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U.S. Population Change: The Roles of Amenities and Transportation

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Studying the spatial distribution and redistribution of population has long been a major concern of demography, because population changes can reflect deep and massive social changes. For decades, the major population change was the moving of people from rural to urban regions. However, with the advancement of transportation and information technology, many new regions have become more attractive to people, such as small and new metropolitan, nonmetropolitan, suburban, and rural areas. Traditional migration and population redistribution studies emphasize economic and social factors. Relatively little attention is paid to how natural amenities and transportation affect changes of population size and net migration.

Using data from various sources, such as the U.S. Census Bureau, National Land Cover Database, United States Department of Agriculture, National Transportation Atlas Database, and Air Carrier Activity Information System, this dissertation examines the roles of natural amenities and transportation in explaining population change and the net migration rate from 2000 to 2010 in the United States at the county level. Spatial regression models are used to treat spatial dependence and investigate relationships between variables and their neighboring values.

Results show that population growth is higher in counties with higher natural-amenity-ranking values, regardless of whether those counties are in metropolitan or nonmetropolitan areas. However, natural-amenity-ranking values only positively affect net migration rates in nonmetropolitan counties. Forest coverage only positively affects population change and the net migration rate in nonmetropolitan counties. Land developability is negatively associated with population change in nonmetropolitan counties. Man-made amenities are negatively associated with population change and the net migration rate in both metropolitan and nonmetropolitan counties. Population growth and the net migration rate are higher in counties characterized by greater airport accessibility. Highway density is positively associated with population change in nonmetropolitan counties only. This dissertation illustrates the importance of natural amenities, forest coverage, land developability, highway density, and airport accessibility as correlates of population growth in America, especially in nonmetropolitan counties.

DEDICATION

This dissertation is dedicated to my baby boy, the best thing I have in life, who has given me love and joy in my worst moments; to my husband, the man who deals with me 24/7, and still loves me; lastly, to my always supportive parents.

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CHAPTER I

INTRODUCTION

Studying the spatial distribution and redistribution of the population has long been a major concern of demography, because population changes can reflect deep and massive social changes. Social changes in the U.S. such as war, waves of immigration, construction of interstate highways, industrialization and urbanization, economic depression, the decline of the Rust Belt, and the rise of Silicon Valley, have transformed the location and growth of the population (Beeson et al. 2001). For decades, the major population change was the moving of people from rural to urban regions. Before the 1970s, metropolitan counties in the United States experienced population growth; however, with advances in transportation and information technology, many regions have emerged as newly attractive, including small and new metropolitan, nonmetropolitan, suburban, and rural areas. Recently, examining the dynamics of how people move across these regions has become a central focus of researchers' inquiry. For instance, many researchers found unpredictable directions of rural population growth and migration in the 1970s and 1990s (Johnson 1999; Johnson and Beale 1994, 2003; Frey 1988; Fuguitt 1985). U.S. Census data have also demonstrated that nonmetropolitan territory experienced substantial net in-migration between 1975 to 1980 and 1995 to 2000 (see Table 1.1). Such new and massive changes in residence within the U.S. are the result of various internal migration patterns of populations that differ in terms of age, race, gender, and social status.

Table 1.1 Migrations between Nonmetropolitan Territory and Metropolitan Areas

Flow	1975 to 1980	1985 to 1990	1995 to 2000
Metropolitan to Nonmetropolitan	6,618,149	6,020,438	6,166,532
Nonmetropolitan to Metropolitan	5,622,077	5,969,024	5,656,044
Net Migration to Nonmetropolitan Territory	996,072	51,414	510,488

Note: Metropolitan areas were defined by the Office of Management and Budget as of June 30, 1999.
Source: Migration and Geographic Mobility in Metropolitan and Nonmetropolitan America: 1995 to 2000, Census 2000 Special Reports.

Although many theoretical perspectives have been developed to understand internal migration, Lee's (1966) push-pull theory remains the most widely used model for explaining the motivation behind migration. Every migration, domestic or international, involves push and pull factors between origin and destination. Push factors include undesirable conditions that lead people to consider leaving, such as unemployment, economic decline, and lack of public services. In contrast, pull factors include desirable conditions that attract people to new areas such as job opportunities, better living conditions, and local welfare policies. However, a simple calculation of the push and pull factors does not necessarily determine the act of migration. Intervening obstacles constitute a third set of factors that influence the migration decision. These obstacles include physical distance and barriers, cost of transportation, and strength of social ties in origin or destination, among others.

Previous research has emphasized the economic and social factors motivating population relocation. For example, wage differences and employment conditions induce individuals to move for income maximization (Todaro 1989). Families and households collectively seek to maximize expected income and minimize risks to maintain or enhance their economic well-being (Stark 1984). Social capital (i.e., the resources of trust, information, and assistance that individuals obtain through social ties) influences an individual's migration and facilitates the spread of migrant networks. Such networks help reduce the costs and risks of subsequent migration (Massey 1990). Traditional migration and population redistribution studies have emphasized all these economic and social factors. However, relatively little attention has been paid to how natural amenities and transportation affect changes in population size and net migration.

More empirical studies are needed to investigate the impacts and consequences of individuals' preferences for natural amenities on population change. Chen et al. (2013) attempted to develop a theoretical model of such amenity-led migration to examine the conditions under which natural amenity-led migration can cause population concentration and dispersion. They argued that the relationship between population growth and natural amenities in rural areas is conditioned by built capital investment, the sensitivity of the ecosystem, and the substitutability of the ecosystem and built capital. Once the increasing population concentration in amenities-rich areas degrades the ecosystem, the population in the concentrated region will become dispersed regardless of the input of capital investment in the region. Accordingly, in the long run, amenity-led migration might foster population dispersion in rural amenity areas. Similarly, Rickman and Rickman (2011) found that population growth in the top high-amenity areas is converging, a phenomenon related to the capitalization of amenities into land prices and the deterioration in quality of life resulting from population pressures.

Amenities are qualities that make a region an attractive place to live and work (Power 1988), including the natural landscape features, climate, social environment (e.g., schools, public services), cultural environment (e.g., community integrity, cultural institutions), and human-built environment (e.g., homes, business infrastructure) (Power 2005). Moss (2006: 19) defined amenity-driven population change as "amenity migration" that results from "people moving into mountains to reside year round or intermittently, principally because of their actual and perceived greater environmental quality and cultural differentiation." Since amenities include such broad attributes, most studies have chosen one or two characteristics to define amenities. For example, McGranahan (1999) focused on climatic conditions such as temperature, sunlight, and humidity; English et al. (2000) emphasized the availability of natural resources such as forests, mountains, and lakes; and Beale and Johnson (1998) addressed the importance of opportunities for recreational activity.

A growing body of research has indicated that amenities have significant effects on regional population growth and development. For example, Ullman (1954), by examining the greatest changes in the distribution of the U.S. population between 1940 and 1950, argued that large scale suburban flight is driven by amenities. He argued that "for the first time in the world's history, pleasant living conditions – amenities – instead of more narrowly defined economic advantages are becoming the sparks that generate significant population increase, particularly in the United States" (Ullman 1954:119). Ullman suggested that amenity factors should be considered in predicting regional population and development. In a nonmetropolitan population study, Goe and Green (2005) found that nonmetropolitan areas with high levels of multiple types of amenities promoted locality well-being. In their study, locality well-being was measured by total employment, aggregate income, and total population. Natural amenities are also positively related to population, employment, and per capita income growth (Deller et al. 2001; Green 2001). Similarly, Gottlieb's (1994) study showed that amenities do not directly induce employment growth. Instead, they attract migrants, who create new demand for goods and services, thereby bringing new jobs. In rural areas, Rudzitis (1999) investigated the motivation of people who migrate to high-amenity counties and found that both physical and social environment amenities are important reasons why people move to rural areas. Only 30 percent of the respondents in his study cited job-related reasons as their motivation for moving.

Natural amenities are potentially important because economic and technological developments have transitioned the U.S. into a post-industrial stage. In this stage, a fundamental shift in values is reflected in the general desire for a high quality of life, which is mostly measured by the living environment, leisure, recreation, and the like. As Rudzitis (1999) found in his study of high amenity western counties, migration to the rural West was motivated by features of the social and physical environments, such as the pace of life, outdoor recreation, landscape, scenery, and other attributes of the natural environment. The demand and concern for natural amenities and environmental quality are thus predicted to increase in a post-industrial society. Such new demand and concern will in turn have a significant impact on population distribution and redistribution across amenity-rich areas in two ways. On one hand, people's strong preferences for natural amenities can generate amenity-led migration that spurs population growth in amenity-rich rural areas (McGranahan 1999; Deller et al. 2001; Kim et al. 2005) and nonmetropolitan recreation counties (Johnson and Beale 2003). On the other hand, the continued population congestion in high-amenity areas can reduce growth in the long run.

Although the attractiveness of amenities is becoming an important pull factor affecting migration decisions, access to amenities (e.g., physical distance, cost of transportation) is an essential condition for migration to actually occur. The development of a transportation infrastructure can promote accessibility. Ullman (1954) noted that the automobile makes amenity-seeking suburban flight possible. “The greatly increased mobility of the American people, because of universal auto ownership and good roads, makes transcontinental moves reasonably commonplace and permits Americans to discover amenable regions during longer vacations” (Ullman 1954:128). Numerous studies have provided useful new insights into the relationship between transportation and population change. For example, in a case study of Wisconsin, researchers found that highway expansion had a strong causal effect on population change (Chi et al. 2006, Voss and Chi 2006). Humphrey and Krannich (1980) used the key variables of distance between places and distance to nearest highway interchanges to examine the relationship between mobilization of local resources and population change in Pennsylvania’s small urban areas. These investigators found that places with high promotion of local commercial and industrial development experienced lower population growth.

To date, most researchers study amenity-led and transportation-led population change separately. However, some scholars have recently examined both types of population change. For example, Beeson et al. (2001) examined the effects of natural characteristics and produced characteristics on U.S. population change at the county level from 1840 to 1990. Natural characteristics are described as access to natural transportation features (coastlines and rivers), climate, and mineral resources. Produced characteristics include industry mix, access to build transportation networks, and educational infrastructure. Their investigation found that both natural and produced characteristics explain population variation and growth. The central purpose of this dissertation is to use more recent data and more detailed amenities and transportation variables to better understand the roles of natural amenities and transportation in explaining population change in the United States from 2000 to 2010.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter first describes and explains recent patterns of population distribution in the U.S. It next focuses on theories and empirical studies of the influence of natural amenities on population change. A review of research on the development of transportation and population change then follows, and the final section discusses the spatial analysis perspective in sociology.

2.1 Recent Population Redistribution Patterns in the U.S.

The most common characteristic of urbanization is rural to urban population movement. In most developing countries, urbanization is still in process and the urban population continues to grow. However, most developed countries have already completed the urbanization stage. They have entered a post-industrial stage of societal development which differs from the urbanization stage. For example, heavy manufacturing and industry shift to developing countries, and high technology industries become more prevalent in urbanized areas. Moreover, the demand for professional and service workers increases, while traditional manufacturing job opportunities shrink dramatically. Zelinsky (1971) argued that the distinctive feature of mobility in a society reaching the highest level of development is the emergence of noneconomic motivations for migration. Zelinsky believed that, in the most advanced and affluent societies, "almost constant change and movement have truly become a way of life." Furthermore, he argued that in these societies, people "are in almost nonstop daily, weekly, or seasonal oscillation across and within spatial and social zones, indulge in a vast range of irregular temporary excursions, and frequently migrate, in the sense of formal change of residence" (Zelinsky 1971:247).

When the United States entered the post-industrial stage, the rural to urban population distribution pattern changed (Table 2.1). A trend in population change variously called the "nonmetropolitan turnaround," "rural renaissance," or "counter-urbanization" was identified in the 1970s (Johnson et al. 2005; Frey 1990a; Long 1981; Fuguitt 1985). During this time, the U.S. experienced a reversal of population redistribution which included: a higher growth rate for the nonmetropolitan population than for the metropolitan population, a population gain in small and peripheral metropolitan areas, and accelerated growth in the less industrialized South and West coastal regions (especially in those areas with recreation and retirement industries). However, the 1980s saw renewed population growth in metropolitan areas. Some metropolitan areas returned to traditional urbanization patterns (Frey and Speare 1992; Johnson and Beale 1994). In the 1990s, a rural rebound was again observed: More people moved from urban to rural areas and fewer people left rural areas. Johnson (1999) found that this rural rebound occurred in nearly every part of the U.S. regardless of people's age and county variations.

Table 2.1 Historical U.S. Population Distribution Patterns (Long and DeAre 1988; Frey and Speare 1992; Johnson 1999)

Before World War I	Metropolitan population was growing.
1920s-1950s	Metropolitan population accelerated.
1960s	Metropolitan population reached its peak.
1970s	Nonmetropolitan turnaround occurred.
1980s	A demographic recovery occurred in the metropolitan northeast.
1990s	A rural rebound occurred.

Three theoretical perspectives are commonly used to explain the counter-urbanization phenomenon in the U.S. The first is the period explanation, which views population decline as temporary. It argues that the 1970s metropolitan decline was caused by unique economic and demographic circumstances such as the oil crisis and economic recession. Due to the recession, manufacturing industries in large metropolitan areas declined, which resulted in the loss of jobs. In addition, large baby boom cohorts entered the labor market, which intensified the imbalance of labor supply and demand in metropolitan areas. In response to these developments, people moved from the oversaturated labor markets of metropolitan areas to look for socioeconomic opportunities in nonmetropolitan areas and in new and small metropolitan areas (Frey and Speare 1992; Frey 1993).

