Context and Death: A spatial investigation of the impacts of social capital and natural amenities on mortality in U.S. counties.

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Abstract

The proliferation of spatial data and the statistical techniques to analyze them have naturally given rise to increasing attention to relationships between place characteristics and human health. While some is known about how social capital and natural amenities affect individual health, their impact on mortality remains unexplored. We address this issue through analysis of data on U.S. counties, and in so doing rectify three shortcomings in the relevant literature: the crude and limited measures of social capital, the unknown impacts of natural amenities on mortality, and insufficient attention to spatial dependence which can yield incorrect findings. Our exploratory spatial data analysis demonstrates an obvious mortality clustering pattern where the Appalachian region, the Black Belt, and the Mississippi Valley are disadvantaged relative to the Great Plain and the Mexico border region. Furthermore, the spatial explanatory analysis not only indicates social capital and natural amenities benefit human health, but also indicates that spatial structure cannot not be ignored.

Introduction

The proliferation of spatial data and the statistical techniques to analyze them, have naturally given rise to increasing attention to relationships between place characteristics and human health. The increasing array of spatial characteristics available for analysis has allowed researchers to be increasingly creative and broad minded in their inclusion of explanatory factors. While some is known about how social capital and natural amenities affect individual health, their impact on mortality remains unexplored. We address this issue through analysis of data of U.S. counties, and in so doing rectify three shortcomings in the relevant literature.

First, measures of social capital at the aggregate level, particularly at lower levels of aggregation, are not readily available, and this has impeded needed advances. The General Social Survey provides two items that can be used as indicators of social capital at the state level: the proportion of residents reporting people can be trusted and the per capita density of membership in the voluntary groups. Capitalizing on this, several state-level analyses have been conducted over the past decade which find a negative correlation between mortality and social capital (Kawachi et al., 1997; Wilkinson et al., 1998; Kawachi et al., 1999). Despite this advance, few policy implications can be offered due to the inherent crudeness of state-level analysis and limited quality of available measures.

Second, though the impact of weather and other natural amenities on mortality have been explored among major cities and some other metropolitan counties in the U.S. (Kalkstein and Davis, 1989; Kalkstein and Greene, 1997; Fairley, 1990; Kinney and Ozkaynak, 1991), it remains unknown whether these impacts hold for other cities or counties. Our study provides a nationwide investigation on the relationship between natural amenities and mortality.

Third, the importance of spatial structure has not been emphasized sufficiently in the literature. Comparatively few ecological studies have incorporated a spatial perspective into their analysis, despite increasing awareness of spatial associations embedded in data which can bias analytic results or yield incorrect findings. We estimate models that account for spatial autocorrelation.

The next section will review the literature and elucidate the effects of social and natural environment on mortality. This is followed by a description of measures and data sources. The methods section will introduce the exploratory spatial data analysis, which is used to assess the pattern of spatial association in the data, and explicate our spatial models in detail. We then present our results and conclude with a summary and discussion of policy implications.

The Effects of Social and Natural Environment on Mortality

To explore the relationship between context and mortality, four concepts will be employed: social capital, natural amenities, population composition, and rural/urban residence. The following discussion describes how mortality is affected by these elements and, at the same time, elaborates on shortcomings in the literature, which we seek to rectify in this paper.

Social Capital

The linking of social connections to health outcomes has a long history in social science. Durkheim (1897) analyzed suicide data and suggested that the extent of social integration may explain self-destructive behaviors. In his seminal work, suicide rates were found to be higher for people who had fewer social interactions, such as adults who are not married. Durkheim argued that the tighter integration and closer family systems among Catholics reduced suicide rates among this group.

Durkheim’s ideas have been extended to various areas of health research over the years. Numerous studies have taken advantage of longitudinal data collected in Alameda county, California, since 1965 and confirmed the preventive effects of social connectedness (Berkman and Syme, 1979; Seeman, et al., 1987; Kaplan and Reynolds, 1988; Reynolds and Kaplan, 1990; Roberts, et al., 1997). Social and community ties were believed to be crucial determinants for human health. Even after taking individual lifestyles (e.g., smoking and alcohol consumption), self-reported health status, and socioeconomic status into consideration, the most socially isolated men and women still had higher risks of death compared to their counterparts who were socially active (Berkman and Syme, 1979; Seeman, et al., 1987). The Tecumseh County Health Study, initiated in 1959 and designed to examine health and disease determinants in Michigan, also supported the positive effects of social capital. Adjusting for age and other risk factors, men having more social relationships and participating in more activities were less likely to die during the follow-up period (House, et al., 1982).

Although an association between health and social connections is well documented, one might question the causal relationship. That is, might not physical or mental illness lead to social isolation? However, longitudinal data sets, like those of the Alameda and Tecumseh studies, have been analyzed and suggest that indeed social isolation compromises health. It was suggested that people who were socially disconnected had over twice the probability of dying of all causes in contrast to matched individuals who were tightly connected with friends, families, and communities (Berkman and Glass, 2000). The beneficial effects of individual social involvement on health are significant; however, since social capital is to some degree a community rather than individual level attribute, evidence from higher analytic units is needed.

A cohesive and relatively stable Italian-American community in Roseto, Pennsylvania, has drawn researchers' attention since the 1950s. Compared to its geographical neighbors, Roseto demonstrated a lower mortality of cardiovascular diseases. Roseto's age-adjusted heart attack rate was less than half of that of its neighbors, and not a single Roseto resident below forty-seven had passed away due to cardiovascular diseases over a seven-year investigation. Important predictors of heart disease, like diet, exercise, weight, and genetic factors, had been considered but none of them could explain why Rosetans were healthier. Indeed, they had greater risk factors than did residents of other towns (Bruhn and Wolf, 1979).

Digging deeper, the researchers discovered the distinct social processes among residents of Roseto.. Due to the more homogeneous background of residents, many public facilities where residents could interact or communicate were created, such as churches, sports clubs, a labor union, a newspaper, a park, and athletic field. Not only was the conspicuous display of wealth disdained, but also stronger family values and good behaviors were encouraged. Therefore, Rosetans established a community with both physical and emotional support, and the stronger linkage among inhabitants explained the lower heart attack rate (Bruhn and Wolf, 1979).

