. For example, in their study of 27 Teesdale neighborhoods, Pless-Mullioli et al. (1998) used a proximity-based measure of exposure to air pollution.

Demographic Data

Age-standardized lung cancer mortality rates are higher among African-American males than among whites males. For example, the age-standardized lung cancer mortality rate for 2000-2002 for males 45 and older is 209.5 per 100,000 among whites and 276.3 per 100,000 among African-Americans. In contrast, there is little difference in lung cancer mortality rates for women, although these rates are slightly higher for whites. Among women 45 and older, the age-standardized lung cancer mortality rate for 2000 - 2002 was 118.6 per 100,000 among whites and 109.9 per 100,000 among African-Americans. Thus, I expect that variation in the percent of African-Americans across states predicts interstate differences in lung cancer mortality among males, but not among females. I also include a variable indicating the percent Hispanic or Latino in a state's population.

Several factors which have been shown to affect smoking behaviors could also be useful in explaining variation in lung cancer mortality across states, including poverty and educational attainment (Centers for Disease Control and Prevention 2005b). Poverty might also affect health care access. In this analysis, health insurance coverage status (as measured by the percent of individuals having neither public nor private health coverage) is used as a proxy for health care access. I obtained data on state poverty rates from the 2000 Census Summary File 3 and health coverage by state from the U.S Census Bureau Current Population Survey Annual Social and

Economic Supplement for the years 2000 to 2002. For health coverage by state, I computed a mean value for the years 2000 to 2002 to obtain a state estimate of the uninsured population. I expected that poverty and the lack of health coverage would be positively associated with lung cancer mortality across states since lack of adequate coverage could adversely impact health care utilization and the potential for timely diagnosis and treatment.

Educational attainment may also affect lung cancer mortality rates. Consistent with the literature on smoking prevalence, I expected that states with higher proportions of college graduates to exhibit lower lung cancer mortality rates. To measure educational attainment, I calculated the percent of each state's population having at least a college degree. A variable reflecting urbanization was also included, indicating the percent of a state's population living in urbanized areas. I obtained data on race (the percent of African-Americans to the total state population), educational attainment and urbanization from the U.S. Census 2000 Summary Files 1 and 3 (educational attainment). For the female model, I also included a measure of female labor force participation in 1990. This data was obtained from the 1990 Decennial U.S. Census, Summary Tape File 3.

Industrial Data

Numerous studies have tried to link occupational and industrial exposure to the risk of lung cancer mortality. (Devesa et al. 1999; Blot and Fraumeni 1976). Moreover, the National Institute on Occupational Safety and Health published a volume which highlights industries and occupations with the highest lung cancer prevalence. (Center for Disease Control and Prevention 2003) Thus, data on industrial employment, in particular mining, was obtained from the U.S. Census Bureau Decennial Censuses of 1970, 1980, 1990 and 2000. It was expected that these variables would be positively associated with lung cancer mortality.

RESULTS

I ran nested models sequentially incorporating various blocks of variables (smoking behaviors, environmental characteristics, state demographic characteristics, industrial characteristics) into my models. The models presented here represent the set of variables that provided the best fit. Table C1 in the Appendix reports coefficients and standard errors for ordinary least squares and spatial models for males and Table C2 reports results for females. After running the OLS model reported in Tables C1 and C2, I tested for spatial autocorrelation in the residuals using a variety of spatial weights. Due to the inconsistency of results obtained, I could not rule out spatial dependence in explaining state variations in lung cancer mortality.

In order to address this problem, I also estimated spatial autoregression and spatial lag models. Because the results were substantively similar in all three models, I summarize them here. In the all models, behavioral and demographic variables were significant in predicting state variations in lung cancer mortality for both men and women. Environmental factors also had an influence on male mortality rates.

Consistent with expectations, the smoking behavior variables were positively related to lung cancer mortality. Higher rates of smoking current were significantly associated with higher lung cancer mortality across states for both males and females. In a model regressing lung cancer mortality rates on current and former smoking across states, variation in smoking behavior explains nearly three-fifths of the differences in lung cancer mortality rates for both men ($R^2 = 0.59$) and women ($R^2 = 0.58$) (Results not shown).

Moreover, the estimations revealed the expected positive relationship between pollutants (as measured by the median air quality index) and lung cancer mortality across states. However, while the median air quality index remained robust in the adjusted male model, it was not significant in explaining cross-state variations in lung cancer mortality the female adjusted model. In general, the effect of air quality on lung cancer mortality seems to be larger for men than for women. Potential radon exposure did not predict lung cancer mortality.