The second theoretical perspective is the deconcentration explanation, which attributes population decline in metropolitan areas to the development of technology and the economy. The innovations in transportation and communication technology loosen the constrains of physical distance. Most industries shift to high-technology and telecommunications-based work systems. Thus, work locations can be more flexible and less constrained by the proximity of producers and consumers. Social and economic conditions improve, allowing people to pursue a higher quality of life, for example, by moving to low density areas and enjoying more outdoor recreation. This perspective assumes that the counter-urbanization trend is a long-term phenomenon. Large metropolitan areas will experience population decline while smaller metropolitan and nonmetropolitan areas will experience population growth (Frey and Speare 1992; Frey 1990a, 1993).

The third theoretical perspective, the regional restructuring explanation, puts the American economy into the broad context of a global and international economic system. Population decline in larger metropolitan areas is seen as an inevitable consequence of America's industrial restructuring. The global economy stimulates international business and cooperation that allow all material and human resources to be traded worldwide. Multinational corporations play an important role in creating and distributing these resources. Because of cheaper labor, abundant natural resources, and local environmental protection concerns, many manufacturers shift from developed countries or core areas to developing countries or peripheral areas. With the help of advanced technology, heavy industry also becomes less labor intensive (Long and DeAre 1988; Frey and Speare 1992; Frey 1990a, 1993).

The regional restructuring perspective argues that all large metropolitan areas[1] experience such economic transformation. With the demand for manufacturing and heavy industry labor constantly decreasing, this transformation inevitably creates a surplus population searching for new employment opportunities. However, this perspective does not assume that the loss of population in large metropolitan areas is a long-term process. Rather, it predicts a return to population gain in these areas as long as the large metropolitan areas can successfully shift their traditional economic structure to a stable system with knowledge-based industries and high technology research and development. Once these large metropolitan areas complete this transformation, they will win "more dominant 'command-and-control' positions in the metropolitan hierarchy" (Frey 1988:597).

2.1.1 Natural Amenities and Population Change

2.1.1.1 Theoretical Background: Population Growth, Human Ecology, Natural Resources, and Environmental Sociology

Although classical sociological theorists did not develop comprehensive arguments about the relationship between environment and population, they still provided inspiring perspectives for understanding the interaction between social and environmental systems. For example, Karl Marx believed that humans can utilize environmental resources and have the ability to control the material world. He emphasized the material side of society—productive forces and labor. In contrast, Emile Durkheim focused more

[1] According to Frey (1993), large metropolitan areas include the 39 Consolidated Metropolitan Statistical Areas and Metropolitan Statistical Areas with 1990 populations exceeding 1 million.

on human consciousness. He believed that human activities are constructed by culture and social meanings that in turn affect the interactions of humans with the environment (Barbosa 2009). According to Catton and Dunlap (1978), all classical sociological theories view humans as a species independent of the environment; thus, humans can presumably use natural resources without considering the consequences of their activities for the environment. Catton and Dunlap (1978) called this perspective the "human exceptionalism paradigm (HEP)." This paradigm only looks at one direction, how humans control the environment, and ignores another direction, how the environment affects humans. In response to the limits of HEP, Catton and Dunlap (1978) introduced the "new ecological paradigm (NEP)," which realizes that humans are dependent on the environment and that nature cannot provide infinite resources. "The NEP's recognition that the welfare of modern societies, even with their complex forms of social organization and sophisticated technologies, is intricately linked to the health of the ecosystems on which they depend for their existence represents a major departure from the HEP" (Dunlap 2002: 336). Only when humans understand and respect the ecological system can development of the society be sustainable. Sociologists adopting NEP developed the sub-field of environmental sociology to investigate "how social systems interact with ecosystems" (Gould and Lewis 2009:2)

Many social scientists have attempted to understand the relationship between population change and the environment, developing different theoretical perspectives. The earliest is Malthusianism, which originated from social theorist Thomas Malthus (1798). His main idea was that the increasing rate of food production cannot catch up with the increasing rate of human reproduction because the population grows exponentially while food increases arithmetically. Malthus believed that reproduction decisions are driven by human nature and that men and women tend to have as many children as naturally possible. When the population reaches the limit of food production, disequilibrium (in the form of famine and war) between population and food will arise, which Malthus argued is the major cause of most social problems such as poverty. According to Malthus' view, two checks on population growth can restore and maintain equilibrium, positive checks and preventive checks. Positive checks are actions that increase mortality, such as famine and war. Preventive checks are actions that decrease the fertility rate, such as late marriage and birth control. Malthus saw preventive checks, especially later marriage (he opposed birth control within marriage), as the desirable way to keep the population on a level with the means of sustenance. Malthus' perspective over-emphasizes what he called "the general laws of nature"; it does not take social and economic progress into consideration and thus underestimates the production of food over the long term.

With technological innovation, the production of food was dramatically increased after the Industrial Revolution. Therefore, it was understood that population growth in the long run was not limited by a shortage of food and that other factors are related to population problems. In contrast to Malthus, Marx and Engels believed that humans can control nature. They acknowledged the power of humans to change the material world, asserting that human's reproduction decisions are related to modes of production rather than to their inability to control their sex drive. Human beings can consciously produce sustenance to guarantee their life and utilize the environment to realize individual pursuits. Human reproduction behaviors reflect the mode of production in a society. For example, in a bourgeois family, the reproduction decision is determined by the interest of legal heirs in the family business. In a proletariat family, the goal of reproduction is to increase the number of wage laborers and ensure the family's survival (Wiltgen 1981). In short, Malthusians omit very essential factors from their consideration. Marxists argue that population problems such as famine and poverty are not necessarily the result of too many people and too few resources but instead are the result of how social systems unequally distribute social, economic, and political power (Bates 2009).

Examining Marx's theory of metabolic rift, Foster (1999) concluded that capitalism's preference for large-scale industry and large-scale agriculture alienates humans from nature. Humans are supposed to interact harmonically with the environment; "Marx employed the concept of metabolic rift to capture the material estrangement of human beings in capitalist society from the natural conditions of their existence" (Foster 1999: 383). Focusing more on power, inequality, and the distribution of resources, Marxists advocate policy change and global equality and do not blame complex social problems exclusively on overpopulation, that is, the point at which population reaches or exceeds the limit of food production possibilities.

Some adjustments were made by neo-Malthusians to respond to the critiques and new changes in the modern period. Neo-Malthusians such as Ehrlich (1968) proposed an alternative explanation for the relationship between population and environment in the *The Population Bomb* and *The Population Explosion* (Ehrlich and Ehrlich 1990). Ehrlich argued that environmental degradation is affected by three variables: population growth, affluence, and environmentally harmful technologies. These three variables interact to influence the environment. Absolute population size is no longer the sole determinant of environmental degradation. Ehrlich recognized the importance of humans' adaptability and creativity, taking into consideration society's choices of technology, consumption, and waste. Although changes in life style and consumption, such as eating vegetation, can temporarily relieve the tension between environment and population, Ehrlich believed that the increasing use of harmful technologies and the increasing population growth rate can degrade the environment and reduce the earth's carrying capacity for humans in the long run. Nevertheless, neo-Malthusians still believe that the population will grow beyond the production capacity of food and eventually will deplete the supply of resources. As a result, the Malthusians predict that famine, disease, and war will be inevitable and widespread (Bates 2009).

Unlike the neo-Malthusians' perspective, the cornucopian perspective asserts that a growing population will not cause severe crises because a larger population will in the long run bring more geniuses and workers to solve all problems. Developing new techniques to cope with shortages of food or other resources, humans have the ability to find substitutes, and in this sense, natural resources are limited only by human ingenuity. Simon (1981) argued that population growth will increase economic performance in the long run. However, in the short run, population growth may yield negative impacts, especially in developing countries. Simon believed that humans who are innovatively skilled, spirited, and hopeful are the ultimate resource. Environmental degradation and limitations of the earth's carrying capacity are not caused by overpopulation, this view suggests, but by a lack of scientific and technological knowledge. More people means more knowledge and creativity. Economically free people can create more resources and wealth and solve the problems that population growth may cause. Government should not interfere with population growth (Hartman 1995).

Simon's cornucopian perspective emphasizes the ability of human beings but, according to critics, it ignores and misunderstands the basic facts "that species have many different types of dependence; that diverse ecosystems are generally more stable than homogeneous ones; that ecosystems do in fact have finite (but changing) carrying capacities; that the earth's vast and interrelated ecosystems, about which we know very little, do in fact produce essential services for humans, and that humans possess the power to overexploit ecosystems, thereby reducing carrying capacity for many forms of life, including humans" (Swaney 1991: 501-502).

In sum, the cornucopian perspective overemphasizes human inventiveness as the solution to mankind's problems, while the neo-Malthusian perspective overemphasizes the finite nature of resources. Both perspectives overlook humans' adaptation, the evolution of scientific knowledge, and the dynamic interactions between humans and the environment (Swaney 1991).

In urban sociology, Park and his colleagues (Park et al. 1925), Burgess (1925), Thrasher (1927), Wirth (1928), and Frazier (1932), known as the Chicago School scholars, developed the perspective of human ecology to study different ethnic groups and social classes in cities. For example, they observed that immigrant communities such as the Jewish ghetto are concentrated in a specific spatial area, the "zone in transition" characterized by residential deterioration. The Chicago School scholars focused on many of the social and spatial changes resulting from explosive growth and spatial and occupational distributions of the city population.

Human ecology (Hawley 1950), a sociological perspective derived partly from biological ecology, analyzes the interdependencies and functions between a population and its environment. Human ecology can answer questions like: How does the population form, maintain, and break an equilibrium ecosystem? How do populations collectively adapt to the biophysical (e.g., climate, plant, animal life) and ecumenical (e.g., culture and socioeconomic features) environments? Human ecologists attempt to understand the impacts of humans on the built and natural environments and, conversely, the impact of these environments on the social systems of humans. The relationships of a population to its environment have temporal and spatial dimensions. Population's spatial mobility can reflect social mobility in a society. For instance, Massey (1985, 1996) argued that social mobility is associated with spatial mobility. He believed that "in the twenty-first century the advantages and disadvantages of one's class position will be compounded and reinforced through ecological mechanisms made possible by the geographic concentration of affluence and poverty, creating a deeply divided and increasingly violent social world" (Massey 1996:395).

Human ecologists pay attention to diversity in ethnicity, culture, and social stratification, recognizing that population change is closely linked to spatial variations in landscape and resource conditions. For example, Duncan (1961) suggested a simplified model for analyzing human ecosystem processes, defining the human ecosystem in terms of interactions among four variables: population, organization, environment, and technology (P.O.E.T.). He used the case study of air pollution in Los Angeles to illustrate the application of the POET framework to sociological studies.

Natural resource sociology, developed by early rural sociologists, also realized the importance of studying the physical environment (Frey 1990b). Influenced by human ecology, geography, and regional economics, natural resource sociology emphasizes society-environment interaction, especially how the use and development of natural resources reshape rural regions with respect to social organizations, interactions, and changes in natural resource-dependent communities (Field et al. 2002). Because natural resources usually have spatial and temporal dimensions, natural resource sociologists typically apply spatial analytical tools such as geographic information systems in their studies (Luloff and Befort 1989). For instance, Krannich (2011) proposed an integrated theoretical framework to explore the social, demographic, and economic transformations of America's rural communities. He applied this framework to studying transformations involving tourism, recreation, and other activities associated with rural landscapes and natural resources, especially high natural amenity resources. The latter include great scenic qualities and recreation opportunities associated with a varied topography, ready access to open space and undeveloped landscapes, warm climates, and proximity to rivers, lakes, or seashores (Krannich et al. 2011:2). Krannich's framework integrates human behavior, community structure, and ecosystem change across time and space to better explain the relationship between human populations and the biophysical environment. Describing this framework, Krannich et al. state: "interdependence of socially constructed landscapes, the extant community structure, individual land parcel ownership, and the relationships among those living on these parcels with others and with the resources thereon is a core characteristic of this framework" (Krannich et al. 2011:20).

In the early and mid-1970s, environment sociology became a recognized field because increasingly environmental problems resulted from human behavior. Dunlap, Catton, and Schnaiberg are among the founders of environmental sociology. Dunlap and Catton (1979, see also Catton and Dunlap 1978) argued that conventional sociology cannot adequately understand environmentally related questions. A new ecological or environmental paradigm should therefore be incorporated into sociology, a paradigm that acknowledges the biophysical bases of social structure and social life and recognizes that both biophysical environments and social factors affect human activities. Conventional sociology refuses to interpret social issues in terms of biophysical and geographic factors. Natural features of the earth such as weather, soil, forests, and water are excluded from sociological studies because they are not social variables. The emergence of environment sociology thus introduces the importance of biophysical variables into sociological inquiry. "A 'real' environmental sociology would involve examination of environmental variables (especially as causes or effects) in relation to social variables" (Dunlap 2002:331).

In contrast, Schnaiberg offered an alternative view that emphasized the treadmill of production and consumption in Western countries (Schnaiberg 1980; Schnaiberg and Gould 1994). The notion of a treadmill of production and consumption is based on the political economy perspective and suggests that modern capitalism exacerbates the ecological crisis by increasing resource use and pollution. Although Dunlap and Catton (1979) and Schnaiberg (1980) offered different explanatory frameworks for environmental issues, they all call attention to the importance of material-ecological substructures of modern societies.

There are two general categories of research in environmental sociology. "One category consists of 'ordinary' social practices and phenomena that have environmental dimensions or implications, although they remain invisible or unrecognized" (Buttel 1996:66). The second category "consists of behaviors or institutional patterns that are self-consciously environmental or environmental relevant" (Buttel 1996:67). This dissertation study of the relationship between natural amenities and population change fits into the second category of research in environmental sociology. As discussed in the previous section, much research has focused on how social factors affect population change. This dissertation incorporates biophysical variables (such as natural amenities and land uses) to explain population change.