Further substantiating this conclusion, in subsequent years a breakdown of traditional family values and community cohesion coincided with an elevated heart attack rate in Roseto (Wolf and Bruhn, 1993). Egolf and associates (1992) examined the mortality difference of myocardial infarction between Roseto and its neighbor, Bangor, from 1935 to 1985. The results suggested the existence of consistent mortality differences during a time when Rosetans exhibited higher social solidarity and homogeneity. The authors concluded that "Roseto was shifting from its initially highly homogeneous social order-made up of three-generation households with strong commitments to religion and to traditional values and practices- to a less cohesive, materialistic, more ‘Americanized’ community in which three-generation households were uncommon and inter-ethnic marriage became the norm” (Egolf, et al., 1992, p.1090), and attributed the diminishing “Roseto effect” to the collapse of social capital and integrity. The longitudinal and systematic investigation of Roseto offered reasonably compelling evidence of the effect of social capital on health. We refer to social capital as the social interaction, norm, mutual trust, and features of social organizations that would bring social resources both tangible and invisible. Other studies also told a similar story. The probability of dying is shown to be negatively correlated with number of social ties, phone calls with relatives and friends, regular attendance of meetings, and memberships of voluntary organizations (Berkman and Syme, 1979; House, et al., 1982; Blazer, 1982; Orth-Gomer and Johnson, 1987).

Kawachi and his colleagues (1997, 1999) broke a new ground in establishing the relationship between individual self-rated health and state-level social capital. They defined social capital as “those features of social organization – such as the extent of interpersonal trust between citizens, norms of reciprocity, and density of civic associations – that facilitate cooperation for mutual benefit” (Kawachi, et al., 1999). Three indicators of social capital which were derived from the General Social Survey included social mistrust, sense of reciprocity, and per capita membership of voluntary associations. Individual self-rated health data were from the Behavioral Risk Factor Surveillance System. Their results suggested that state-level social mistrust was positively correlated to the percent of people in fair or poor health, and the sense of reciprocity and per capita memberships were negatively associated with poor health (Kawachi et al., 1997; Wilkinson et al., 1998). These results both assess the effect of social capital at a higher level of aggregation and echo empirical findings at the individual level.

How Social Capital Affects Health

Prevailing research points toward a significant and apparently causal relationship between social capital and health outcomes. However, how social capital might improve health is still unclear. Though a definitive explanation is needed, several plausible theories are worthy of discussion. First, social capital enhances both tangible and intangible assistance, such as money, food, convalescent care, or health information (Putnam, 2000; Kawachi, et al., 1999; Rogers, 1983). For instance, the diffusion of innovations is found to be more rapid in a community where residents know and trust one another and that are more tightly bounded (Rogers, 1983). Once a new preventive medical service is created, more people will adopt it due to the information diffusion, thereby improving population health.

Second, social capital reinforces healthy behaviors and exerts control over deviant ones. People who are socially isolated tend to have more unhealthy behaviors, like diet disorder, heavy smoking, and excessive alcohol consumption (Kaplan, et al., 1977; Berkman, 1985; Kawachi, et al., 1999). The stronger bonds that social capital represents will discourage the occurrence of unhealthy behaviors because of the potential damage to the group caused by these risk factors. On the other hand, good behaviors, like regular exercise, are encouraged for their possible benefits. Communities with higher social capital may also have greater political influence and the wherewithal to procure and maintain proper access to health care. The degree of mutual trust within a neighborhood determines the extent of social capital (Sampson, et al., 1997; Kawachi, et al., 1999).

Third, social capital can promote health through its psychosocial benefits. In the case of Roseto, flaunting personal wealth was a scorned, while offering help was valued. In this circumstance, social capital can be regarded as a the source of self-esteem, reciprocal regard, and mutual respect. Social ties and networks, for instance, help explain why socially isolated individuals living in a more cohesive society demonstrate fewer symptoms of psychological illness than their counterparts in a less cohesive community (Seeman, et al., 1993; Schoenbach, et al., 1986; Reed, et al., 1983).

Finally, in line with positive psychosocial effects, social capital can serve as a catalyst of better immune systems, which could fight diseases more efficiently and recover sooner. According to current biomedical theory, low social capital and high isolation is a chronically stressful condition (Berkman, 1988) and induces the “fight or flight” response, which has two stages (Memmler, et al., 1996; Thibodeau and Patton, 1997). Initially, the hormones increasing heart rate, blood pressure, and respiration rate; dilating the blood vessels of the heart, lungs, and muscles; stimulating the sweat glands; and suppressing the saliva glands, are released from the adrenal medulla. These endocrine responses to environment could be experienced as illness if the responses happen frequently and detach from certain stimuli (Pike, et al., 1997). At the next stage of “fight or flight,” the adrenal cortex releases hormones that repress pain, inflammation, allergy, and immunity. The substances released in both phases not only reduce physical ability to fight infections and cancers (Glaser, et al., 1999), but also make lymphocytes unable to detect and destroy abnormal or infectious cells. Consequently, social and psychological pressures do harm to human immune systems directly and therefore impair health. Ross and Mirowsky (2001) asserted that neighborhood disorder had an independent and negative effect on health. People residing in a neighborhood with weaker social control, dirty and dangerous streets, more vandalism, and weaker sense of safety, were more likely to have illness, like obesity and high blood pressure (Caspersen et al., 1992; Duncan et al., 1991).

Previous literature is consistent with the assumption that higher social capital leads to better health outcomes. At the individual level, more social activities, tight-knit networks, and high community involvement facilitate personal health via tangible resources and information diffusion. A community with less stress and more reciprocal respect and concern is a good place to live. On one hand, residents have healthier mental conditions due to stronger social bonds. On the other hand, fewer social and psychosocial threats and pressures strengthen immune systems and thus reduce the likelihood of ailing. Even at the state-level, lower mortality is associated with higher social capital, despite the crudeness of measures and limited data availability. Next we turn to a very different correlate of health, ambient environment.