In terms of the demographic variables, states with higher proportions of Latinos had lower rates of male lung cancer mortality. This latter result might reflect the Hispanic paradox – Latinos in the US have better health and mortality outcomes than African-Americans, even controlling for socioeconomic status. Somewhat surprisingly, differences in the proportion of African-Americans across states are not significantly associated with lung cancer mortality among men or women. However, this variable is correlated with smoking behaviors and poverty rates and its effect in the model may therefore be diluted. Indeed, state poverty rates are positively associated with higher male lung cancer mortality rates but are not significantly associated with lung cancer mortality rates among women. In contrast, the proportion of uninsured persons in a state is positively associated with lung cancer mortality rates for women, but not for men. However, it should also be noted that poverty and uninsurance rates are highly correlated ($r = 0.5633$), suggesting that the effects of poverty and uninsurance may also be confounded in these models. Moreover, the correlation coefficient between poverty and current smoking behavior for females is 0.28, suggesting that although the relationship is positive as expected, the class differences in smoking behaviors among women are not as sharp as those among men.

In Tables C1 and C2 , we report the likelihood ratio for the spatial autoregression and spatial lag models. This statistic permits us to compare the performance of models against one another. However, the likelihood ratio test can only be used to compare the performance of nested models. In this case, the OLS model is a special case of the spatial autoregression model and the spatial lag model, so we can compare the performance of the OLS model to each of these models in turn. As seen in Table C1, when rook contiguity weights are used, both models provide a better fit than the OLS model for males but only the spatial lag model performs better than the OLS model in explaining state variation in female lung cancer mortality. Further, the spatial models “explain” a higher proportion (with one exception) of the variance in age-standardized lung cancer mortality rates across states.[1]

After estimating these three models for state lung cancer mortality rates for males and females, a Moran’s I was calculated for the residuals from each model to determine whether the unexplained variance exhibited spatial autocorrelation. (Cliff and Ord, 1972). As shown in Table 2 below, the Moran’s I statistics for the residuals are no longer significant for males or females. Therefore, the spatial models seem to account for any spatial dependence in lung cancer mortality rates across states.

TABLE 2: Moran’s I for Age-Adjusted Lung Cancer Mortality Rates 2000 - 2002 and Moran’s I for Residuals from Adjusted Multivariate OLS Estimation (Rook Contiguity Weights)

	OLS	**Spatial Autocorrelation**	**Spatial Lag**
Males	0.2251*	0.1430^{+}	0.0576
Females	0.1909*	0.0409	0.0978

***p* <0.01; * *p*<0.05

3. PATTERNS IN LUNG CANCER AND ALL-CAUSE MORTALITY

In *Mortality From Tobacco in Developed Countries,* Peto and Lopez (2005) demonstrate how age and sex-specific lung cancer rates can be used to estimate the excess number of deaths attributable to smoking overall from lung cancer as well as a host of other diseases. Here, I use

[1] The pseudo-R^2 is provided rather than the R^2 because the error term does not have constant error variance.

lung cancer as a proxy for smoking in a univariate model to assess how much state variation in mortality can be explained by variations in mortality from smoking. As seen in Table 3 below, the coefficient for lung cancer mortality is positive and significant, suggesting that higher rates of lung cancer mortality within a state are associated with higher rates of mortality overall, for both males and females. Among males, differences in lung cancer mortality rates account for 82 percent of the variation in all-cause mortality rates across states. For women, lung cancer mortality rates "explain" less than 40 percent of the variation in all-cause mortality across states. As Figures A and B (See Appendix) reveal, there is less variation in lung cancer mortality rates for women (for most states, rates range between 100 and 150 per thousand). These results support the strong causal link between smoking prevalence and all-cause mortality across states, especially for men.

Robust standard errors are reported in Table 3 to correct for heteroscedasticity. However, these results are preliminary, as other factors which might influence mortality have not been controlled for, but will be in future revisions. Moreover, given the geographical clustering of mortality for both males and females (See Maps 3 and 4 in the Appendix), it is conceivable that spatial estimation techniques will need to be systematically explored.

Table 3: Regression Results: Univariate Models
Dependent Variable: Age-Adjusted All Cause Mortality, Ages 45 and over
β Coefficients (Robust Standard Errors in parentheses)

	MALES	**FEMALES**
Age-Adjusted Lung Cancer Mortality, 45+	5.43 (0.36)*	5.67 (1.04)*
Constant	1,565.87 (78.26)*	1,279.30 (120.89)*
N	51	51
Adjusted R^2	0.82	0.37
F	227.56	29.89

p<0.01

DISCUSSION

The results presented here suggest the importance of behavioral and selected demographic factors in explaining state variations in lung cancer mortality for both men and women. They also point to the need for a more nuanced analysis of the relationships between behaviors, place and outcomes. From the analysis above, it is clear that geographic patterns of lung cancer mortality differ for males and females. State lung cancer mortality patterns for males more closely mirror overall mortality patterns than do those for females. In particular, age-adjusted lung cancer mortality rates exhibit a spatial clustering pattern. However, the apparent spatial clustering may not act independently of other determinants of lung cancer mortality, such as poverty rates.

Despite the differences in the spatial pattern of lung cancer mortality among men and women, there are few differences in the role of different factors in predicting lung cancer mortality rates. For both men and women, smoking prevalence, particularly the proportion of current smokers in a state, have a strong predictive effect for lung cancer mortality. Environmental and socioeconomic factors also impact lung cancer mortality rates for males and females. However, there appears to be differences in the magnitude of these effects, with behaviors having a stronger effect for men and socioeconomic status (as measured here by the proportion uninsured) having a stronger effect in explaining state lung cancer mortality for women.