2.1.1.2 Empirical Studies of Natural Amenities and Population Change

Natural amenities have become a topic of research in geography, ecology, economics, demography, and sociology. Natural amenities are desirable aspects of the physical environment. McGranahan (1999) developed a measure of natural amenities that includes six elements: warm winters, winter sunshine, summer temperature, low summer humidity, topographic variation, and water areas. His indicator is used by the United States Department of Agriculture (USDA) as a standard natural amenities scale. McGranahan conducted a nationwide study of how natural amenities affect population change. He found that natural resources once attracted people through economic activities such as mining and logging, but that now natural amenities are a significant factor in residential choices. Therefore, amenity-oriented migration has become a relatively new research topic.

At the local level, Chi and Marcouiller (2009a) systematically investigated how natural amenities affect migration in Wisconsin. In their study, natural amenities included forests, water areas, wetlands, public lands, riverbanks, lakeshores, coastlines, golf courses, and slopes (changes in elevation). Using three ordinary least squares regression models to analyze migration, they found that the effects of natural amenities on population change are conditioned by many contextual variables including demographic characteristics, socioeconomic conditions, transportation accessibility, and land developability. Based on these results, Chi and Marcouiller (2009b) suggested that the spatial dynamics of migration should be taken into account in the study of population change. Using a spatial regression approach to modeling migration effects of natural amenities, they concluded that natural amenities might be regarded as only a catalyst rather than a direct cause of migration.

Chi and Marcouiller's (2013a) subsequent study of Wisconsin emphasized regional variation (across urban, suburban, rural-adjacent, rural-exurban, and rural-remote areas) in how migration is affected by natural amenities. Several results suggest that the effects of natural amenities on in-migration vary across regional areas: (1) natural amenities do not affect in-migration to urban areas; (2) water significantly affects suburban migration; (3) in-migration to rural-adjacent areas is affected by water areas, public lands, golf courses, and slopes; (4) for rural-exurban areas, changes in elevation have positive effects and forests have negative effects on in-migration; and (5) in-migration to rural-remote areas is negatively affected by forests. Furthermore, Chi and Marcouiller's (2013b) study of eight remote rural counties in Wisconsin found that public lands and water significantly influence migration to rural-remote areas.

At the macro level, Hunter et al. (2005) used national-level data to study the economic impacts of high population growth in high amenity and recreational regions. They found that long-term rural families in high growth amenity and recreational regions have higher family income and higher costs of living than do their counterparts in non-growth amenity areas. In another macro-level study, Schewe et al. (2011) investigated the role of natural amenities in social and economic development in the nonmetropolitan intermountain West. Their results showed that those areas with a concentration of highly desirable natural amenities consistently experienced high levels of population growth and economic development from 1970 to 2000. In contrast, areas with fewer amenities struggled to maintain population growth and development. This study suggested that population growth in high natural amenity areas will persist as Americans place more emphasis on quality of life. Gosnell and Abrams (2011: 303) described such amenity-oriented population movement as amenity migration, defining this concept as "the movement of people based on the draw of natural and/or cultural amenities…resulting in significant changes in the ownership, use, and governance of rural lands, as well as in the composition and socioeconomic dynamics of rural communities." The attractions of pleasant and desirable natural amenities can be regarded as pull factors, and the dis-amenities of urban spaces such as high population density and pollution can be seen as push factors.

The promotion and prevalence of rural lifestyle ideals is another important motivation for natural amenities-led migration. It is easy to understand that a common bond or belief can generate voluntary behaviors such as population movement. The social constructions of rurality thus play an important role in affecting individual decisions to relocate. Many European scholars have begun to study rurality consumption, a way of transforming natural or semi-natural rural spaces to high-end consumptive commodities (Smith 1998). For example, Phillips (1993) examined rural gentrification in the Gower Peninsula, South Wales, and argued that the rural landscape is socially and culturally transformed by new middle class settlement, which also marginalizes the lower income class. Smith and Phillips (2001) investigated the affluent middle class' rurality consumption practices (e.g., buying highly prized spaces) in the villages and remote locations in Hebden Bridge, West Yorkshire, England, and emphasized the cultural preferences of in-migrants for green residential space. Their study explored how different migrations were motivated by cultural aspirations to consume specific features of rurality. Rural areas with high amenities have potential market value, which can be crafted, advertised, and sold. Affluent families have the ability to buy and gain a sense of identity, belonging, and status by consuming these areas. Through such rurality consumption practices, affluent households preserve a social and cultural distance from low income households. Smith and Phillips (2001) therefore concluded that "the consumption of reinvented images of rurality can provide a source of identity, shared living experiences, membership of social space and group, and can be perceived as a medium for obtaining a 'sense of place' in the world" (Smith and Phillips 2001:458).

Several scholars have examined the role of specific natural amenity indicators on migration across different population groups. Graves' (1979) life-cycle analysis of migration and climate suggested that climate influences population migration. Rising economic conditions for individuals stimulate an increased demand for a better natural environment, such as a more desirable climate. His study assumed that rising incomes predict a demand for certain aspects of climate. Climate-oriented relocation emerges accordingly. In addition, such climate-related migration varied by race and age. Graves (1979) found that whites were moving toward both warm and cold areas and away from annual temperature variance, wind, and humidity, while nonwhites had similar patterns except they moved toward warmth. These climate factors are seen as particularly important for those of retirement age. Greenwood and Gormely (1971), Bass and Alexander (1972), and Cebula (1974) observed that whites are attracted to temperature and climate, but blacks are repelled by these conditions.

Amenity migration can change the geographic distribution of economic activity. For example, in the western U.S., locations of extractive and manufacturing industries have been transformed to locations of service-sector and high-tech industries (Vias and Carruthers 2005). Henderson and McDaniel (2005) also found a positive correlation between natural amenities and population, employment, and income growth. Natural amenities attract not only migrants but also tourism-based industries, services, and investment. Henderson and McDaniel further showed that compared to other types of industrial sectors, such as nonfarm and manufacturing industries, natural amenities have more effects on the growth of service and retail sectors.

In addition, amenity migration, like other types of migration, generates certain social and economic consequences. First, for both rural and urban areas, there will be many changes in patterns of land development and use because of amenity migration. Agricultural land may be turned into exurban residential developments because of population growth. City areas may even attempt to produce rural space to satisfy rural ideals and thus attract migrants. These changes present big challenges for landscape planning. Second, a large volume of amenity migration will have both positive and negative socioeconomic effects. On one hand, people from urban areas can enhance the human capital of rural areas. Such people are generally more educated, experienced, and skilled than the residents of rural areas. They also can bring investment, increase tax bases, and spur economic development. On the other hand, excessive population will strain local public services and may socially destabilize the local community. Lastly, amenity migration may precipitate tensions and cultural clashes between newcomers and local residents. Local residents are more integrated into the local community; newcomers may challenge long-established local traditions, culture, and even shift the local balance of political power. Such challenges may lead to various hardships for long-term residents (Gosnell and Abrams 2011; Krannich and Petrzelka 2003).

2.2 Transportation and Population Change

Although a range of studies has demonstrated the important role of natural amenities in attracting population, migration is a multidimensional process. One essential condition for natural amenity migration is accessibility, which can be highly influenced by development of transportation.

2.2.1 Theoretical Background

Theories of classical sociology have usually viewed transportation as an internal property of social systems. Irwin and Kasarda (1994) summarized the main ideas of the classical theorists. Herbert Spencer argued that a transportation system is intrinsically embedded in the organic nature of a society. He maintained that territorial cohesion depended on the efficiency of transportation systems. The advance of transportation technologies, according to Spencer, led to further spatial differentiation and interdependence and finally to societal growth. Emile Durkheim emphasized the role of transportation and communication in the formation of the division of labor. In his view, social change was marked by the process of urbanization, industrialization, and the advancement of transportation. Karl Marx claimed that transportation was a consequence of the forces and relations of production. For Max Weber, transportation was a material foundation of society and played a concrete role in the pursuit of the common interests of groups in a socio-spatial system. In addition to these classical theorists, Cooley (1894) in his work, "The Theory of Transportation," argued that the character of transportation is determined by inter-relations among physical and social forces and conditions. Cooley described the social function of transportation as follows:

> Sociologically considered it [transportation] is a means to the physical organization of society. Development or evolution, the organization of social forces implies unification of aim, specialization of activities in view of a common purpose, a growing interdependence among the parts of society. Such organization, such extension of relations, involves a mechanism through which the relations can exist and make themselves felt. This mechanism is Communication in the widest sense of that word; communication of ideas and of physical commodities, between one time and another and one place and another. These are the threads that hold society together; upon them all unity depends. And transportation, the means of material communication between one place and another, is one of the strongest and most conspicuous of these threads (p. 42).

Yago (1983) identified four lines of investigation on transportation in sociological research. The first focuses on transportation and ecological processes. Urban-ecological studies investigate the impact of transportation technology on urban growth. Facilitated by interregional transportation, urban population can increase or decrease. In turn, when the population consistently concentrates until it generates central city congestion, a spill-over effect will materialize and affect a broad region. The second line of investigation focuses on transportation in urban economics and political science, emphasizing the consumer's role in land choice and costs. The third line of investigation focuses on industrial organization, institutional progress and the development of transportation policy. The focus is on how changes in these aspects of society will affect the form and function of transportation. The fourth line of investigation focuses on social consequences of transportation, including energy and land use, distributional impacts, and social interaction.

Instead of viewing transportation only as an internal feature or consequence of a society, the human ecological perspective also regards transportation as part of the external environment, an independent variable, a cause, and even a determining effect of population and social change. The society can be shaped by external transportation systems as well as by the technology of transportation.

In contrast to classical theories of sociology, human ecological theory examines complex social phenomena in terms of their physical and measurable dimensions, such as the interaction between environment and humans, the growth of cities, the spread of industry, the extension of highways, and the movements and distribution of people and utilities. In this sense, human ecology is an interdisciplinary field that investigates the spatial and temporal relationship between social organization and the natural environment. Hawley (1950) emphasized that human ecology studies the relationships between living organisms and their environments, observing that these relationships have spatial aspects. For example, he viewed the increase of urban populations as the most pervasive spatial process facilitated by the evolution of transportation technology. With the change of transportation patterns, the dense, cellular patterns of urban areas will also change.

Hawley (1950) argued that transportation technology influences urbanization through both centripetal and centrifugal population movements. On one hand, population flows inward to the central city to access the developing markets, services, and industrial units. In turn, the central city's size and diversity of activities are expanded. On the other hand, population flows outward to the periphery to develop new resources and to pursue supplementary functions such as leisure and outdoor recreation.

Moreover, these population movements spatially redistribute community characteristics. Burgess (1925) proposed that the urban pattern consists of five concentric zones: a central business district, a transitional zone characterized by deterioration and poverty, a zone of working-class residences, a zone of middle-class residences, and a zone of upper-class commuters residences. Hoyt (1939), on the other hand, argued that urban patterns are more accurately represented by a series of sectors instead of zones, proposing that people and their activities are organized in pie shaped sectors along railroads, highways, and other transportation modes. For example, industry sectors follow roads, rivers, canals, or railroads. Low income populations reside near or in industry sectors where people can access entry-level jobs, but must also endure pollution and a poor living environment. Middle and high income populations reside in areas farther from industry sections, enjoying a more desirable environment and accessible highways. Thus, the spatial pattern of a community is affected by road, highway, and airport expansion. Community patterns might also emerge because of transportation development. For example, Alonso's (1964) land use theory suggested that faster commuting time resulting from transportation advances can increase the demand for suburban locations.

2.2.2 Airport and High way Studies

Kasarda and Lindsay (2011) studied a new form of urbanization they called "aerotropolis," asserting that it will be the major trend in future city building. In their formulation, airports will be in central positions and cities will be built around them. The radial effects of airports, they argue, will redistribute urban populations, leading to differential city growth corresponding to the degree of accessibility to airports.

Airport expansion can furthermore lead to employment change, which will then lead to population change. Some studies have supported this view. Exploring relationships between airport enplanement and the size of the labor market, they show that passenger transportation volumes are closely tied to overall economic activity, because business trips and travel to work are directly involved in economic contexts. Alkaabi and Debbage (2007) examined the relationships between skilled labor markets and air transportation in U.S. metropolitan areas, observing the association between employment patterns, especially in the professional, scientific, technical, and high technology sectors, and air passenger demand. The study found a link between employment opportunities and the geography of air passenger demand. Similarly, Brueckner (2003) found that an increase in air boarding passengers in a metropolitan area will increase the employment rate in service-related industries rather than in goods-related industries. In addition, by analyzing the spatial and temporal patterns of air passenger flows by airport in the U.S. Carolinas, Debbage (1999) found that airports and airline operations are involved in urban and regional development. His findings suggest that when airports experience significant gains in air passenger volume, the local labor market tends to experience comparable gains in administrative and auxiliary workers, particularly in the manufacturing sector. Moreover, in an analysis of a larger sample, administrative and auxiliary employments were correlated with enplaned passenger volume (Debbage and Delk, 2001).

In Rasker et al.'s (2009) study, air service was selected as a criterion to classify rural and urban areas, because air service can determine an area's accessibility to larger population centers and markets. Thus, travel distance to airports generated a new definition of the concept of rural. Rasker et al. identified three distinct county classifications: "metro," "isolated," and "connected." This new county classification system underscored the increasing importance of airports in regional economic development, especially in high-amenity rural areas.