Heat-Related Natural Amenities

The impact of natural environment is an ancient but fundamental cause of death for human beings. Extreme temperatures, drought, and other calamities all have obvious impacts on mortality. Although the development of new technology, nutrition, and public hygiene offsets the threats from nature, natural factors remain as important determinants of mortality. Among them, heat is the most prominent weather-related cause of death in the U.S. (Changnon et al., 1996). With time series analyses of daily death counts and ambient temperatures in both developed and developing countries, it is concluded that the overall mortality rate increases as temperature rises in summer (Hajat et al., 2002; Curriero et al., 2002; Katsouyanni et al., 1993; Kalkstein and Greene, 1997). Similarly, evidence that cold winter temperatures affect mortality is also reported (Donaldson et al., 1998; Huynen et al., 2001).

Davis and his associates (2003) recently created an index that combines air temperature and humidity, and examined its relationship with mortality for 28 metropolitan areas in the U.S. from 1964 to 1998. Although they found a “systematic desensitization of the metropolitan populace to high heat and humidity over time,” which was attributed to the advance of technology and increased availability of air conditioning, the urban mortality rates still responded to temperature and humidity (Davis et al., 2003). Moreover, several northern U.S. cities demonstrated significantly higher mortality on unusual hot and humid days (Bridger et al., 1976; Oechsli and Buechley, 1970). All these studies unanimously agree that temperature and humidity are related to population health in urban areas.

How do the severe heat-related conditions affect human health? Hot and humid weather in summer burdens human cardiovascular systems with excessive physiological cooling demands (Kilbourne, 1997). In a hot environment, body temperature and heart rates will rise to maintain normal physical and brain function and dissipate excessive heat from the body (Nag et al., 1997; Marszalek, 2000). Sweating causes loss of water and electrolytes, jeopardizing human health immediately. On the other hand, low temperature and less sunlight lead to the mortality peaks in winter when epidemiological respiratory diseases spread (e.g., influenza, pneumonia) (Curriero et al., 2002). Also, the respiratory system is particularly sensitive to exposure to the cold. Chronic cold exposure would induce morphological changes such as hypertrophy of airway muscular fascicles and increased muscle layers of terminal arteries and arterioles, causing right heart hypertrophy, right heart hypertrophy, bronchitis, and other chronic obstructive pulmonary diseases (Giesbrecht, 1995). Apparently, heat-related natural amenities play a role in explaining mortality variation across spaces owing to their direct influence on the human body.

Despite the evident causal relationship between temperature and health, several shortcomings are shared by earlier work. First, the temperature-mortality association seems to be significant in metropolitan areas, but the question of whether the effect of heat on mortality still holds elsewhere or stands after controlling for social conditions are unanswered. Admittedly, anthropogenic activities and urbanization correlate with increasing temperature. Nonetheless, we are interested in determining whether heat is a common determinant of mortality or a special feature for urbanized places. Second, though time series analysis was commonly used in earlier research, spatial analysis has not been considered. Weather is a space dependent factor and places proximate to each other will necessarily exhibit more similar climatic conditions. In this nationwide study, a spatial perspective is employed to avoid biased estimates. Third, the elderly are more sensitive to temperature and humidity than other age groups. Previous studies barely took population structure into account. Once the age-sex structure is controlled, whether natural amenities still impact human mortality deserves further investigation. Finally, temperature correlates with other geographical features, such as winter sunlight and water area, but these factors are not emphasized in the literature. Water area could help to adjust weather and avoid extreme temperatures.

Population Composition

Population characteristics have obvious implications for the mortality rates of places. Most obviously, crude death rates are heavily influenced by the age-sex structure of places (Preston et al., 2001). Hence, for the purpose of comparison across groups, standardizing age-sex structure is common. In addition to age-sex structure, having well-educated residents, and high socioeconomic status are all associated with low mortality (Curtiss and Grahn, 1980; Rogers, et al., 2000). Also, controlling for population composition is to isolate the effect of social capital discussed previously. These factors reflect the ability to access preventive health-care, get health insurance, and acknowledge the severity of illness. Explicitly, when people face the threat of health, education, and monetary support could reduce the likelihood of death. A place featured by these factors would demonstrate lower mortality. Conversely, poverty, unemployment, and female-headed family indicate poor standard of living, such as malnutrition, overcrowded or uncomfortable housing, and insufficient resources related to health-care. These disadvantages would hinder the length and quality of life (Link and Phelan, 1995; Phelan et al., 2004).

Race/ethnicity also is an important component of population health. In contrast to non-Hispanic Whites, African Americans are found to have a higher mortality rate (Rogers 1992; Rogers et al., 2000). However, despite the comparable socioeconomic profiles with Blacks, Hispanics -in what has come to be known as the Hispanic paradox- show a lower death rate than do Whites (Markides and Coreil, 1986; Abraido-Lanza, 1999; Palloni and Morenoff, 2001). The impact of race/ethnicity on health holds even if other covariates, like income and education, are considered. Accordingly, it is important to control for the race/ethnicity composition of places.

Deriving from the issue of race/ethnicity, one intriguing concept related to mortality has drawn our attention: residential segregation. Dating back to 1950, much of the literature has investigated how black-white segregation influences various health outcomes (Yankauer, 1950; Massey, et al., 1987; La Veist, 1989, 1993; Potter, 1991; Polednak, 1991, 1993; Hart, et al., 1998, Guest, et al., 1998; Collins and Williams, 1999). We highlight three salient features shared by these studies. First, residential segregation had uniformly negative implications for blacks. Second, the subjects of study were all metropolitan areas or major cities, such as Philadelphia tracts (Massey, et al., 1987), Chicago tracts (Guest, et al., 1998), and New York City (Yankauer, 1950). Third, “black-white” residential segregation had an independent effect on health.

Although this literature has suggested that residential segregation is harmful to human health, there are several shortcomings that need to be addressed. First, earlier studies were confined to urban areas, so a nationwide investigation is needed. Second, most research concerned black-white segregation to the neglect of other race/ethnic groups. Third, although most of the literature on residential segregation has reported the detrimental effects on mortality, homicide rates, and infant mortality, the possibility of a protective effect of segregation is ignored. That is, as some have suggested, residential segregation could result in better mental and physical health for minorities if it means protection from hostility and discrimination (Williams and Harris-Reid, 1999; Acevedo-Garcia and Lochner, 2003). And elsewhere, the literature in education attainment and delinquency has suggested a protective effect of Latino-white residential segregation (Massey & Denton 1993; Jencks and Mayer 1990; Sampson and Raudenbush 1999).