There are several limitations to the analysis presented here. Although an attempt was made to capture a myriad of risk factors, including behavioral, environmental and industrial, the operationalization of these variables did not capture the lifetime exposure to risk faced by adults 45 and older. Thus, the analysis could benefit from more complete historical measures which would better capture exposure to risk of lung cancer mortality among older adults. Moreover, the specification of industrial variables certainly did not capture the entire spectrum of industries/occupations with elevated risk of lung cancer incidence. Second, this study has implicitly assumed that migration does not occur. Environmental conditions in the state of death are assumed to be the conditions to which an individual was exposed over time. In addition, no corrections were made for potential multicollinearity, although several of the independent variables were correlated with each other and therefore likely to be confounded. Thus, a systematic attempt will be made to correct for multicollinearity in the model.

Moreover, Rogers et al (2004) point out that the prevalence and risk of smoking and lung cancer mortality on overall mortality varies by age, with distinct patterns characterizing smoking related deaths among the middle aged, among those 65 to 75 and among those of older age. But this study aggregates mortality rates for persons in aged 45 and older, obscuring these patterns. Further, the measure of smoking does not adequately account for frequency, although lung cancer mortality is associated with a dose-response (Rogers 2005).

In addition, aggregating the analysis to the state level masks county-level variations in mortality and other variables. Variations in lung cancer mortality may be more diluted in the state context than it would be in a small-area analysis. Moreover, any area analysis risks the ecological fallacy. But in this study, no claims are made about the relationship between the independent variables and lung cancer mortality at the individual level. This paper examined how differences in behavioral, environmental, and demographic variables influenced variations in mortality rates across states. No conclusions are drawn regarding the influence of these variables on individual outcomes.

This study also does not address trends in lung cancer mortality among men and women. Preston and Wang (2005) demonstrate that trends in sex mortality rate differentials could be explained by cohort patterns of smoking. But these cohort patterns are also likely to affect sex differences in lung cancer mortality across time. To the extent that there are geographical shifts in smoking prevalence as suggested by Devesa, et al. (1999), these cohort patterns might exhibit themselves across both time and space.

TABLE A: Covariates, Description and Data Source

Variable	Description	Source
MORTALITY		
Lung Cancer Mortality	Age-Adjusted Lung Cancer Mortality Rates for states, 2000 – 2002	CDC Compressed Mortality Database
All-Cause Mortality	Age-Adjusted All-Cause Mortality Rates for states, 2000 – 2002	CDC Compressed Mortality Database
BEHAVIORAL VARIABLES		
Current Smokers	Percent of state population who reported having smoked >100 cigarettes during their lifetime and who currently smoked every day or some days.	BRFSS
Former Smokers	Percent of state population who reported having smoked >100 cigarettes during their lifetime and who currently did not smoke at all.	BRFSS
ENVIRONMENTAL VARIABLES		
Air Quality Index	State Median of Median Air Quality Index for counties	EPA
Radon	Percent of state population living in counties with high potential radon exposure	EPA/Census 2000
DEMOGRAPHIC VARIABLES		
Race/Ethnicity	Percent of state population that is African-American; Percent of state population that is Hispanic and/or Latino	Census 2000
Poverty	Percent of state population that had income below the poverty level in 1999	Current Population Survey, March Supplement 2000-2002
Educational Attainment	Percent of state population who completed college	Census 2000
Urban Residence	Percent of state population residing in urban area	Census 2000
Health coverage	Percent of state population with covered by health insurance (public or private)	Current Population Survey, March Supplement 2000-2002
INDUSTRIAL VARIABLES		
Percent employed in mining	Percent of employed persons employed in mining (Total nonfarm employment)	Current Employment Survey, Bureau of Labor Statistics

Table B: Summary Statistics : Means

	N	Mean
AGE-ADJUSTED MORTALITY RATES (per 100,000)		
Lung Cancer Mortality, Males 45+	51	212.9
Lung Cancer Mortality, Females 45+	51	115.0
All Cause Mortality, Males 45+	51	2,721.5
All Cause Mortality, Females 45+	51	1,931.5
BEHAVIORAL VARIABLES		
Percent of current smokers, Males 45+	51	19.0
Percent of current smokers, Females 45+	51	16.9
Percent of former smokers, Males 45+	51	44.4
Percent of former smokers, Females 45+	51	27.5
ENVIRONMENTAL VARIABLES		
Median Air Quality Index	51	32.5
Percent living in counties with high potential radon exposure	51	33.5
DEMOGRAPHIC VARIABLES		
Percent African-American	51	11.4
Percent Hispanic/Latino	51	7.8
Percent with income below poverty level 2000-2002	51	12.1
Percent college graduates 2000	51	25.2
Percent residing in urban areas	51	72.2
Percent with health coverage 2000-2002	51	13.3
Female labor force participation rate 1990	51	57.5
Female labor force participation rate 2000	51	61.8
INDUSTRIAL VARIABLES		
Percent employed in mining 1970	51	1.3
Percent employed in mining 1980	51	1.3
Percent employed in mining 1990	51	1.0
Percent employed in mining 2000	51	0.6