The development and expansion of highways in the twentieth century have additionally influenced population redistribution. The expansion of highways not only promotes urbanization, it also disperses population and economic activity to remote rural areas, decentralizing industry and trade areas. Lichter and Fuguitt (1980) examined the relationship between interstate highways and population and employment change in nonmetropolitan counties during three time periods (1950-1960, 1960-1970, and 1970-

1975). They found that counties with interstate highways had higher levels of net migration and employment growth than did counties without interstate highways. Chi et al. (2006) and Voss and Chi (2006) studied the relationship between highway expansion and population change in Wisconsin. Their investigations synthesized the literature and concluded that the findings of past studies were often conflicting and ambiguous because these studies originated in different disciplines and had different emphases. For example, some studies focused only on one causal direction of highway expansion and population change, or only one stage and type of highway development, or only rural areas. In addition, most studies neglected the spatial dimension of analysis. Chi et al. (2006) and Voss and Chi (2006) attempted to systematically analyze the relationship between highway expansion and population. They examined the bi-directional causes between improved highways and population change, took into consideration the different stages of highway development, included both rural and urban areas, and considered the influence of spatial dependence. Their findings showed that improved highways have growth influences and spillover effects on population change in nearby communities. In a related investigation, Baum-Snow (2007) examined the effects of highway construction on central city populations between 1950 and 1990 in the United States. He found that urban transportation improvements can reduce city population, concluding that "each new highway causes constant geography central city population to decline by about 18 percent, all else equal" (Baum-Snow 2007:776).

2.3 Spatial Analysis in Sociology

When geographers used geo-referenced data to investigate spatial patterns of the earth's physical characteristics, few sociologists realized that such a spatial perspective can be used to analyze human behavior. With the development of global positioning systems (GPS), remote sensing systems, and smart mobile applications (e.g., GPS on phones or other mobile devices), geo-referenced or geospatial data are now available. Not only can land features, environmental characteristics, natural disasters, and climate changes be spatially analyzed; human actions, demographic characteristics, economic stratification, and social networks can also be spatially analyzed. Logan (2012) has therefore argued that the development of spatial technologies and the growing availability of spatial data sets have evoked sociologists' interest in spatial analysis. For a long time, he points out, sociologists have studied diverse social, political, and economic phenomena that occur in space and time, but sociologists have overlooked the geographic characteristics of these phenomena because of the limitations of data, methods, and theory.

The spatial analytic perspective is becoming popular in social science research (Anselin 2000; Doreian 1981). In particular, the concepts of proximity, network, exposure, spatial dependence, spatial heterogeneity, and distance are considered in many studies of health, political behavior, neighborhoods, residential segregation, migration, and deindustrialization. In addition, new theoretical models and statistical and econometric techniques are being developed to take account of spatial effects (Ryngnga 2010).

In the social sciences, spatial thinking promises a better understanding of human activities and interactions between micro elements and macro outcomes through visualizing, analyzing, and integrating different sources of information. Geographic information system (GIS) software is a technological tool used to put spatial thinking into practice. GIS can perform exploratory analyses that visualize spatial patterns, elicit hypotheses, and suggest associations. Moreover, GIS can be used to incorporate standard data models with spatial models (Chang 2010).

Two types of spatial data can be analyzed in a GIS context: vector data and raster data. Vector data use points, lines, and polygons to represent spatial features. A point has only the property of location. A line has the properties of location and length. A polygon has the properties of location, perimeter, and area (Chang 2010). For example, in this dissertation, an airport's location is a point feature, highways are line features, and counties are polygon features. Raster data use a regular grid to represent spatial features. The value in each grid cell corresponds to the characteristics of a spatial phenomenon such as elevation. Each individual cell value can be used to perform calculations. For example, in this dissertation, the proportion of forest coverage in each county is calculated by raster data derived from the National Land Cover Database.

The GIS approach has been applied in research in human ecology, urban and rural sociology, natural resource sociology, and environmental sociology. The GIS approach extends beyond mapping to spatial analysis. GIS can integrate census data, remote sensing images, maps, and other social data, and many analyses can be performed, including spatial modeling, network analysis, and raster analysis (Ryngnga 2010). For instance, Verd and Porcel (2012) incorporated GIS with computer-aided qualitative data analysis software to study the transformation of Barcelona, illustrating the integration of geographic data and qualitative data in urban sociology. Crooks (2010) used GIS to translate the urban environment into lines, polygons, and data points to examine the residential segregation hypothesis suggested by Schelling (1971). Crooks' vector GIS data model demonstrated how individuals' behavior and interaction over space and time can cause macro scale residential change. Chi and Zhu (2008) suggested that spatial data analysis is becoming important in demographic studies.

2.4 Statement of Hypotheses

As stated above, over the past century, American's rural areas have experienced many economic, demographic, and social transformations. The advances of technology, transportation, and communication systems have changed the traditional images of rural communities as places that are dominated by agriculture and extractive activities. Some rural areas are experiencing income, population, and employment growth instead of poverty and losses of people and jobs. These areas are usually endowed with natural amenities and are enjoying economic development through tourism and outdoor recreation. Many rural areas capturing the economic benefits of such development are attracting different groups of people. Such amenity related growth is not well understood. This dissertation attempts to address the knowledge gaps by examining the relationship between population change and amenity-related characteristics at the county level, controlling the demographic and socioeconomic variables influencing or conditioning this relationship. The study seeks to determine if counter-urbanization continued after the 1970s and 1990s by investigating the roles of natural amenities and transportation in this population change. Based on the relevant literature, the central hypotheses in this research are: (1) amenities and transportation will significantly influence net migration rates and population changes and (2) different natural amenities and transportation modes will vary in their power to explain net migration and population change. The specific hypotheses are as follows:

- Hypothesis 1: Higher natural-amenity-ranking counties have higher net migration rate and population growth than lower natural-amenity-ranking counties.
- Hypothesis 2: Counties with higher forest coverage have higher net migration rate and population growth than counties with lower forest coverage.
- Hypothesis 3: Counties with lower values of land developability have higher net migration rate and population growth than counties with higher values of land developability.
- Hypothesis 4: Counties with greater human-made amenities (establishments of arts, entertainment, and recreation) have higher net migration rate and population growth than counties with fewer human-made amenities.
- Hypothesis 5: Counties with better airport accessibility have higher net migration rate and population growth than counties with worse airport accessibility.
- Hypothesis 6: Counties with higher density of highways have higher net migration rate and population growth than counties with lower density of highways.

These hypotheses are tested in U.S. all counties, nonmetropolitan counties and metropolitan counties, respectively.

CHAPTER III

DESCRIPTION OF DATA, VARIABLES, AND ANALYTIC STRATEGY

This chapter describes the data and explains the measurement of the dependent, explanatory, and control variables. Variable names, descriptions, and data sources are listed in Table 3.2. The chapter also outlines the methodological procedures for the analyses.

3.1 Dataset

The unit of analysis is the county, a political and geographic subdivision of a state. There are 3,109 counties in the contiguous United States excluding the counties in Alaska, Hawaii, and off-shore U.S. territories because no neighborhood structure can be defined for Alaska and Hawaii in spatial analysis. The Topologically Integrated Geographic Encoding and Referencing database (TIGER) from the U.S. Census Bureau provides a legal and statistical county shapefile which can be linked to census data (such as American Community Survey data) as well as to data on roads and other geo-reference data. The 2003 Urban-Rural Continuum codes (USDA ERS, 2003) provide 9 classifications that distinguish metropolitan counties by population size and nonmetropolitan counties by degree of urbanization and adjacency to a metropolitan area. By using these codes, this study can separate county data into two groups (Table 3.1) to analyze metropolitan and nonmetropolitan population change. The distribution of metropolitan and nonmetropolitan counties is illustrated in Figure 3.1.

Table 3.1 County Code Description

2003 Rural-Urban Continuum Codes	
Code	**Description**
Metropolitan counties:	
1	Counties in metro areas of 1 million population or more
2	Counties in metro areas of 250,000 to 1 million population
3	Counties in metro areas of fewer than 250,000 population
Nonmetropolitan counties:	
4	Urban population of 20,000 or more, adjacent to a metro area
5	Urban population of 20,000 or more, not adjacent to a metro area
6	Urban population of 2,500 to 19,999, adjacent to a metro area
7	Urban population of 2,500 to 19,999, not adjacent to a metro area
8	Completely rural or less than 2,500 urban population, adjacent to a metro area
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area

Source: http://webarchives.cdlib.org/sw1wp9v27r/http:/ers.usda.gov/Briefing/Rurality/RuralUrbCon/

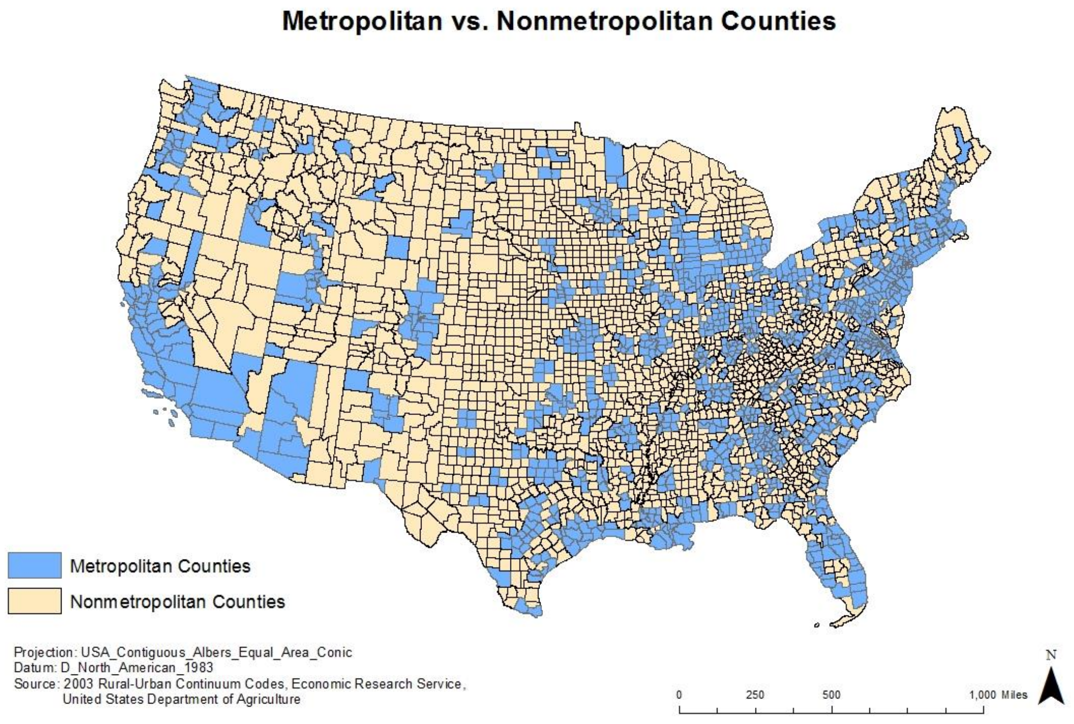

Figure 3.1 Distributions of Metropolitan and Nonmetropolitan Counties

The data are drawn from various sources: data on population change and social, economic, and demographic characteristics are from the U.S. Census Bureau and the Age-Specific Net Migration Estimates for U.S. Counties, 1950-2000, a county level database created by Winkler and her colleagues (Winkler et al. 2013a). This database provides six decades of county-level net migration data by five-year age-groups, race, Hispanic origin, and sex. Data on forests, one of the natural amenities indicators, are available from the 2006 National Land Cover Database (NLCD). These data are based on a 16 class land cover classification scheme (Figure 3.4) across the conterminous United States at a spatial resolution of 30 meters. The United States Department of Agriculture (USDA) provides data on natural amenities in the form of a natural amenities scale dataset created by McGranahan (1999). The data for amenities establishments are from the County Business Patterns data (available from the U.S. Census Bureau), which provide subnational economic data by industry such as the total number of establishments. The land developability index is created by Chi and Ho (2013) and is retrieved from their website. Transportation data are mainly from the National Transportation Atlas Database, a set of nationwide geographic databases of transportation facilities, transportation networks, and associated infrastructure, and the Air Carrier Activity Information System, which provides data on revenue passenger boarding and all-cargo data.

The dependent and independent variables have a time order because this study assumes that population change is predicted by previous events. The dependent variables measure population change from 2000 to 2010. Most independent variables are around 2000. Some independent variables measuring relatively stable geographic characteristics, such as land and highways, are from recent years due to the data availability.

Table 3.2 Variable Descriptions and Data Sources

Variables	Variable Descriptions	Data Sources
Dependent Variables		
Net migration, 2000-2010	Net migration rate per 100 individuals, 2000-2010	http://www.netmigration.wisc.edu
Population change, 2000-2010	Ln (total population 2010/total population 2000)	U.S. Census Bureau
Explanatory Variables		
Natural amenities		
Forest coverage	Proportion of forest coverage	National Land Cover Database, 2006
Natural amenity scale	Sum of the Z scores of six natural amenities variables	USDA Natural Amenity Scale, 1999
Land developability	Percentage of lands available and suitable for development	http://landdevelopability.org, created in 2013
Arts, entertainment, and recreation establishments	(Number of establishments in 2004/population 2000)*1000	U.S. Census Bureau, County Business Patterns
Transportation		

Table 3.2 (Continued)

Airport accessibility	$Ln\left(\frac{1}{d^2} \times enplanement\right)$ *d*: the distance from the centroid of a county to its nearest major airport, 2011 Enplanement: Passenger boarding for primary and non-primary commercial service airports, 2000	National Transportation Atlas Database Federal Aviation Administration
Highway density	Total lengths of major roads divided by square root of each county area, 2011	National Transportation Atlas Database
Control Variables		
Population density	Average population per square mile in 2000	U.S. Census Bureau
Income	Median household income in 1999	U.S. Census Bureau
Educational attainment	Percentage of persons 25-34 years old with a bachelor's degree or higher credential, 2000	U.S. Census Bureau
Middle age net migration	Net migration rate of persons, 30-54 years old, 1990-2000	http://www.netmigration.wisc.edu

Table 3.2 (Continued)

Old age net migration	Net migration rate of persons, 55-74 years old, 1990-2000	http://www.netmigration.wisc.edu
White net migration	White net migration rate, 1990-2000	http://www.netmigration.wisc.edu

Table 3.2 (Continued)

Variables	**Variable Descriptions**	**Data Sources**
Black net migration	Black net migration rate, 1990-2000	http://www.netmigration.wisc.edu
Hispanic net migration	Hispanic net migration rate, 1990-2000	http://www.netmigration.wisc.edu

3.2 Measures of Dependent Variables

Two variables will indicate population change—the net migration rate and population size change. The visualization of these dependent variables is illustrated in Figure 3.2. The net migration rate measures the difference of in-migrants and out-migrants in an area in a period of time. This variable can indicate the population gain and loss in a particular area resulting from people's moving actions. Population size change measures the population increase or decrease in a particular area resulting from all factors affecting population change: number of births, number of deaths, number of people who move in, and number of people who leave. This dissertation study will examine not only how natural amenity and transportation variables affect migration, but also how such variables influence total population variation.