A final population characteristic concerns population mobility , Recent studies report that residential movement is associated with worse health status and that the mortality rates of receiving areas would be adversely affected by the in-migration those with health problems (Verheij, et al., 1998; Larson, et al., 2004). However, the traditional perspective points to positive selection of migrants with respect the health (Boyle et al., 1999; Davey Smith et al., 1998). These contradictory findings encourage us to incorporate migration patterns into our study to better understand this important empirical question.

Rural/Urban Residence

While rural and non-metropolitan populations are characterized by lower average income, a higher proportion of poor people, less health insurance coverage, and less access to preventive medical services (Kitagawa and Hauser, 1973; Norton and McManus, 1989; Hummer, 1993), these disadvantages seem not to affect overall mortality. Rural areas sometimes exhibit higher crude death rates, but (age, sex and race) adjusted rates reveal a rural advantage (Clifford and Brannon, 1985; Clifford et al., 1986; Miller et al., 1987). There are three commonly noted conceptualizations of rurality: ecological, occupational, and sociocultural (Miller and Luloff, 1981; Willits, et al., 1990). The ecological dimension refers to the population scale of a place, and the occupational perspective relates to industrial structure and the economic relationship between residents and the natural environment (i.e. farming, fishing and forestry), and the sociocultural,dimension focuses on prevailing attitudes and culture. In addition, for rural areas, adjacency to a metropolitan area is often important (ERS, 2004). Little is known about whether these dimensions of rurality relate to mortality, something we explore here..

To sum up, we explore spatial variations in mortality in the United States with emphasis on their relationship to social capital, natural amenities, population composition, and rurality. We are among the first to draw together all these dimensions into one analysis and to do so using a spatial perspective rather than merely for urban areas or particular localities at the national level. The next section will describe the measures of these concepts and the data sources.

Measures and Data Sources

In this paper, we analyze the five-year average mortality rates of counties in the contagious U.S. and seek the explanations for mortality differential across space. Here, we describe the data and measures, and detail the statistical techniques in the subsequent section.

Mortality

We use the *Compressed Mortality Files* (CMF), 1989-1998 and 1999-2003, from the National Center for Health Statistics (NCHS) to calculate five-year (1998-2002) mortality rates (NCHS, 2003, 2006) standardized with 2000 U.S. age-sex population structure. Race/ethnicity is not included because CMF only categorizes races into three groups: white, black, and others. We have chosen therefore to keep the rate unstandardized by race, and to control for a race/ethnic variable that includes Hispanics as a separate category.

Social Capital

We draw on recent endeavors by Rupasingha et al. (2006), who have developed a social capital index for U.S. counties that pulls together a number of widely recognized indicators of this concept. They developed a county-based social capital index, which includes the following variables. Based on Putnam's work (1995), the total number of the following establishments per 10,000 people in a county represents the first variable, "association density:" civic organizations, bowling centers, golf clubs, fitness centers, sports organizations, religious organizations, political organizations, labor organizations, business organization, and professional organizations. To constitute a broader view of social capital, Rupasingha and colleagues also incorporated the percentage of voters participating in presidential elections (Alesina and La Ferrara, 2000), the county-level response rate to the decennial census (Knack, 2002), and the number of tax-exempt non-profit organizations. A single social capital index is created by extracting the first principal component out of the four variables (Rupasingha, et al., 2006).

Along with the index, we use three additional measures of social capital: religious adherents, neighborhood safety, and residential stability. *The 2000 Religious Congregations and Membership Study* (RCMS), designed and completed by the Association of Statisticians of American Religious Bodies (ASARB) from the Association of Religion Data Archives (ARDA), provides the rate of religious adherence per 1,000 population in a county. Neighborhood safety is a factor score based on the incidence of a variety of crimes, and is used to reflect the absence of mutual trust and the sense of safety (and thus weaker social capital).[1] To reduce random variation, five-year average rates are calculated for 1998-2002 from the FBI's *Uniform Crime*

[1] The crimes and factor loadings are: embezzlement (.59), forgery/counterfeiting (.82), fraud (.60), and total part I property crimes (.76).

Reports. Since this concept is measured in the inverse, it is expected to have a positive effect of mortality.[2]

Finally, a recent study suggests social capital is higher among homeowners (Glaeser, et al., 2002). Their finding implies a stable neighborhood is good for residents' interaction and facilitates the development of social capital. Hence, we include a residential stability index that is created by combining the percent of county population living at the same address in 1995, the percent of owner-occupied housing units, and the percent of people living in mobile homes, respectively, and then averaging the three z-scores. *The 2000 Census of Population and Housing SF3 Files* enables the calculation of residential stability.

Heat-Related Natural Amenities

The county-level heat-related variables are from McGranahan (1999) and assumed are to be invariant over time. We include four variables: the average July temperature from 1941 to 1970, the mean relative summer humidity (1941-1970), the mean hours of sunlight in the winter (1941-1970), and the natural log of water area percent. As discussed above, both cold and hot environment are reported to have adverse effect on mortality (Kalkstein and Davis, 1989; Fairley, 1990; Kinney and Ozkaynak, 1991). The temperatures in January and July, and winter sunlight are used to represent the natural heat-related surroundings. Water not only could adjust for temperature and avoid extreme weather, but also is a natural amenity in its own right.

Population Composition

As found in the literature, socioeconomic status and other related measures of social class are associated with rurality and have impacts on mortality. Following prior research (Massey and Denton, 1993; Sampson et al., 1999), we begin to describe the social structure of a county with social affluence and concentrated disadvantage. The former comprises the following variables:

[2] Table 1 shows the expected sign for all predictors.

log of per capita income (factor loading is .88), percent of population age 25 with a bachelor degree or over (.93), and percent of population employed in professional, administrative, and managerial positions (.78), and percent of families with incomes over 75,000 (.92) are used in a principal components factor analysis for the purpose of reducing variables and eliminating multi-collinearity. One single factor emerged that explained 78 percent of the variance and hence a single factor score is used to represent the degree of social affluence.