Table C1: Spatial Regression Results for Age-Adjusted Lung Cancer Mortality, Persons 45 and older (Nearest Neighbor Weights)

	Ordinary Least Squares Model	Spatial Autoregression Model	Spatial Lag Model
Variable			
Constant	-183.43*	-94.33	-219.88*
% Current Smokers	8.23**	6.49**	8.43**
% Former Smokers	2.55*	1.64*	2.59*
Median Air Quality Index	2.58**	1.05*	1.58*
% High Radon Exposure	0.06	0.12	-0.06
% Mining Employment	-1.08	0.17	0.03
% Black	-0.19	-0.26	-0.48
% Hispanic	-2.28*	-2.28**	-2.47**
% Urban	-0.17	-0.18	0.10
% Below Poverty Level	3.51*	2.12*	2.94*
% Uninsured	1.87	2.01	1.65
% College or More	0.25	0.55	0.66
Female Labor Force Participation Rate			
Rho		1.00**	
Lambda			0.24**
R^2	0.83		
Pseudo R^2		0.91	0.90
Log Likelihood		-204.93	-205.89
Likelihood Ratio		433.87	437.79

$^{+}$ p<0.10; * p<0.05; ** p<0.01

Table C2: Spatial Regression Results for Age-Adjusted Lung Cancer Mortality, Persons 45 and older (Nearest Neighbor Weights)

	Ordinary Least Squares Model	Spatial Autoregression Model	Spatial Lag Model
Variable			
Constant	-9.39	-61.17	-40.28
% Current Smokers	3.74**	3.29**	4.10**
% Former Smokers	2.25**	2.43**	2.00**
Median Air Quality Index	0.99*	0.45	0.53
% High Radon Exposure	-0.04	0.03	-0.02
% Mining Employment	-1.16	-0.21	-0.73
% Black	-0.33	-0.47⁺	-0.31
% Hispanic	-1.21*	-1.39**	-1.27**
% Urban	0.03	0.32*	0.13
% Below Poverty Level	-0.21	0.04	-0.32
% Uninsured	2.48*	2.55**	2.38*
% College or More	0.03	-0.28	0.05
Female Labor Force Participation Rate	-0.87	-0.25	-0.52
Rho		1.00**	
Lambda			0.19*
R^2	**0.68**		
Pseudo R^2		0.84	0.79
Log Likelihood		-175.90	-182.55
Likelihood Ratio		377.79	393.10

$^+$ *p*<0.10; * *p*<0.05; ** *p*<0.01

Figure A: Age-Adjusted Lung Cancer Mortality and All-Cause Mortality 2000-2002, Males, 45+