3.2.1 Net Migration Rate

The net migration rate is derived from a data set developed by Winkler et al. (2013a) with county-specific net migration listed by five-year age groups, Hispanic origin, race and sex from 2000-2010. Winkler et al. use a vital statistics version of the forward cohort residual method to generate these data, describing the methodology as follows (Winkler et al. 2013b):

The basic methodology begins with the fundamental demographic balancing equation:

$$P1 = P0 + (B - D) + (IM - OM) \quad (3.1)$$

Which, upon reorganization of terms, yields:

$$IM - OM = (P1 - P0) - (B - D) \quad (3.2)$$

The equation states that the difference between in-migration (IM) and out-migration (OM) is equal to the population change over the decade (P1 – P0) less the "natural increase" over the decade (B – D). Since IM and OM generally are not measured quantities, we cannot know the difference precisely. We can, however, estimate this difference (by using the terms on the right side of the equation), which, following common convention, we call "net migration" (NM). We assume these right-hand terms either are known or are capable of being well estimated. Thus, net migration is estimated as the residual of the difference between population change and natural increase over an intercensal period (p. 1).

Net migration is widely used as a dependent variable in amenity migration research to examine the influence of amenity resources on migration patterns (Marans and Wellman

1978), on nonmetropolitan recreation and amenity migration (Beale and Johnson 1998; Johnson and Beale 2003; McGranahan 1999), and on demographic trends in urban proximate recreation counties (Johnson and Stewart 2005).

3.2.2 Population Change

Population change from 2000 to 2010 is a dependent variable that measures the difference between total population in year 2000 and 2010 for each county. The natural log transformation LN (population in year 2010 / population in year 2000) helps to adjust the skewed distribution. This variable is easy to interpret: the negative value of LN (pop2010/pop2000) means that (pop2010/pop2000) is less than 1 which indicates that the population of 2010 is less than the population of 2000. Therefore, negative values reflect a decrease of population and positive values reflect an increase of population.

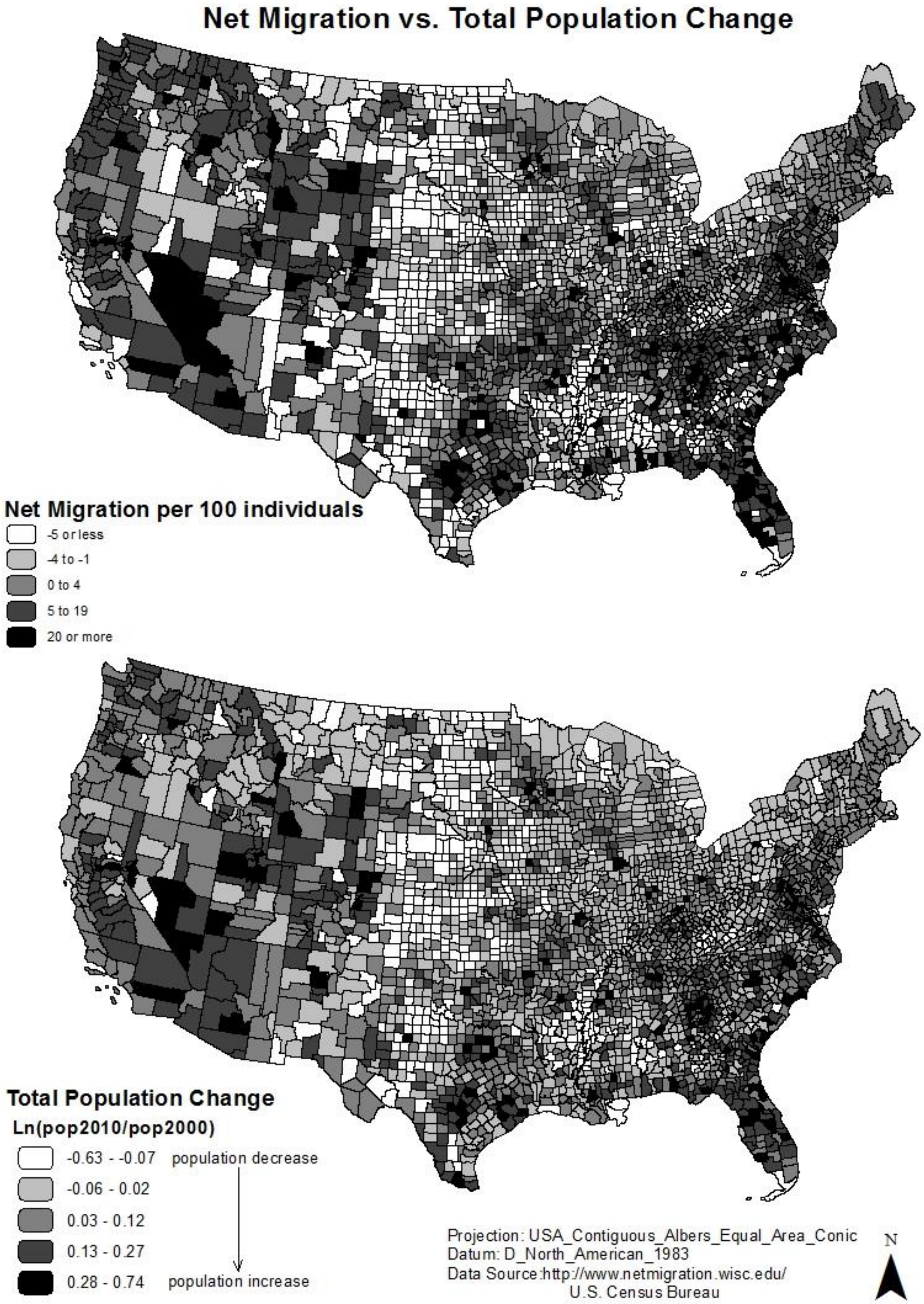

Figure 3.2 Visualization of the Dependent Variables

3.3 Measures of Explanatory Variables

3.3.1 Natural Amenities Scale

Natural amenities are various environmental qualities: climate, forest, wild life, lakes, and the like. Measuring natural amenities is challenging because the physical environment is multidimensional, and sometimes it is difficult to quantify all relevant dimensions. Past research suggests three ways to measure natural amenities.

The first is the single factor approach. This is the most straightforward approach, including all natural amenities variables. While the individual measures are easy to interpret, it is difficult to include all relevant variables in a single model.

The second approach is the principle component method. It relies on a complicated mathematical procedure to reduce several natural amenities variables into a set of principal components. For example, the research of Marcouiller et al. (2004) uses principle component analysis to convert 50 natural amenities variables into 5 variables which are distinguished as "land-based," "river-based," "lake-based," "warm-weather-based," and "cold-weather-based." The advantage of this approach is that it ensures a multidimensional analysis. However, the results are difficult to interpret if the researcher wants to examine the effect of one particular amenities attribute.

The last approach is the widely used summary index approach. This approach uses a single index of different amenity attributes to represent natural amenities. The Economic Research Service of the U.S. Department of Agriculture (McGranahan 1999) employs this index as a standard natural amenities ranking scale. This scale is generated by six variables: average January temperature, average January days of sunshine, low winter-summer temperature gap, low average July humidity, topographic variation, and water areas. The natural amenities scale is the sum of the Z scores of these six variables (Figure 3.3). The drawback of this approach is the subjectivity involved in selecting the amenities attributes that generate the summary index.

Although McGranahan's scale is widely used, it ignores many other amenities attributes. The concept of natural amenities is multi-faceted, and includes more dimensions than climate and topography. For example, Power (2005) believes that the range of amenities is quite broad, including not only natural characteristics but also characteristics that are social (e.g., quality of schools, public services, community), cultural (e.g., local diversity, cultural richness, integrity), and human-built (e.g., density, quality of homes and businesses, basic public and commercial infrastructure).

This study uses McGranahan's scale of natural amenity variables. In addition, a measure of forests, a very important natural amenity which McGranahan omitted, is incorporated in the analysis. As explained later below, two other amenity measures are analyzed. Land developability is included to measure natural features that have been neglected in previous amenity-population studies. The number of establishments for arts, entertainment, and recreation is included, a measure that reflects the social and human built amenities emphasized as important by Power (2005).

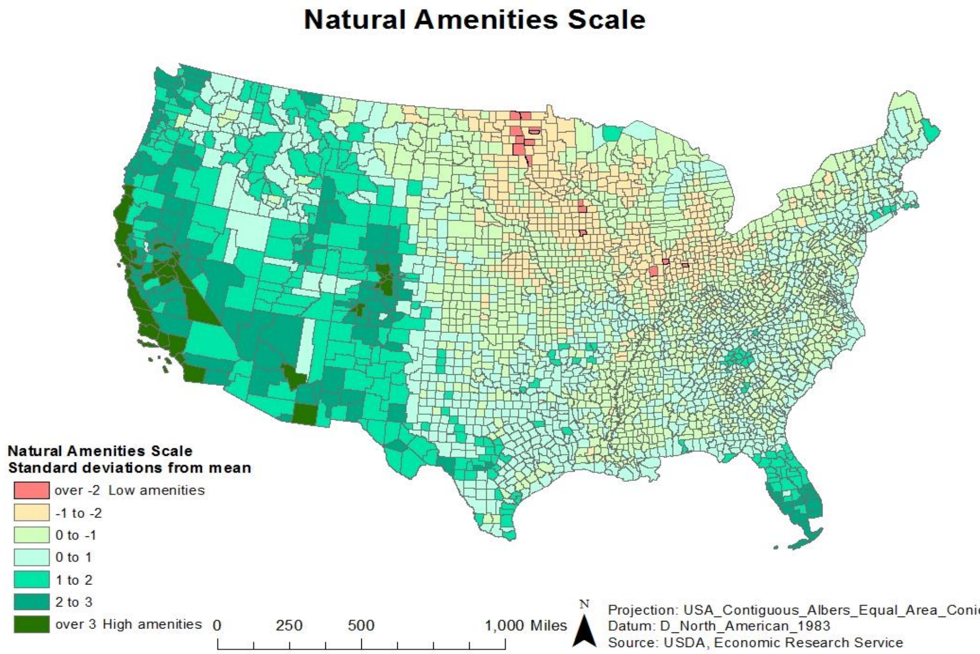

Figure 3.3 Natural Amenities Ranking Scale

3.3.2 Forests

Forest coverage data are extracted from the U.S. Land Cover Landsat Image. These remote sensing data have a spatial resolution of 30 meters. In ArcGIS software, these data are treated as raster data which can be used in multiple analyses. In these data (Figure 3.4), there are 20 different land covers. The present study is only interested in forest cover, which is divided into 3 categories in the U.S.: deciduous forest, evergreen forest, and mixed forest. Using the "reclassify" tool in ArcGIS, these land cover categories are reclassified to create new raster data (30 x 30 meter resolution) that show only the U.S. forest coverage (Figure3.5).

In order to obtain the percentage of forest in each county, the zonal statistics tool is used to calculate values defined by a zone data set. The U.S. county shapefile is used to define the zone. In the first step, the county boundary is the zone field and the new U.S. forest coverage raster data layer is the target data. The zone statistics tool calculates the total number of grids in the target data layer within each zone field, obtaining the total number of 30 x 30 meter forest grids in each county. The second step converts the U.S. county shapefile, which is a vector data layer, into a 30 x 30 meter resolution raster layer. In the same way, the zonal statistics tool calculates the number of 30 x 30 meter grids in each county. Finally, the percentage of forest coverage is equal to the total number of 30 x 30 meter forest grids divided by the total number of 30 x 30 meter grids in each county. Figure 3.6 shows the calculated percentage of forest coverage, the distribution of which is similar to that of the remote-sensing extracted forest coverage displayed in Figure 3.5.