In contrast to social affluence, concentrated disadvantage consists of the subsequent covariates: poverty rate (.89), percent of persons receiving public assistance (.85), unemployment rate (.87), and percent of female-headed households with children (.78) are considered as one indicator of concentrated disadvantage because the principal factor analysis indicates that 72 percent of the variance is shared by these variables. The main purpose of dividing all the socioeconomic variables above into two factor scores is to unveil the opposite effects of affluence and disadvantage on human health.

As pointed out earlier, the prevalence of race/ethnic groups is included as a predictor of mortality. The percent of the county population that is Hispanic, and the percent black are used in the analysis. While both minority groups are known to be deprived relative to whites, prevailing literature suggests that Hispanics have lower mortality than whites (referred to as the Hispanic Paradox), while blacks have higher mortality. We have no reason to think the same results will not hold here.

As noted in the literature, the question of how migration pattern affects mortality rates need to be examined. The in-migration of elders has been found to be positively correlated with health concerns and have impact on mortality even after age-sex composition is controlled (Findley, 1988; Verheij et al., 1998). On the other hand, the movement of youths is related to lower risk of death and better health status. Thus, we extract two variables from *the Migration Data* to constitute a variable of concentrated migration: the percent of in-migrants who are elderly (aged 55 and over), and the percent of out-migrants who are young (aged 20 to 29). The average z-score of these two variables is used in future modeling.

The last population composition indicator is racial and ethnic segregation. As discussed earlier, the segregation issue and its impact on mortality are under-explored. This study follows the work by Lichter and his colleagues (2007) and uses the index of dissimilarity (D) to measure segregation. Four races are identified: non-Hispanic White, non-Hispanic Black, Hispanic, and others. In addition, each county could be decomposed into numerous census tracts. We employ these tracts to assess the county-level segregation, which is weighted by minority population size. Relative to Whites, the dissimilarity indices for other three groups are calculated and the weighted average of the three values expresses the degree of racial segregation of a county. In other words, the black-white, Hispanic-white, and other-white dissimilarity indices are included in our analyses.

Rural/Urban Residence

Several important perspectives of rurality/urbanity are overlooked or measured indirectly. In this study, residence is measured by six variables (described below) derived from the *2000 Census of Population and Housing SF3* to reflect the residential features. Factor analysis indicated that the six variables could be summarized into three dimensions of residence: industrial structure, denseness, and exogenous economic integration (EEI). We calculated the factor scores with regression method and used them as indicators of rural/urban residence.

The first dimension, industrial structure, comprises only one variable: percent of the population employed in farming, forestry, and fishing (factor loading is .934). Although the industrial structure in rural areas has been changed greatly, natural resource extractive industries are still a distinctive feature of many places in rural America. The factor loadings of other variables are all lower than .40, which excludes their involvement into this concept.

The second, denseness, consists of three variables related to total population of a county: population density (total population divided by land area, factor loading is .931), road density (the length of major roads per squared kilometer, loading is .800), and percent of workers commuting by public transportation (factor loading is .947), capture the converse of rurality. In other words, higher scores reflect greater population density, the opposite of sparseness. The third characteristic of rurality is exogenous economic integration (EEI), which indicates the economic influence by neighboring metropolitan areas. Two variables are identified to capture the idea: percent of the workers traveling over an hour to work (factor loading is .866), and percent of the workers working outside county of residence (.821). The more integrated county is expected to have a higher score and would be more economically dependent on the adjacent counties.

Methods

Exploratory Spatial Data Analysis (ESDA)

In this analysis we employ exploratory spatial data analysis (ESDA). The objectives of ESDA are to detect the spatial association in data and assess the fitness for advanced spatial modeling. According to Anselin (2003), ESDA embraces a range of techniques to visualize data, capture spatial autocorrelations, unveil spatial clusters, and offer insight into complex models. At this stage, we use the software, GeoDA®, developed by Anselin (2003) to visualize data and determine both global spatial association (Moran's I) and spatial clusters of mortality. Moran's I (Moran, 1950) is a correlation coefficient weighted by spatial structure for areal data and used to measure the departures from randomness. Usually, the value of Moran's I falls between 1 and -1, but is not bounded in this interval. Positive spatial autocorrelation indicates the nearby areas have similar attributes and conversely, a negative Moran's I could be translated into the heterogeneity of a certain characteristic within an area..

To detect if a spatial clustering of mortality exists, we use the local indicator of spatial association (LISA) introduced by Anselin (1995). LISA consists of a series of statistics that assess the spatial clustering of interest, and answers the question of whether the areas with high (or low) values flock by chance. Four types of spatial clusters are identified: high-high, low-low, high-low, and low-high. In this application, high-high clusters refer to places with high mortality clustering spatially. Obviously the high-high and low-low clusters exhibit the expected spatial clustering whereby areas with similar characteristics tend to be closer to each other. High-low and low-high clusters are considered as spatial outliers.

If both global and local spatial association indicators confirm the existence of spatial association across the county, the usual regression tool OLS - which assumes the errors independent and homoskedastic - fails to account for spatial dependency. To rectify this methodological shortcoming, we intend to use LeSage's Spatial Econometrics Toolbox for MATLAB to implement both spatial and non-spatial modeling (LeSage, 1999).[3]

Explanatory Spatial Modeling

To fully explore the importance of spatial dependency, the following analytic strategies are designed:

First, we begin with a first-order spatial autoregressive (FAR) model:

$$M = \rho W M + \varepsilon \qquad (1)$$

$$\varepsilon \sim N(0, \sigma^2 I),$$

[3] Rupasingha and Goetz (2004) suggested this toolbox is the best available software for spatial modeling with large data set.

where M is a vector containing county-level mortality data and W is a standardized square matrix reflecting the first-order spatial relationships among counties. That is, W is a symmetric matrix where the diagonal elements are all zeros and those non-zero elements represent the adjacent relationship between two counties. The scalar ρ is a spatial autoregressive parameter. If it is significant, the existence of spatial dependency is re-confirmed.