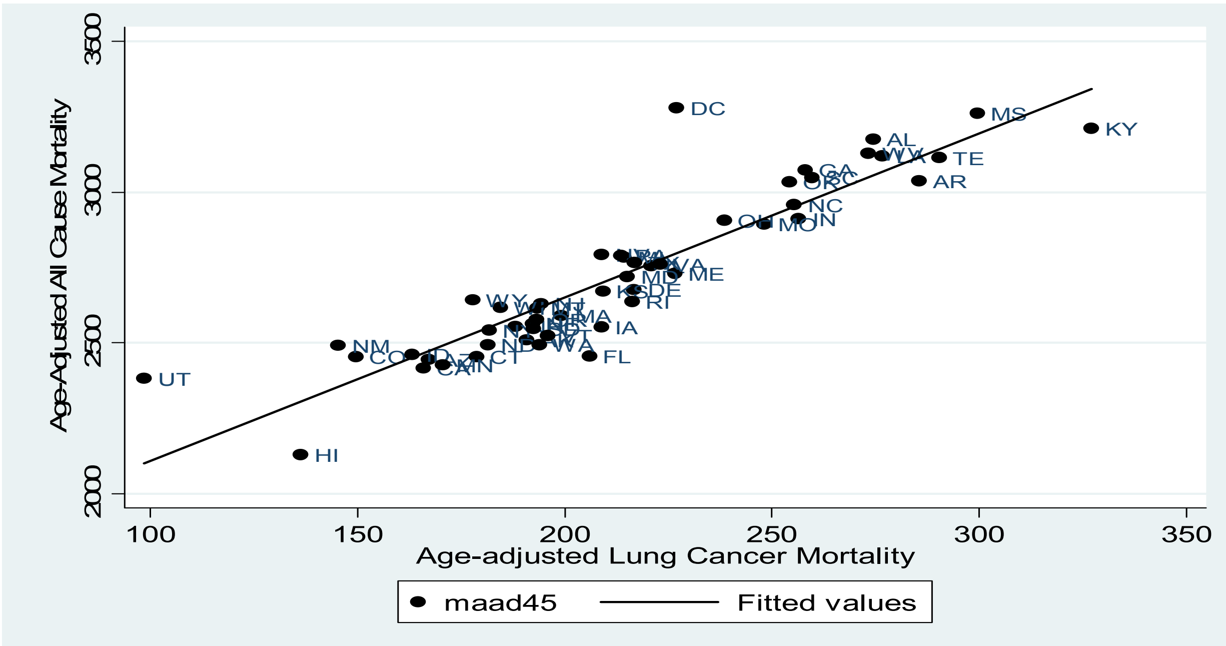
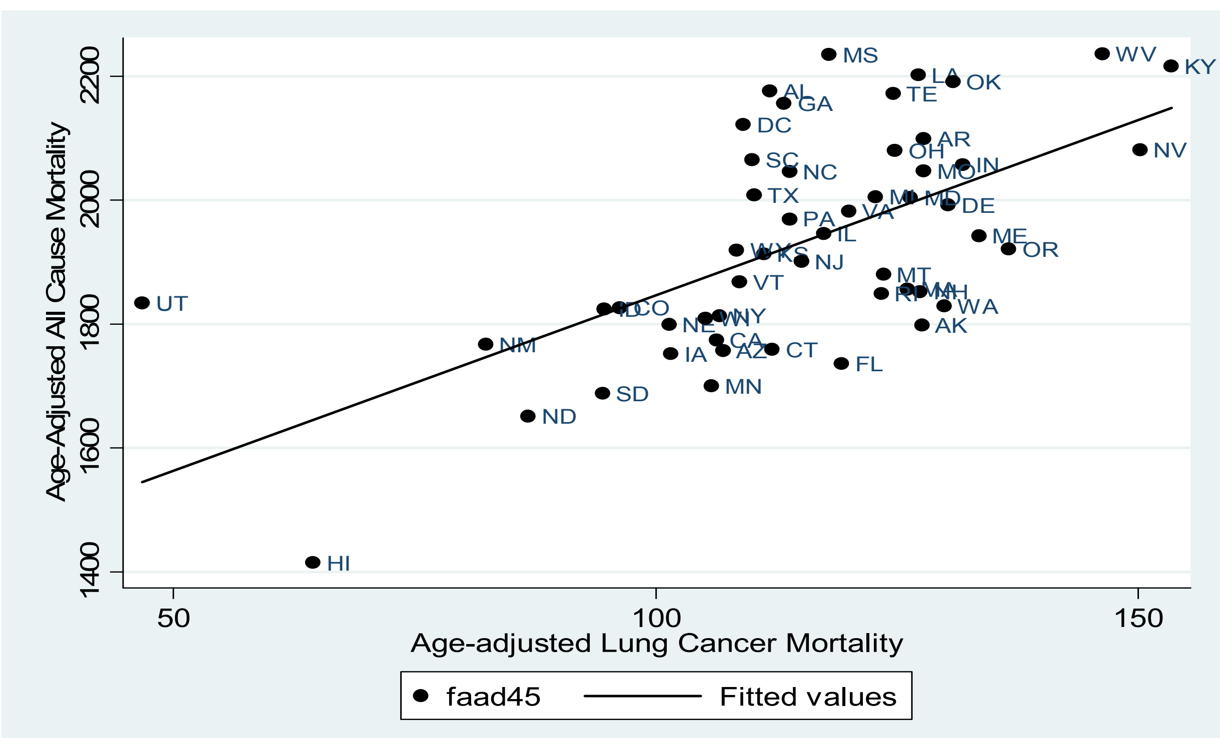