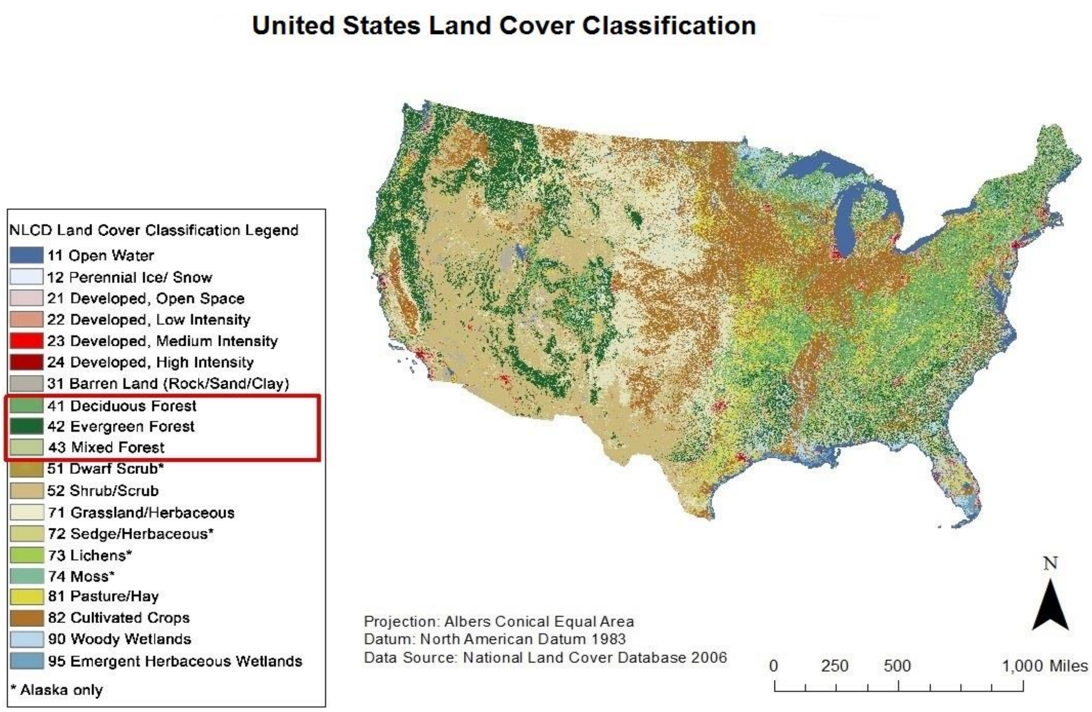

Figure 3.4 U.S. Land Cover Classification

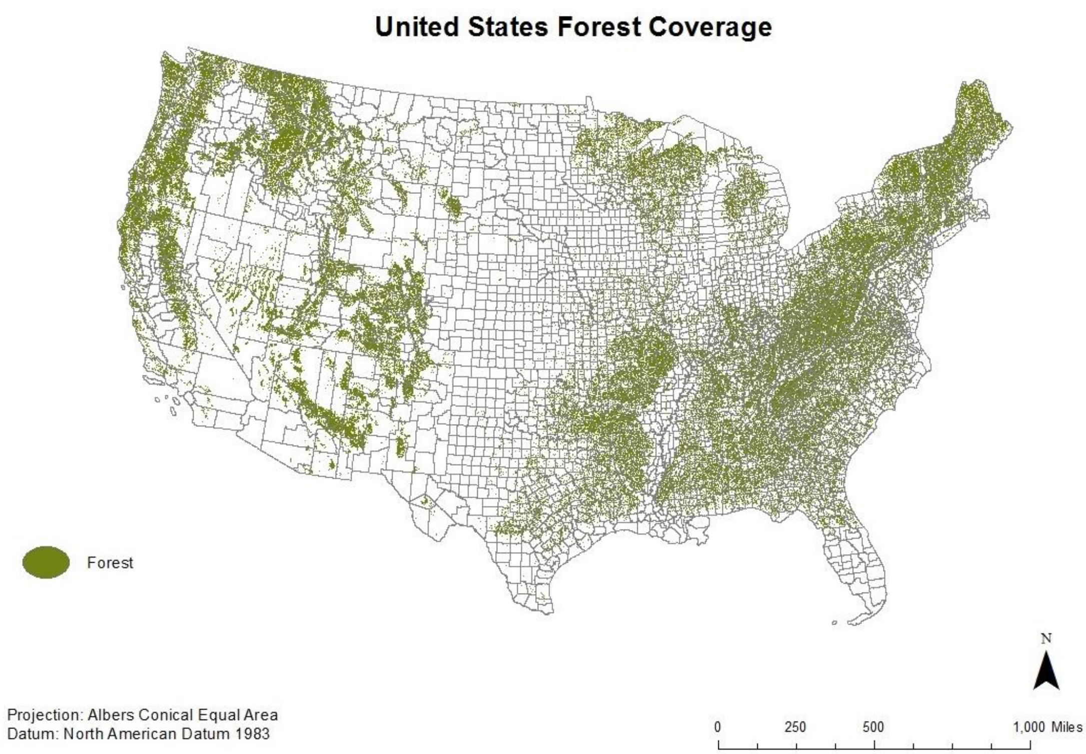

Figure 3.5 U.S. Forest Coverage

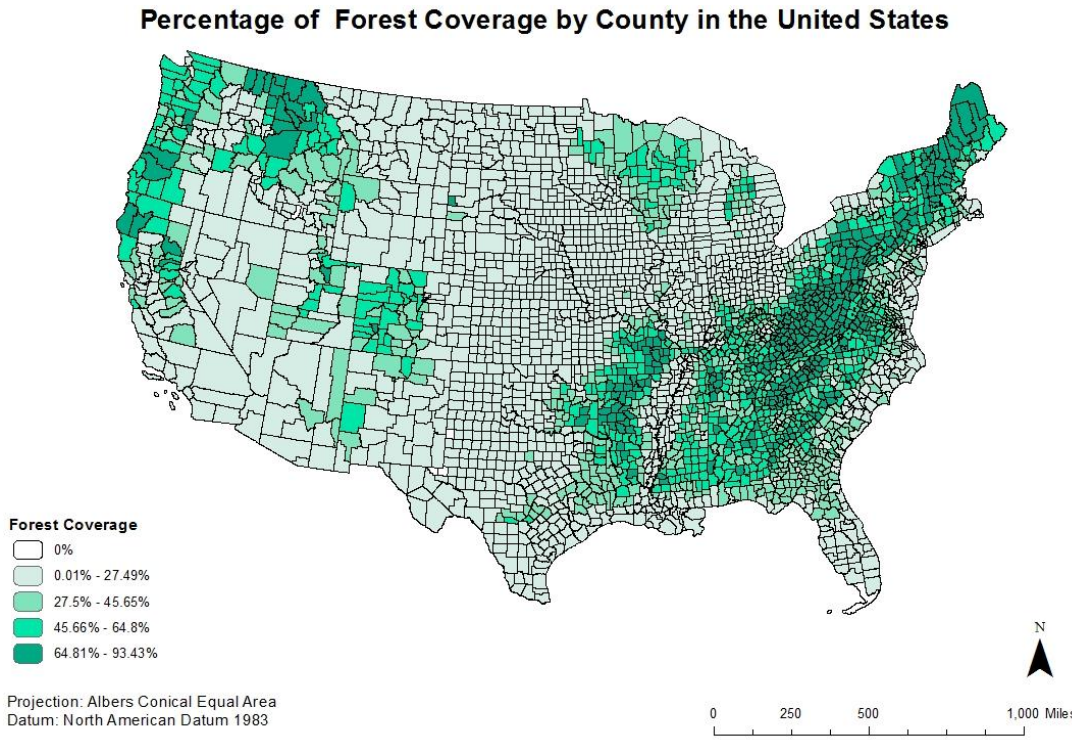

Figure 3.6 Percentage of Forest Coverage

3.3.3 Land Developability

The land developability index created by Chi and Ho (2013) (Figure 3.7) is a measure of land availability by county. It indicates certain natural conditions at the county level and is generated from measures of surface water, wetlands, public owned lands, and steep slopes. Among these measures, wetlands, public lands (usually referring to national parks, wildlife refuges, and fishery areas), Indian reservations, and steep slopes (indicating hills and mountains) are closely related to natural amenity characteristics. Few studies have considered these natural amenity variables. Although Chi and Ho (2013) use this land developability index to study the potential for land conversion and development, the index can also be used to measure natural amenity conditions at the county level. Since this index codes surface water, wetlands, public lands, Indian reservations, and steep slopes as not developable, low values of land developability reflect a high concentration of natural amenities.

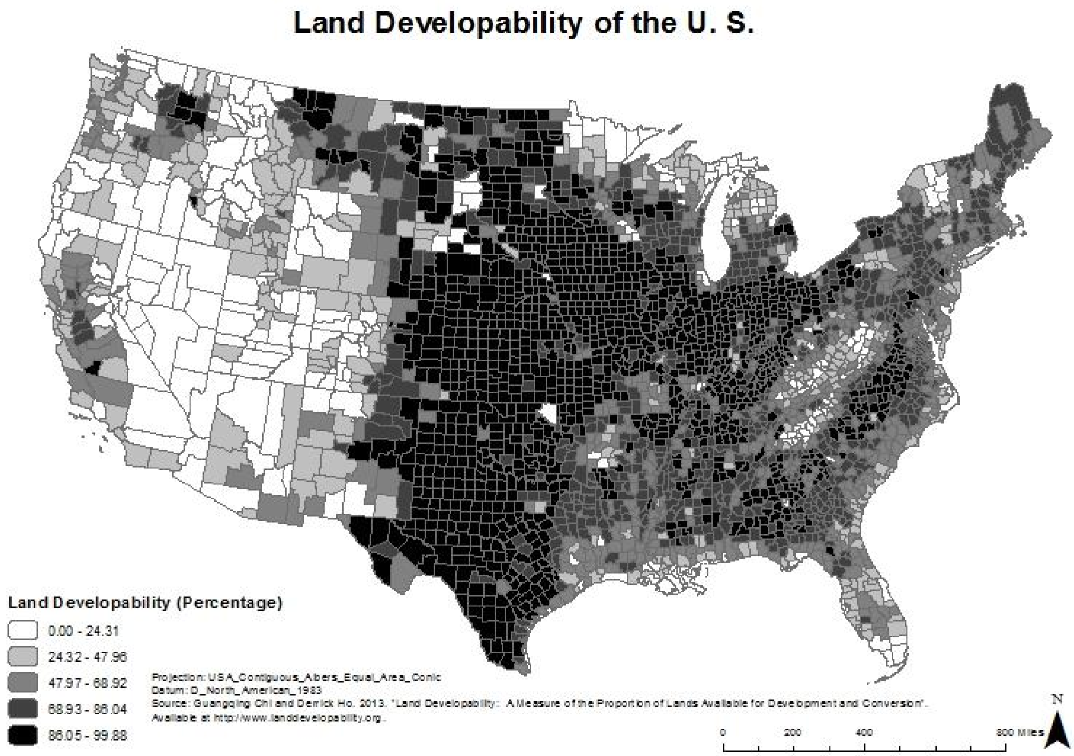

Figure 3.7 Land Developability of the U.S.

3.3.4 Amenity and Recreation Relevant Establishments

The number of establishments devoted to arts, entertainment, and recreation is used to measure the social and human-built dimensions of amenities. According to the U.S. Census Bureau, these establishments include (U.S. Census Bureau, n.d.):

1. Establishments that are involved in producing, promoting, or participating in live performances, events, or exhibits intended for public viewing;
2. Establishments that preserve and exhibit objects and sites of historical, cultural, or educational interest;
3. Establishments that operate facilities or provide services that enable patrons to participate in recreational activities or pursue amusement, hobby, and leisure time interests.

In this study, this variable is normalized by population in the year of 2000 as follows: (number of establishments/population 2000)*1,000.

3.3.5 Transportation

Rivers and railroads have been important factors in population movement and settlement. But since the early twentieth century, highways and airports have played the dominant roles in influencing population change. As the literature reviewed above shows, numerous studies have used measures of highways and airports as explanatory variables in research on population change.

Transportation is operationalized by two variables: airport accessibility and highway density. The geo-referenced transportation data are from the National Transportation Atlas Database (NTAD), which provides data in vector format. Highways are line vector data and airports are point vector data. The airports data from NTAD include all kinds of airports (total number: 19,721) such as balloon ports, glider ports, heliports, seaplane bases, and ultralight ports. The enplanement data from the Federal Aviation Administration (FAA) consider primary and non-primary commercial service airports, and all airports not matching the FAA enplanement dataset are removed. Thus, enplanement data exist for 546 primary and non-primary commercial service airports for the year 2000. The following airports are excluded: 91 airports in Alaska, 2 in the Virgin Islands, 8 in Hawaii, 7 in Puerto Rico, and 6 other airports in off-shore U.S. territories (Guam International Airport, Saipan International Airport, Pago Pago International Airport, West Tinian Airport, Rota International Airport, and Ofu Airport). In addition, 6 airports (Panama City-Bay County International Airport, Glacier Park International Airport, Yuma International Airport, Merrill C. Meigs Field Airport, Clinton County Airport, and Oneida County Airport) from the FAA dataset are missing from the NTAD so these airports are deleted since they cannot be located on a map. Therefore, 426 primary and non-primary commercial service airports are finally selected to calculate the measure of airport accessibility.

Using ArcGIS software, each vector data set is treated as an independent layer. Different layers can be put together as long as they have the same map projection and datum. Figure 3.8 shows that the U.S. county layer is overlaid with highways and airport layers. These data are used to visually illustrate the distributions of each transportation mode and to perform multiple calculations and analyses across different layers.