Second, we estimate an OLS model where no spatial relationship is considered and will conduct a multi-collinearity diagnosis, using the variance inflation factor (VIF) for predictors to ensure our estimates are not biased:

$$\begin{aligned} &M = \beta X + \varepsilon \\ &\varepsilon \sim N(0, \sigma^2 I), \end{aligned} \tag{2}$$

where X is a matrix including all independent variables and β represents the parameters to be estimated for the explanatory variables. Next, the spatial autoregressive (SAR) model handles spatial dependence by adding a spatial lag to the OLS model:

$$\begin{aligned} &M = \rho W M + \beta X + \varepsilon \\ &\varepsilon \sim N(0, \sigma^2 I) \end{aligned} \tag{3}$$

The SAR model takes the mortality rate weighted by adjacent neighbors as one explanatory variable and assumes there is no spatial dependency in the error term.

Besides spatial lag, we also consider the spatial error model (SEM), which captures the spatial dependence through the disturbance term:

$$\begin{aligned} &M = \beta X + u \\ &u = \lambda W u + \varepsilon \\ &\varepsilon \sim N(0, \sigma^2 I), \end{aligned} \tag{4}$$

where λ is a scalar spatial error parameter and u is a disturbance term. This disturbance term is used to estimate the effects of unknown factors which are not included in our models.

If both spatial lag and error parameters are found significant in equations 3 and 4, we should employ the general spatial model (SAC). According to LeSage (1999), the SAC model should be used if the error structure from a SAR model still demonstrates spatial dependence. The SAC model should include both lag and error parameters:

$$
\begin{aligned}
&M = \rho WM + \beta X + u \qquad (5)\\
&u = \lambda Wu + \varepsilon\\
&\varepsilon \sim N(0, \sigma^2 I)
\end{aligned}
$$

After estimating these models, we need to know which model is the most preferable. While the value of log-likelihood is a commonly used indicator of model fit,the total number of parameters used in the model is not taken into account. Therefore, we will employ Akaike's (1974) information criterion (AIC) for model selection.

Results

Table 1 shows descriptive statistics for variables used in the analysis along with their expected impact on mortality. It is noteworthy that the effects of Hispanic-White and Other-White dissimilarity indices are not fully explored in the literature. Hence we do not impose any expected direction on them. All the measures of social capital (safety is measured conversely), sunlight in winter, water areas, concentrated affluence, and percent of Latinos are expected to have negative (beneficial) effects on mortality. Conversely, percent black, concentrated elder in-migration, Black-White dissimilarity index, disadvantaged groups, and heat-related variables are expected to have positive (detrimental) effects on mortality.

[Table 1 About Here]

The ESDA results indicate strong spatial association of mortality across the county. The Moran's I is .53 and significant beyond .001 level. Figure 1 is the LISA map where the four spatial clustering types are shown. Apparently, the standardized mortality rates do not distribute evenly in the U.S. The red counties represent the high-high group in which counties with high mortality rates are surrounded by those also having high mortality. The high-high cluster is concentrated on the southeastern region and includes areas of well-known disadvantage. These areas include the Black Belt, Appalachia,and the Mississippi Valley and Delta regions. On the other hand, the low-low groups (dented in blue), low-mortality counties close to one another, sit in the Great Plains, Mid-West region, and along the US/Mexico border. These spatial pattern is consistent with the literature on the Hispanic Paradox and rural/urban mortality differential. Both global and local indicators of spatial dependency confirm our expectation that spatial modeling should be employed to advance the professional knowledge in this regard.

[Figure 1 Insert Here]

Table 2 shows the regression results. First of all, the FAR model yields a strong spatial lag coefficient and, again, confirms that spatial dependence is an important issue that should not be overlooked. Without any other explanatory variables, over 40 percent of variance has been explained by lagged mortality (adjusted R^2 is .43). Next, the OLS model seems to work well with our data and the variance inflation factor (VIF) indicates multicollinearity is not an issue biasing estimates. Generally, a VIF greater than 10 is problematic. Our largest VIF is 2.56, which is even smaller than the stricter cut off value, 4. Menard (2002) noted that many of the diagnostic statistics for multicollinearity (e.g. VIFs) could be obtained by complementing an OLS regression with the same dependent and independent variables. “Because the concern is with the relationship among the independent variables, the functional form of the model for the dependent variable is irrelevant to the estimation of collinearity (Menard 2002, p. 76).” That is, the VIFs from OLS regression are still valid for further spatial models.

At first glance, the OLS model seems to be better than the FAR model and the results look reasonable. However, earlier ESDA results and the spatial lag coefficient in FAR signify that spatial structure should be considered and the SAR model needs to be examined. In comparison to the OLS results, the coefficients in the SAR model are weaker in magnitude. Moreover, the effect of spatial lag decreases from .67 to .04 because of the inclusion of predictors, although it is still significant. Following our analytic strategy, the SEM model also demonstrates that spatial dependency exists in the error terms. In other words, given the results from the SAR model, both spatial lag and error coefficients should be included simultaneously.

[Table 2 Insert Here]

To further confirm the necessity of a more complex model, we follow LeSage's suggestion and impose a Lagrange Multiplier (LM) test on the residual structure of SAR. The LM value of 272.94 does indicate that a general statistical model where both spatial lag and error are integrated is required. The SAC model has the smallest AIC statistics (1956.992) among various models and hence we have confidence that it is the most appropriate model for our data and the following discussion focuses on these estimates.

Both coefficients of spatial lag and error are significant, but the latter has a stronger impact on mortality. That is, we have not been able to include all important variables that account for mortality variation across space. The significant spatial dependence in the mortality (spatial lag) indicates that the standardized mortality in a particular county associates with the mortality rates in surrounding counties. Controlling for other predictors, a 10 percent increase in the standardized death rates in neighboring counties will lead to .1 percent increase of mortality in a particular county. Though the effect is relatively small, it suggests a statistically significant spillover impact between counties in terms of mortality.