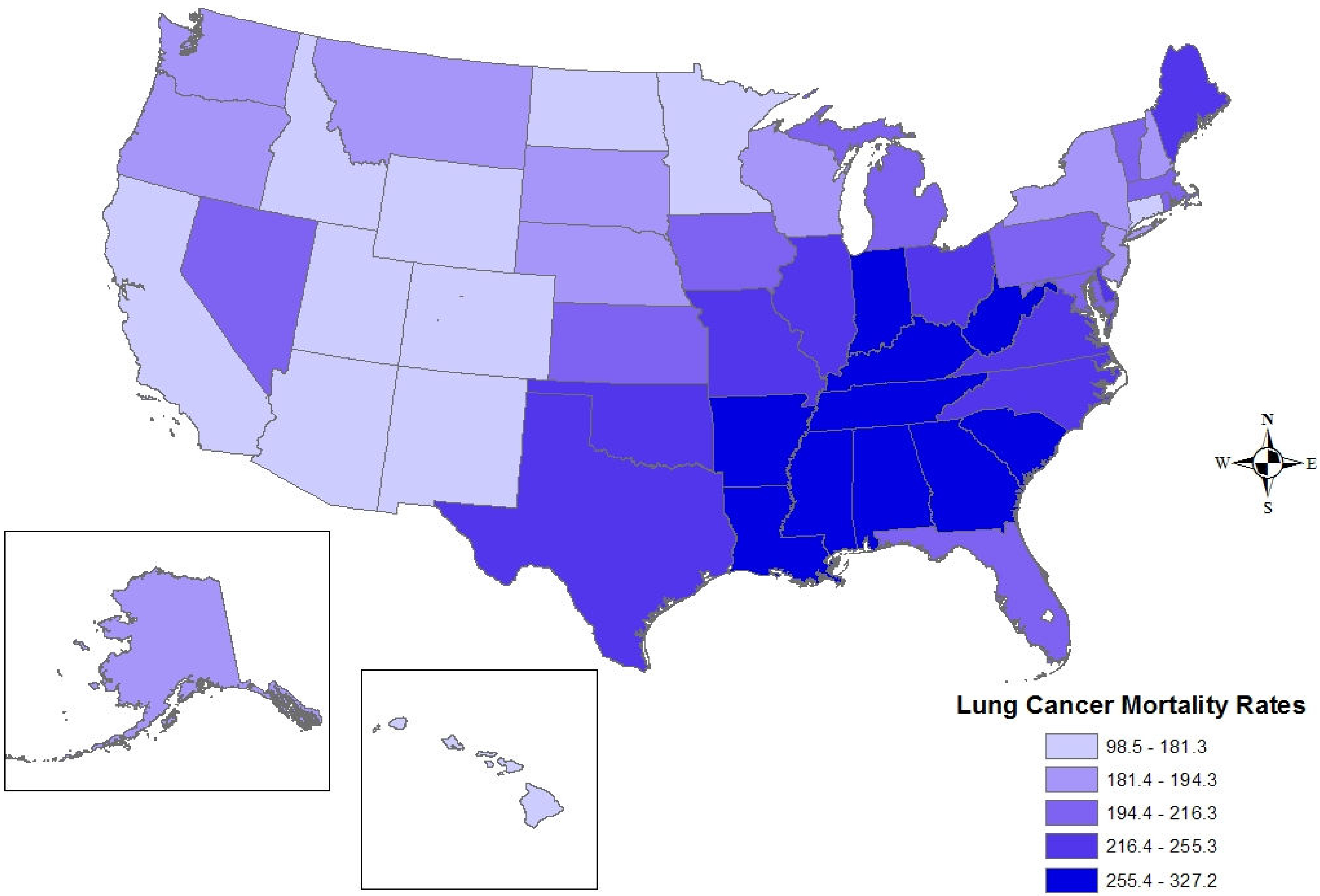