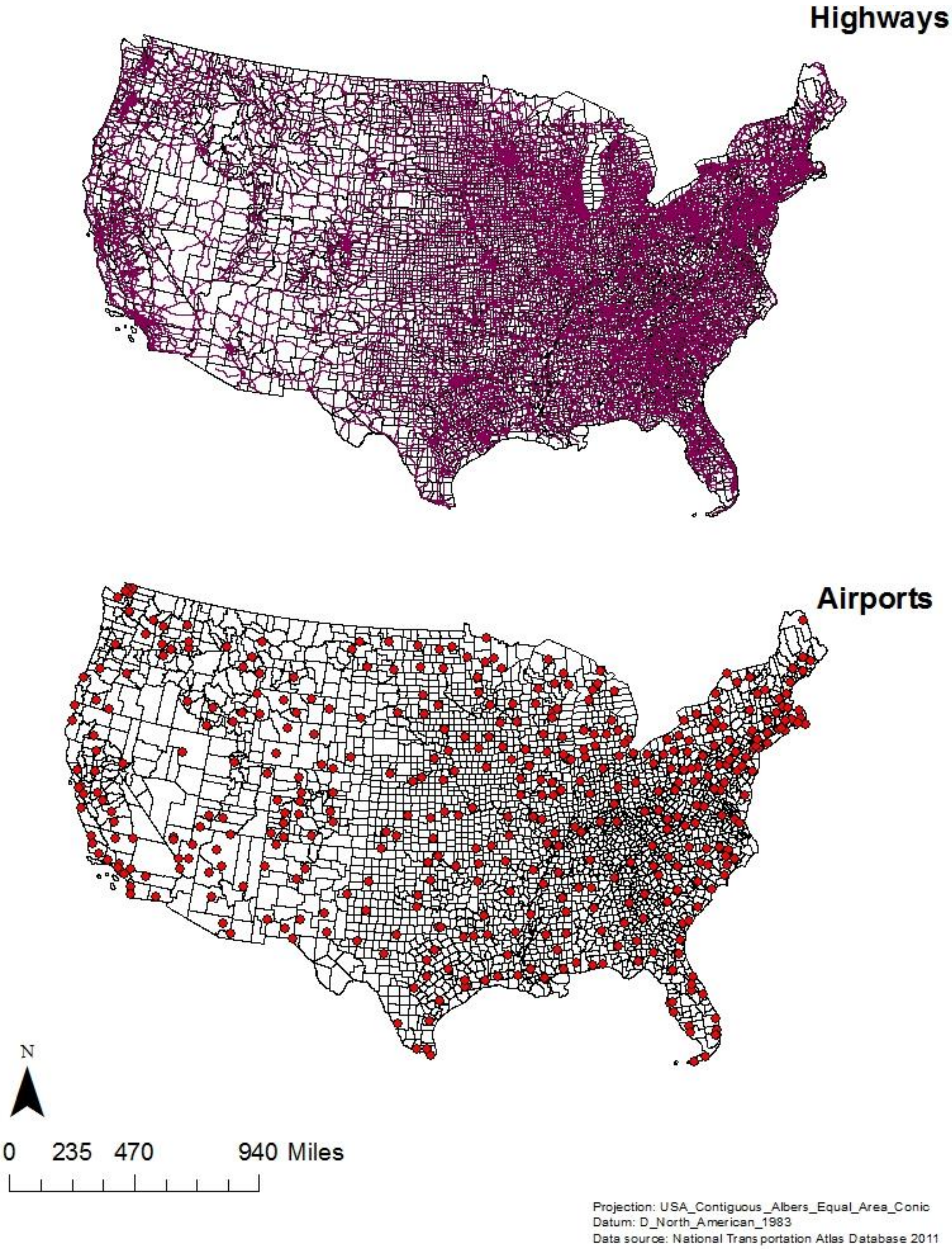

Figure 3.8 Visualization of U.S. Highways and Airports

3.3.5.1 Airport Accessibility

Accessibility is an important concept in transportation evaluation and planning. "Accessibility is defined as the ability of people to reach their destinations to meet their needs and satisfy their wants, and has been long used in transportation planning" (Anderson et al. 2013:683; see also Hansen 1959). This concept has been used to study transportation-related social exclusion, the location of service areas for care facilities, the effect of public transit on employment outcomes, and the existence of food deserts (Páez et al. 2012). Mulley (2014), for instance, found that accessibility improved by public transportation can change land value and promote regional growth. Such growth can be reflected in population growth and an increasing in-migration rate. Therefore, transportation accessibility is relevant to spatially distributed population change.

According to Páez et al. (2012), two basic components are usually used in accessibility measurement: the cost of travel and the quality/quantity of opportunity. There are different ways to operationalize these two components. In this study, airport accessibility is operationalized by two variables, distance and enplanement (Chi 2012):

$$\text{Airport accessibility} = LN\left(\frac{1}{d^2} \times enplanement\right) \tag{3.3}$$

where d is the distance from the centroid of a county to its nearest airport, reflecting travel cost, and enplanement is the volume of passengers, reflecting the capacity of the airport. This formula indicates that airport accessibility is inversely correlated with d and positively correlated with enplanement. Therefore, a high airport accessibility value means residents in a county can access a high quality and high capacity airport within a relatively short time. The visualization of airport accessibility is illustrated in Figure 3.9.

3.3.5.1.1 Distance to Nearest Airports

Since airport location (a point layer) and county boundaries (a polygon layer) are given, the centroid of each county (centroid of a polygon) can be generated with data management tools (feature to point function) in GIS. When the centroids (a new point vector layer) for all counties are created, the distance between the centroid of a county and the county's nearest airports can be calculated with the proximity toolset.

3.3.5.1.2 Enplanements

Enplanements refer to the number of passengers boarding an aircraft. In this study, only enplanements in primary, non-primary, and commercial service airports are analyzed. The FAA has recorded the total number of enplanements for all airports studied.

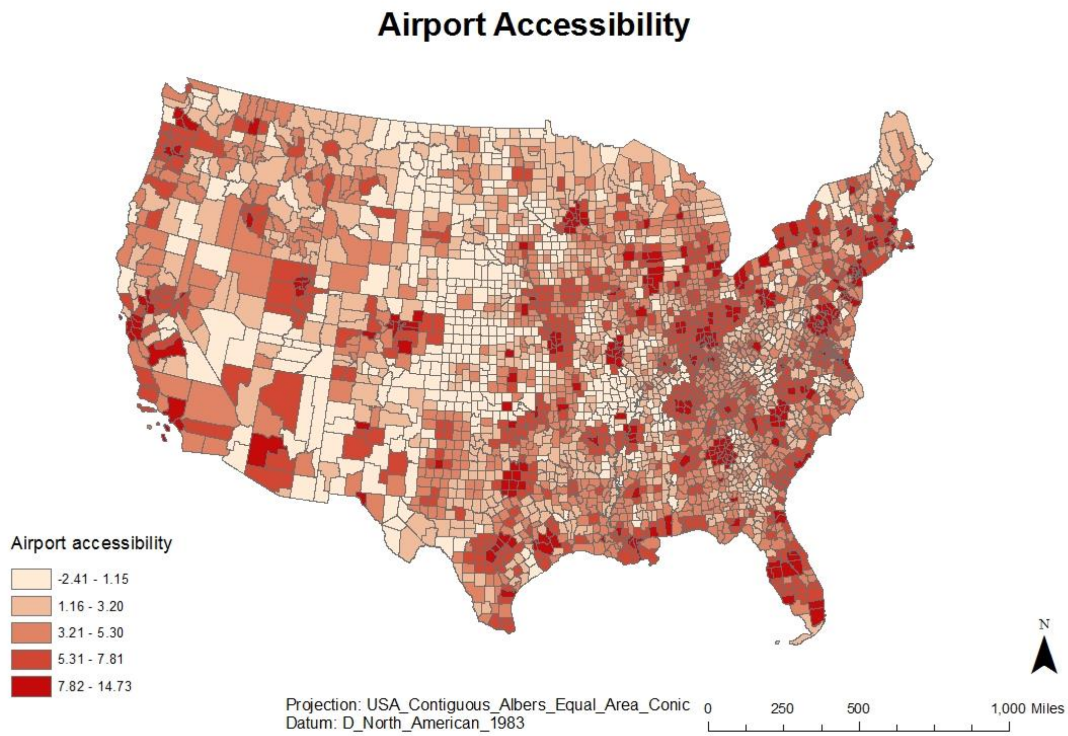

Figure 3.9 Visualization of U.S. Airport Accessibility

3.3.5.2 Highway Density

In GIS, highways are vector line data. The overlay function in ArcGIS can split roads inside county borders, creating a new layer of road information for each county. The lengths of roads are calculated within each county boundary and the sum of the lengths are calculated using the summary statistics tool. The highway density of each county is equal to the total lengths within each county divided by the square root of the corresponding county area. The visualization of calculated highway density is illustrated in Figure 3.10.

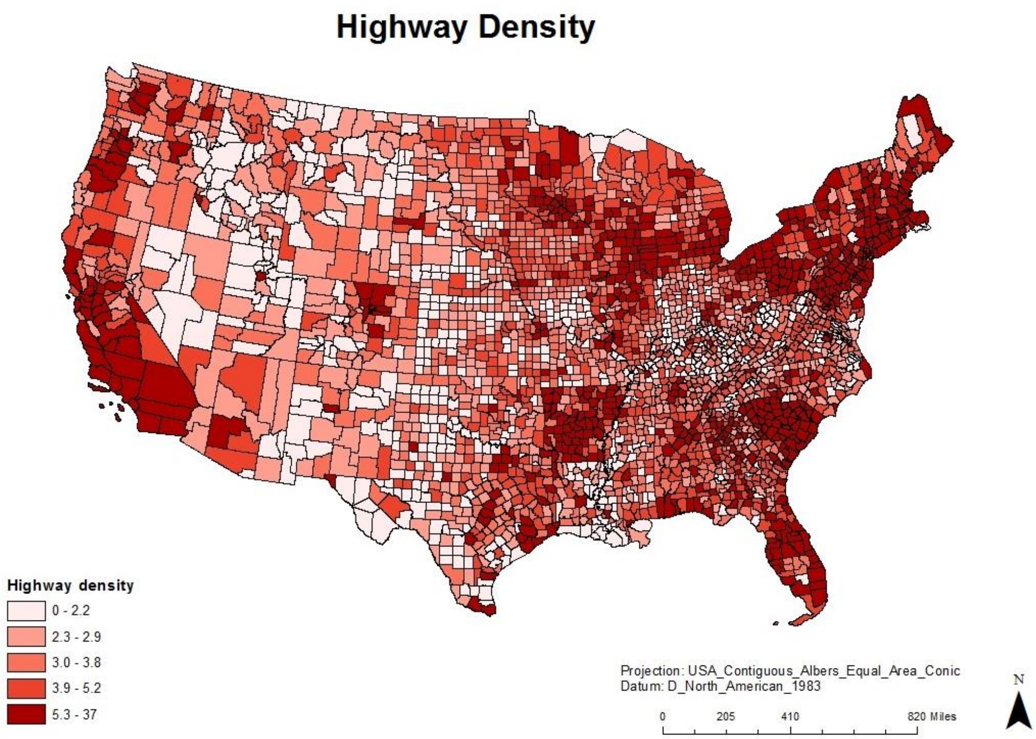

Figure 3.10 Highway Density

3.4 Measures of Control Variables

Socioeconomic status, race, age, and sex are among the most important variables in demographic analysis (Bogue 1969: 147). These variables interact with each other and influence all kinds of population change, including changes of age and sex structure, total population size, and migration. Therefore, in this study, several demographic variables are controlled. These variables are: population density, income, educational attainment, and migration rates by age and race.

Population density is measured with Census data as population per square mile. Income is measured as the median household income. Educational attainment is measured by the percentage of people 25-34 years old with a bachelor's degree or higher level of education.

Separate migration rates for the middle age, old, whites, blacks, and Hispanics are analyzed to control the effects of age and race on population change. These variables are derived from data on age-specific net migration estimates for U.S. counties from 1990 to 2000 (Winkler et al. 2013a). The middle age group includes people 30-54 years old and the old age group includes people 55-74 years old. Working-age adults and retirees prefer high amenity areas (Deller et al. 2001; Gunderson et al. 2008; Whisler et al. 2008). In addition, increased demand for amenities and recreation is associated with rising income and the aging of the population (Graves 1979, 1980; Rappaport 2007).

3.5 Analytical Strategy

There are two types of spatially organized data: point data (such as data for geo-located individual locations) and lattice data (such as data for counties, states, provinces, and countries) (Ward and Gleditsch 2008). The data in this study are the latter type. Lattice data have characteristics of spatial dependence. Thus, in a spatial context, the distributions of the variables in this study do not conform to the assumptions (e.g., independence and uncorrelatedness) of classical multivariate linear regression models. For example, the Y values (population change and net migration rate) in one county may be affected by Y values in adjacent counties; Y values may not only be affected by X values in the same county but also by X values in nearby counties; and the errors may be spatially correlated across counties. Spatial dependence can lead to unreliable standard linear regression results, such as under- or over-estimated regression coefficients and misleading significance tests (Doreian 1980). Since the data are geographically referenced and spatially clustered, spatial regression models should be used to treat spatial dependence issues. Spatial regression models can examine relationships between variables and their neighboring values. Hence, the study's analytical strategy is to: perform exploratory spatial data analysis (ESDA), determine neighborhood structure (create a weights matrix), diagnose spatial autocorrelation, run the classical OLS regression with diagnostics and choose spatial models, and conduct spatial models analysis.

ESDA refers to the description of spatial data by displaying data distributions on maps to discover atypical locations, spatial outliers, spatial homogeneity, and heterogeneity (Anselin 1999; Haining 1990). On maps, the distributions of dependent and independent variables can be observed directly, and the cluster and dispersion of each variable can be identified. Since the dependent variable data in this study are for spatial units (counties) and do have spatial interaction and diffusion effects with each other, according to the literatures reviewed earlier, spatial autocorrelation (spatial dependence) is assured. This means the value observed in one location depends on the values observed at neighboring locations. Indeed, the first law of geography is, "everything is related to everything else, but near things are more related than distant things" (Tobler 1970:234). This law emphasizes that physical adjacency is an essential element in spatial data analysis.

Spatial autocorrelation should be seriously considered because this condition violates the traditional linear regression assumptions (for example, the assumption that the residuals are uncorrelated). The most widely-used measure of spatial autocorrelation is Moran's I statistic (Chi and Zhu 2007). This statistic calculates the linear association between a value in a given location with a weighted average of its neighbors' respective values (Moran 1950). The formula for the Moran's I statistic is (Cliff and Ord 1981:17):

$$\frac{n}{\sum_{i=1}^{n}\sum_{j\neq i}^{n} W_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(z_i - \bar{z})(z_j - \bar{z})}{\sum_{i=1}^{n}(z_i - \bar{z})^2} \tag{3.4}$$

where n is the number of spatial units in the sample; i and j are any two of the spatial units; z_j (or z_i) is the value of the variable of interest for spatial unit j (or i); $\bar{z}$ is the average of neighboring observations; and W_{ij} is spatial weight matrices. Spatial autocorrelation tests indicated by Moran's I "assess the extent to which the observed spatial arrangement of data values departs from the null hypothesis that space does not matter" (Fischer and Wang 2011: 23). The alternative hypothesis is the existence of spatial dependence.