Most measures of social capital are related to mortality. As we expected, the social capital index, neighborhood safety, and residential stability all have protective effects. In contrast to the OLS results, the effect of the social capital index reduces greatly and the effect of residential stability remains the strongest. To reiterate, the social capital index consists of the number of various associations, civic engagement, Census response rate, and the number of non-profit organizations. The decreased coefficient echoes Rupasingha et al.'s paper in which an obvious social capital index cluster was shown (Rupasingha et al., 2006). Were it not for spatial modeling, the influence of association and other organization would be overestimated. On the other hand, residential stability seems to be the most dominant factor in social capital. The longer the residents live, the stronger social capital could be established and accordingly benefits the inhabitants. Moreover, high crime rates hinder the development of mutual trust, assistance, and reciprocity among people and turn out to adversely affect health.

One of the measures of social capital exhibits an unexpected impact. The religious adherent rate is positively related to mortality, which is against earlier findings. We attribute this result to the following reasons. The religious adherent rate is calculated by dividing the total religion statuses by total population in a county. The respondents could report more than one religious belief and hence this variable may mix the effects of various religions. In addition, previous studies usually used the frequency of attending church as the indicator of religion effect. Religious adherents may not participate in related activities, and hence social capital could not exert its influence on mortality.

As expected, the mean temperature and humidity in the summer have significant impacts on mortality. The mean sunlight hours has explained mortality despite its weaker effect. The effects of natural amenities are relatively stable across models. Hot and humid weather in summer relates to higher mortality rates. Recall the high-high cluster residing at the southeastern U.S., those counties are featured by high temperature and humidity in summer. The results indicate that 10 degree increase in mean July temperature results in one additional death per 2,000 residents. While we cannot determine the physiological links between temperature and mortality, the literature suggests that a hot environment stresses the cardiovascular system and is associated with electrolytic imbalance. The effect of water areas decreases from OLS to SAC model, but remains significant. In OLS model, its influence is as important as temperature's, but deflates almost 50 percent after spatial structure is included.

With regard to race/ethnic composition, the pattern of results is in the expected direction, if not necessarily significant. Notably, and consistent with the Hispanic Paradox, percent Hispanic is associated with lower mortality, other things equal. While the percent Black is positive (detrimental), the effect does not achieve significance.

Interestingly, concentrated immigration does *not* have a significant impact until spatial error is accounted for. This indicates that there must be certain unknown factors embedded in the spatial error structure that act to suppress the influence of immigration. After accounting for this statistically, the impact of immigration doubles in magnitude and becomes significant. The results suggest that net of other factors, high elderly in-migration is associated with high mortality. One score increase in concentrated in-migration will lead to five more death per 100,000 population.

The fundamental social conditions of a place, social affluence and concentrated disadvantage, have strong effects that are consistent with expectation and with arguments in the literature (Link and Phelan 1995). Among the coefficients for variables that increase mortality, concentrated disadvantage has the great impact (.53). Similarly, social affluence has among the strongest negative (beneficial) effects (-.32).

The results for measures of residential segregation tell different stories. Like earlier findings, Black-White segregation increases mortality at the county level in the U.S., and the effects diminish only modestly when correcting for spatial error. With respect to Hispanic-White and Other-White residential segregation, the OLS and SAR results indicate a negative (beneficial) effect of such segregation, however these results become insignificant and are thus cast into doubt when correcting for spatial error. The question of whether residential segregation affects human health and what accounts for this connection requires further investigation.

The rural versus urban character of counties also plays a role in explaining mortality. First, the most common definitions of rurality use an ecological approach, and assume that rural places are those with low population density. However, our results suggest no relation between density and mortality. On the other hand, with rurality measured as industrial structure (i.e., the percent of the labor force in farming, forestry, and fishing), our results indicate a beneficial impact of rurality on mortality, a finding that is consistent with other research (McLaughlin et al., 2007). Just what it is about places with greater employment in natural resource extraction that apparently improves health is unclear, though being out of doors and getting regular physical exercise are tempting possibilities. A third residential indictor is EEI, defined here as the percent of commuting over one hour and the percent of working outside the county of residence. We find that EEI bears a negative impact on mortality. The farther commuting distance implies higher risk of unintentional injuries (traffic accidents in particular), which is the major cause of deaths in the U.S. (NCHS, 2006). Also, a high EEI score indicates the lack of economic opportunities in a county. Fewer local economic opportunities would lead to less investment in health care services and health-related facilities. Therefore, these deficits contribute to higher mortality rates, especially when emergencies occur.

Discussion and Implications

We have sought to advance the literature on population health by incorporating social and environmental place characteristics into an analysis of mortality. And we have employed advanced techniques in spatial data analysis that corrected for statistical weaknesses in previously used methods that would have led to biased results.

Our key finding concerns the effect of social capital. Among various social capital measures, residential stability has the strongest effect on mortality. When a neighborhood is stable and home ownership rates are high, residents have more opportunities to know each other, devote themselves to community development, organize voluntary activities, cultivate common interests, and so forth. Accordingly, the degree of mutual trust, reciprocity, and sense of safety in a neighborhood will rise and conduce to higher civil engagement, and a stronger collective conscience. In turn, these may be related to more tangible resource support, better mental health, stronger immune systems and other proximate determinants of physical health and mortality. Whether it is these causal mechanisms that are at play remains unknown, but a key conclusion of our analysis is that net of other factors, places with great social capital do have lower mortality.

We also found that severe weather, heat-related conditions in particular, correlates to higher mortality. Living in a hot and humid environment is detrimental to health, presumably in part because of cardiovascular problems. In a cold environment, respiratory system is particularly sensitive. Our findings suggest that, net of other correlates, high temperature and humidity in summer played a lager role in explaining mortality variation across space, though sunlight time in winter and water areas would slightly offset the detrimental effects.

Several policy implications could draw on the importance of social capital and ambient environment. To improve human health, building up solid social capital at the community level may be ameliorative. For example, providing affordable housing – either through subsidies or low-interest loans – would stimulate home ownership. Moreover, funding a wide range of community activities encourages residents to participate in public affairs and produces more opportunities for community solidarity to develop. Of course, promoting and maintaining the sense of neighborhood safety will enhance mutual trust and increase reciprocal help. These efforts can be used to build social capital. While the positive economic implications of ths are increasingly recognized by community development professional, the positive health effects we suggest here are less widely appreciated.