Figure B: Age-Adjusted Lung Cancer Mortality and All-Cause Mortality 2000-2002 Females, 45+



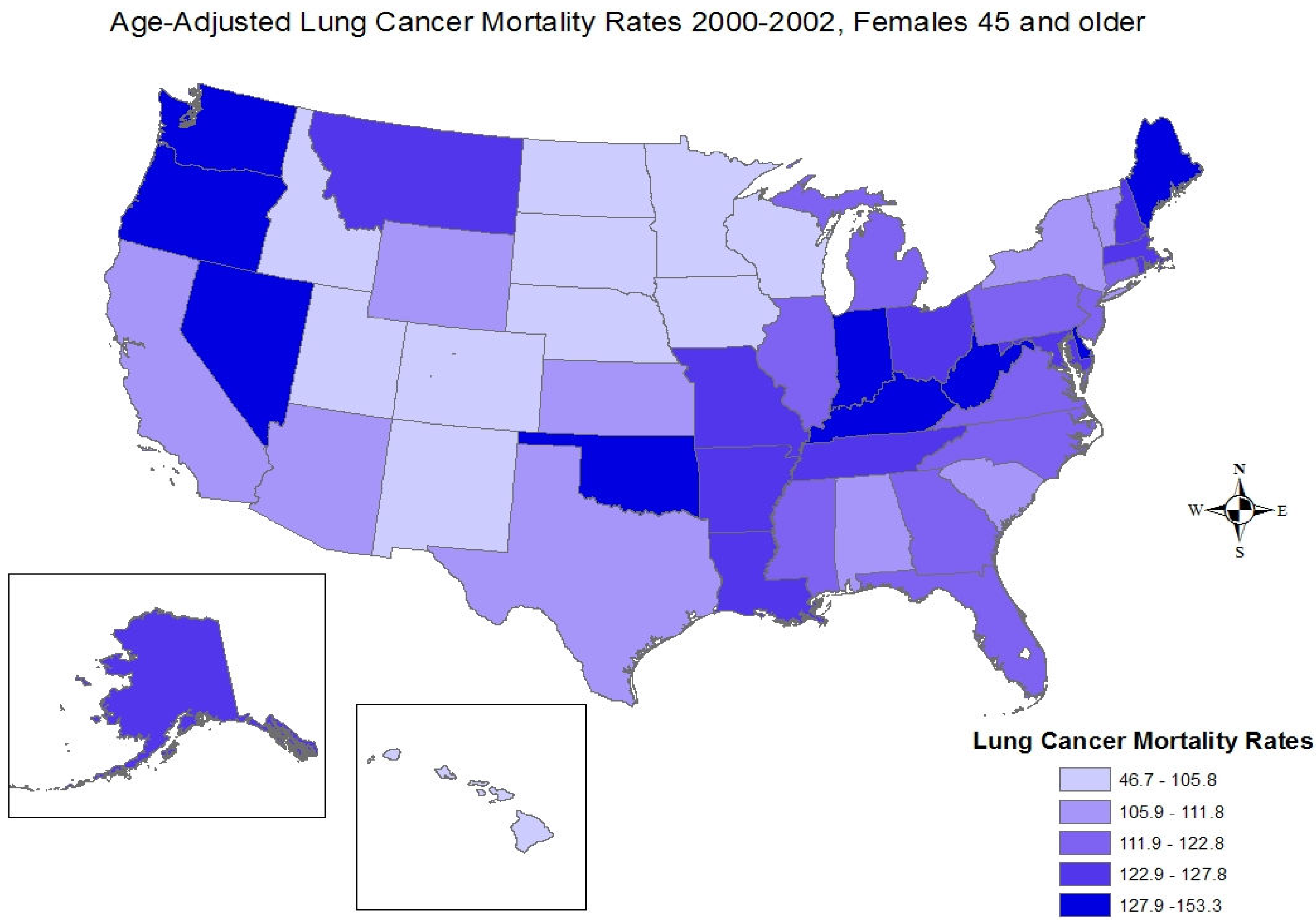
MAP 1

Age-Adjusted Lung Cancer Mortality Rates 2000-2002, Males 45 and older



Source: CDC Compressed Mortality Database

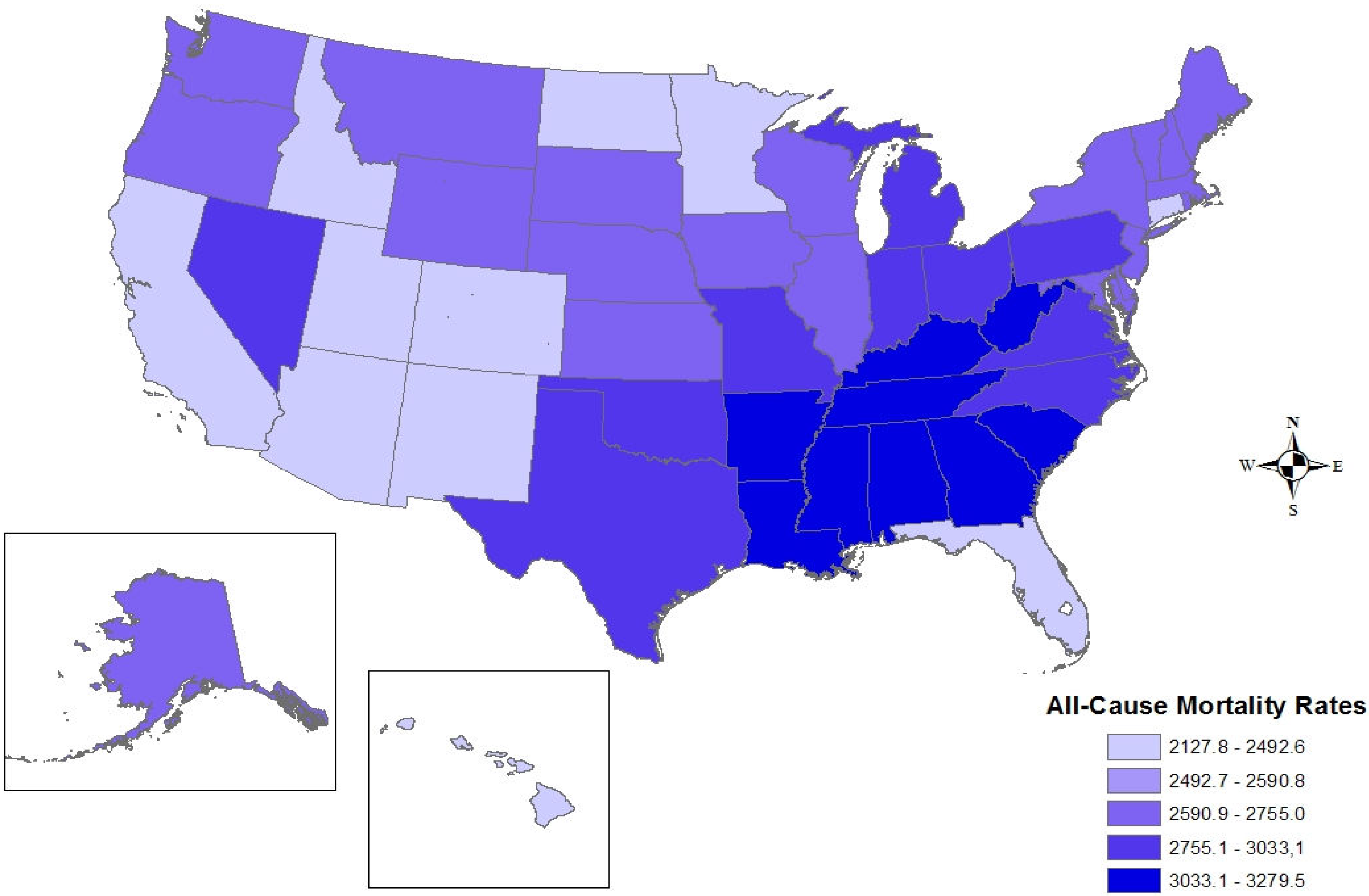
MAP 2



Source: CDC Compressed Mortality Database

MAP 3

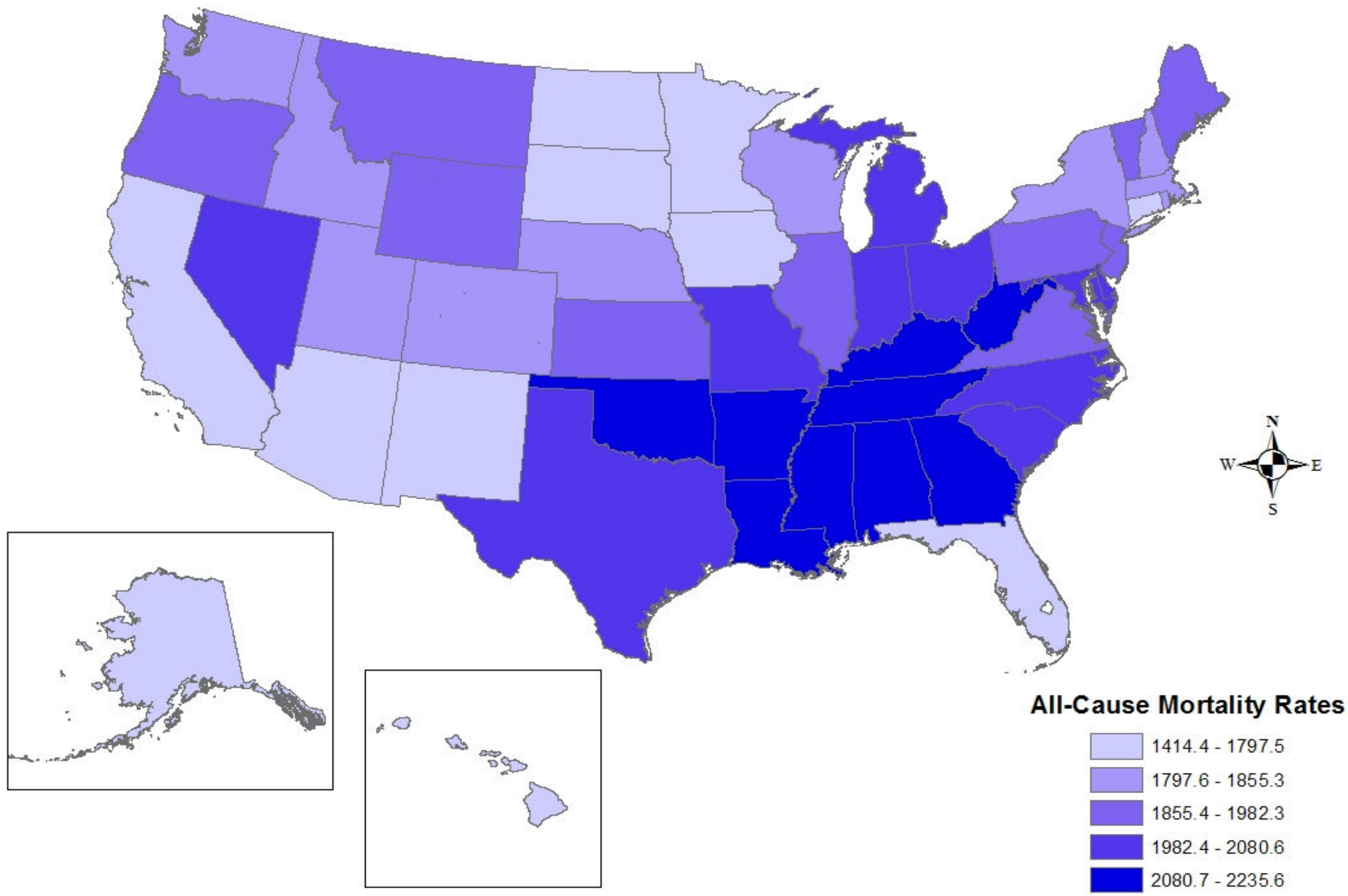
Age-Adjusted All-Cause Mortality Rates 2000-2002, Males 45 and older



Source: CDC Compressed Mortality Database

MAP 4

Age-Adjusted All-Cause Mortality Rates 2000-2002, Females 45 and older



Source: CDC Compressed Mortality Files

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