Policy makers cannot change the weather, so far as we know. However we also would advocate policies to protect vulnerable populations from extremes in temperature. Weatherization programs and energy assistance are obvious ways to help families protect themselves and their families. But educational programs also might be increased to promote greater awareness of the negative health implications of unhealthy local environments, and simple steps families and individuals might take to protect themselves.

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Figure 1. Spatial Cluster of Mortality in the U.S. Counties.

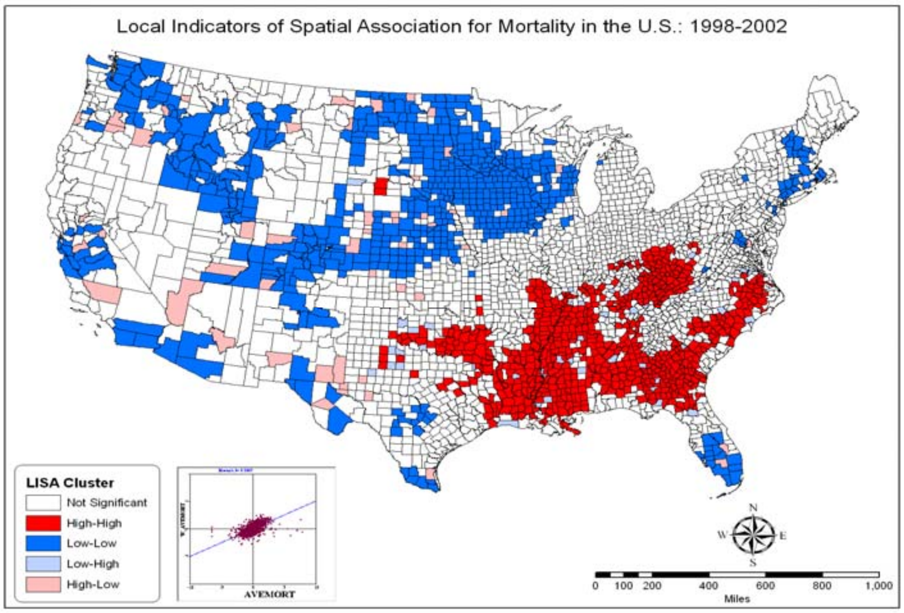

Table 1. Descriptive Statistics and Expected Effect of Variables (N=3072)

Variables	Expected Effect	Minimum	Maximum	Mean	Std. Deviation
Mortality (per 1,000)	N.A.	0.00	19.78	8.89	1.36
Population Composition					
% Black	+	0.00	86.08	8.54	14.35
% Hispanic	-	0.00	98.10	6.18	12.18
Concentrated In-migration	+	-3.35	4.35	0.01	0.90
B-W Dissimilarity Index	+	0.00	1.00	0.67	0.17
H-W Dissimilarity Index	?	0.00	0.96	0.52	0.18
O-W Dissimilarity Index	?	0.00	1.00	0.41	0.17
Affluence	-	-2.43	5.75	-0.01	0.99
Disadvantage	+	-2.54	9.06	-0.01	1.00
Social Capital					
Social Capital Index	-	-4.06	7.66	-0.01	1.27
Neighborhood Safety	+	-1.37	9.20	-0.03	0.93
Religious Adherent	-	0.00	1439.02	629.00	211.18
Residential Stability	-	-5.67	2.76	0.03	0.97
Rurality					
Denseness	-	-0.60	28.70	-0.02	0.98
Exogenous Economic Integration	+	-1.92	4.54	0.00	1.00
Industrial	-	-2.56	8.65	0.02	0.98
Natural Amenities					
January Sunlight Hours	-	48.00	266.00	151.57	33.30
July Temperature	+	55.50	93.70	75.86	5.38
July Humidity	+	14.00	80.00	55.97	14.62
Log of Water Area	-	0.00	8.92	4.55	1.81

Table 2. Non-spatial and Spatial Modeling for Standardized Mortality

Variables	VIF	FAR Model	OLS Model	SAR Model	SEM Model	SAC Model
Constant	--	--	5.091***	4.956***	4.956***	4.944***
Population Composition						
% Black	2.418	--	.003	.003	.002	.002
% Hispanic	1.945	--	-.025***	-.023***	-.022***	-.022***
Concentrated In-migration	1.380	--	.028	.025	.054*	.053*
B-W Dissimilarity Index	1.473	--	.435***	.398***	.313**	.303**
H-W Dissimilarity Index	1.595	--	-.219*	-.227*	-.186	-.192
O-W Dissimilarity Index	1.404	--	-.280*	-.300**	-.094	-.104
Affluence	2.447	--	-.276***	-.278***	-.320***	-.321***
Disadvantage	1.388	--	.519***	.512***	.529***	.529***
Social Capital						
Social Capital Index	1.738	--	-.118***	-.108***	-.069***	-.067***
Neighborhood Safety	1.616	--	.113***	.107***	.103***	.102***
Religious Adherent	2.270	--	.001***	.001***	.001***	.001***
Residential Stability	2.562	--	-.353***	-.344***	-.372***	-.370***
Rurality						
Denseness	1.439	--	-.007	-.001	.000	.003
Exogenous Economic Integration	1.881	--	.119***	.123***	.092***	.094***
Industrial	2.246	--	-.159***	-.162***	-.140***	-.141***
Natural Amenities						
January Sunlight Hours	1.830	--	-.003***	-.003***	-.003***	-.003***
July Temperature	2.068	--	.049***	.047***	.047***	.046***
July Humidity	1.879	--	.010***	.010***	.012***	.012***
Water Area	1.395	--	-.050***	-.043***	-.029**	-.027*
Spatial Parameter						
Rho	--	.670***	--	.037***	--	.010**
Lambda	--	--	--	--	.379***	.374***
Adjusted R-Square		.429	.602	.601	.639	.639
Log-likelihood		-12658.104	-3887.640	-2808.418	-2717.115	-957.496
AIC		25318.208	7813.280	5656.836	5474.230	1956.992

* p <.05; ** p < .01; *** p < .001