Both ArcGIS and GeoDa have the Moran's I tool to evaluate whether data are clustered, dispersed, or random. This study uses ArcGIS to generate all maps and Geoda to run all analyses. Moran's I is a global statistics detecting the overall pattern of data. The value of Moran's I ranges from -1 to 1. A positive value indicates positive clustering, which means that values for neighboring units are similar to one another. A negative value indicates dispersion. The Moran's I of the net migration rate and population change will reveal whether spatial dependence patterns affect these variables. However, Moran's I only yields one value to access spatial autocorrelation.

In contrast, the Local Index of Spatial Association (LISA) (Anselin 1995) provides local spatial clustering statistics for one or a few particular spatial units. In this dissertation, using LISA can identify which counties are significantly clustered. The formula of LISA (Fisher and Wang 2011:27) is expressed as:

$$I_i = (z_i - \bar{z}) \sum_{j \in J_i}^{n} W_{ij}(z_j - \bar{z})^2 \quad (3.5)$$

where n is the number of spatial units in the sample; i and j are any two of the spatial units; z_j (or z_i) is the value of the variable of interest for spatial unit j (or i); $\bar{}$ is the average of neighboring observations; W_{ij} is spatial weight matrices; and J_i represents the neighborhood set of spatial unit i and the summation in j runs only over those spatial units belonging to J_i. As Anselin (1995: 94) states: "the LISA for each observation gives an indication of the extent of significant spatial clustering of similar values around that observation; the sum of LISAs for all observations is proportional to a global indicator of spatial association." Positive LISA values suggest similar clustering and negative LISA values suggest dispersion.

In spatial data analysis, defining the spatial weight matrix is very important because spatial statistics integrate space relationships directly into mathematical process. The spatial weight matrix is like a parameter which should be estimated before conducting an analysis. A spatial weight matrix represents the spatial relationships and structure of a dataset. Common spatial weight matrices are (ArcGIS Resources 2014): (1) inverse distance, which assumes that all features influence each other, but the strong influences come from near and weak influences come from farther away, so a threshold distance value should be specified to make sure neighbors with different distances are weighted differently; (2) fixed distance, which defines a fixed sphere of influence, so that neighbors within the specific distance are weighted equally; (3) K nearest neighbors, which sets the exact number of the closet neighbors to the target feature; and (4) contiguity, which defines neighbors by their common boundary.

The different selection of spatial weights matrices will cause different values of Moran's I. In principle, the selection of spatial weight matrices is based on how the matrices can accurately reflect the features of interest, but there is little theory to guide researchers (Anselin 2002; Chi and Zhu 2007). In practice, one may compare several spatial weight matrices and choose the one that has a high coefficient of spatial autocorrelation along with a high level of statistical significance (Voss and Chi 2006). GeoDa will be used to generate these different spatial weight matrices and then to test the significance of Moran's I using all these weight matrices. The results will indicate which weight matrices can better capture the spatial autocorrelation of the dependent variables.

The Lagrange Multiplier diagnostic will determine the appropriate spatial model using GeoDa. First, the classical OLS regression model with a selected spatial weight matrix will be estimated. Second, residuals for the spatial dependence diagnostics will be checked. Third, the appropriate spatial regression model will be selected based on the Lagrange Multiplier test. Finally, the estimates of the spatial regression model or models will be interpreted. In sociology, two spatial regression models are used in modeling physical and social phenomena embedded with networks of independence (Leenders 2002). One is the spatial error model. The other is the spatial lag model. Both models attempt to correct for spatial dependence in the error term (Anselin 2001).

The spatial error model examines spatial autocorrelation between the errors of neighbors. The function of this model is:

$$y = X\beta + \varepsilon, \text{ with } \varepsilon = \lambda W \varepsilon + u \quad (3.6)$$

where y is a vector of observations for the dependent variable; W is the spatial weight matrix; X is a matrix of observations for the independent variables; ε is a vector of spatially autocorrelated error terms; u is a vector of independent and identically distributed errors; and λ and β are parameters to be estimated (Anselin 2001). The model is illustrated below:

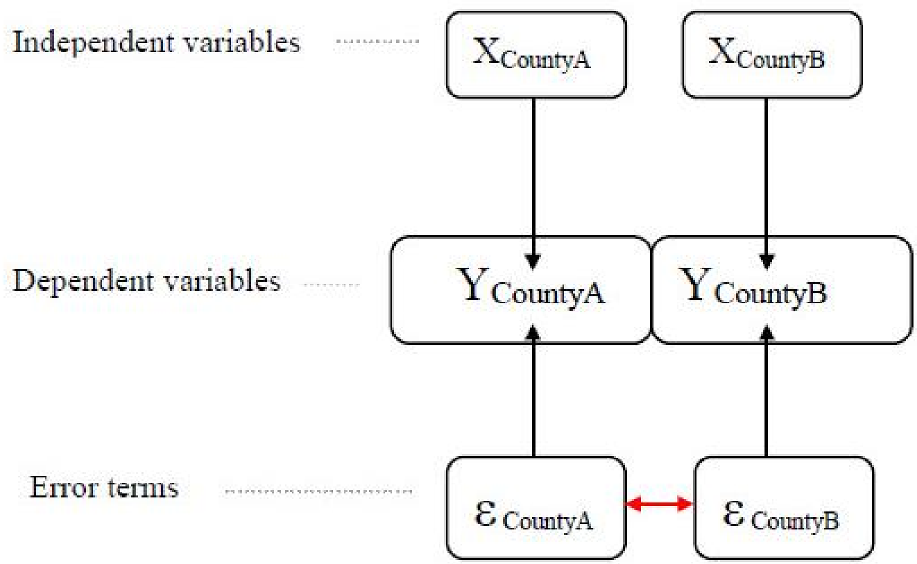

Figure 3.11 Spatial Error Model

In the spatial error model, the error terms across different spatial locations are correlated, e.g., the error term of county A is correlated with the error term of county B. A significant test statistic for spatial error indicates that spatial autocorrelation may be caused by the omission of important explanatory or control variables from the model.

The spatial lag model examines the interaction of values of the dependent variable across spatial units. The function of this model is:

$$y = \rho Wy + X\beta + \varepsilon \qquad (3.7)$$

where y is a vector of observations for the dependent variables; Wy is a spatially lagged dependent variable for weight matrix W; X is a matrix of observations for the independent variables; ε is a vector of independent and identically distributed error terms; and ρ and β are parameters to be estimated (Anselin 2001). This model is illustrated below:

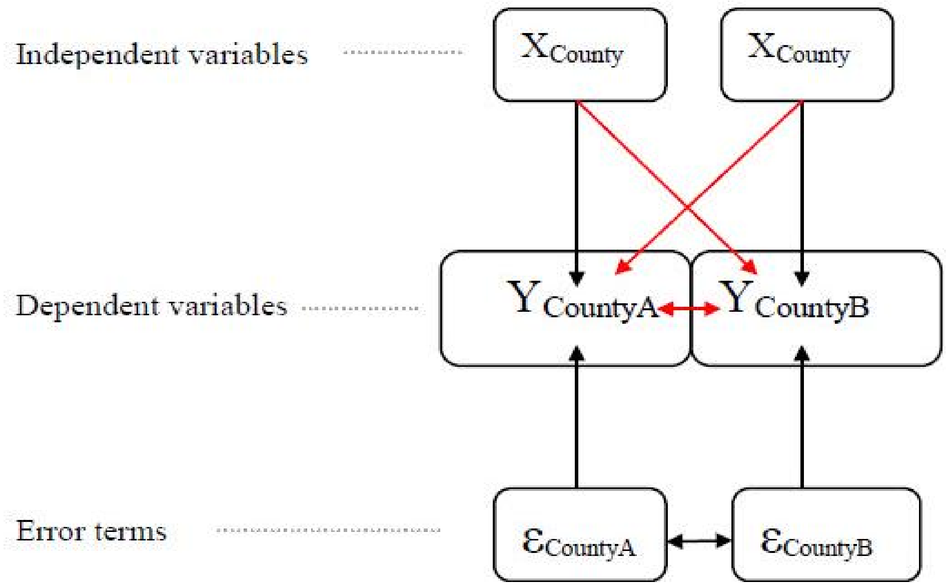

Figure 3.12 Spatial Lag Model

In this example of the spatial lag model, the dependent variable of county A is affected by the independent variables in both county A and county B. A significant test statistic for spatial lag indicates that the value of the dependent variable in one area is directly influenced by the values of the dependent variable in neighboring areas. In this study, the spatial lag model will show if a county's population change is associated with its neighbors' population change. Such association might be a substantive feature of population change in the U.S. If the tests for the error and lag are both significant, then further examination with robustness tests in GeoDa will be conducted to determine the appropriate spatial regression model.

CHAPTER IV

DESCRIPTIVE STATISTICS AND SPATIAL WEIGHT MATRICES

This chapter presents the descriptive statistics of the dependent, explanatory, and control variables for each of the three geographic groups included in the analyses. A correlation matrix for all variables is then provided. The selection of spatial weight matrices is also discussed.

4.1 Descriptive Statistics

There are 3,109 counties in the U.S., which are subdivided into two groups based on the USDA 2003 Rural-Urban Continuum classification (see Table 3.1): 2,023 nonmetropolitan counties and 1,086 metropolitan counties. Table 4.1 shows the valid cases (the number of non-missing values) for each variable for all U.S. counties, nonmetropolitan counties, and metropolitan counties.

Table 4.1 Valid Cases (N) of Each Variable

Variables	All Counties	Nonmetropolitan Counties	Metropolitan Counties
Net migration rate	3,109	2,023	1,086
Population change	3,109	2,023	1,086
Natural amenity scale	3,109	2,023	1,086
Forest coverage	3,109	2,023	1,086
Land developability	3,109	2,023	1,086
Arts, entertainment, and recreation establishments	3,108	2,023	1,085
Highway density	3,109	2,023	1,086
Airport accessibility	3,109	2,023	1,086
Educational attainment	3,108	2,023	1,085
Population density	3,108	2,023	1,085
Household income	3,108	2,023	1,085
White net migration rate	3,104	2,022	1,082
Black net migration rate	2,981	1,903	1,078
Hispanic net migration rate	3,091	2,009	1,082
Middle age net migration rate	3,104	2,022	1,082
Old age net migration rate	3,104	2,022	1,082
Valid N (listwise)	2,977	1,899	1,078

As shown in Table 4.2, the average net migration rate, measured as a percentage, and average population change, measured as the natural log of the county population, over the population ten years earlier, for all U.S. counties, are respectively 2.58 (2.58 per 100 individuals migrating into a county) and 0.04 (population increase in a county). The average net migration rate and average population change are positive for both nonmetropolitan and metropolitan counties. However, the average net migration rate and average population change are higher in metropolitan counties than in nonmetropolitan counties. The difference indicates that, on average, both metropolitan and nonmetropolitan counties have in-migration and population increases; but the metropolitan counties have higher in-migration rates and population increases than nonmetropolitan counties. This trend indicates that the nonmetropolitan turnaround may not continue in the 2000s; rather, the metropolitan counties continue to gain more population than the nonmetropolitan areas in 2000s on the average.

The average score of the natural amenity scale is lower in nonmetropolitan counties than in metropolitan counties. The average forest coverage for U.S. counties is 29.84%. The average percentage of forests is slightly lower in nonmetropolitan counties than in metropolitan counties. The average percentage of land developablity of U.S. counties is 70.75. On average, nonmetropolitan counties have more developable land than do metropolitan counties. Arts, entertainment, and recreation establishments were normalized by the population in the year 2000. The average number of these establishments is 0.43 per 1,000 individuals for U.S. counties. This number is higher in nonmetropolitan counties than in metropolitan counties. On the whole, metropolitan counties have higher natural amenities values (e.g., higher natural amenity scale and forest coverage) and lower human-built amenities values (e.g., less developable land and fewer arts, entertainment, and recreation establishments per 1,000 people) than do nonmetropolitan counties on the average.

Table 4.2 Descriptive Statistics of Variables

Variables	All Counties Mean (std. dev.)	Nonmetropolitan Counties Mean (std. dev.)	Metropolitan Counties Mean (std. dev.)
Net migration rate 2000-2010	2.58 (10.40)	0.39 (8.91)	6.67 (11.66)
Population change 2000-2010	0.04 (0.12)	0.01 (0.10)	0.11 (0.13)
Natural amenity scale	0.05 (2.28)	-0.06 (2.24)	0.25 (2.32)
Forest coverage	29.84 (25.44)	29.49 (26.69)	30.47 (22.93)
Land developability	70.75 (26.56)	72.42 (27.43)	67.65 (24.57)
Arts, entertainment, and recreation establishments	0.43 (0.43)	0.46 (0.49)	0.38 (0.26)
Highway density	4.01 (2.75)	3.21 (1.57)	5.49 (3.69)
Airport accessibility	4.01 (2.79)	2.83 (2.12)	6.20 (2.56)
Educational attainment	16.51 (7.80)	14.36 (5.70)	20.51 (9.44)

Table 4.2 (Continued)

Population density	244.54	44.08	618.30
	(1675.87)	(98.43)	(2795.90)
Household income	35,266.95	31,849.45	41,638.95
	(8836.60)	(5882.60)	(9840.03)
White net migration rate	3.84	2.29	6.75
	(13.69)	(12.62)	(15.08)
Black net migration rate	111.07	135.49	67.96
	(604.17)	(669.14)	(465.15)
Hispanic net migration	109.88	116.10	98.32
rate	(266.64)	(314.83)	(137.51)
Middle age net migration	11.61	10.62	13.47
rate	(18.74)	(16.89)	(21.67)
Old age net migration	9.37	10.58	7.11
rate	(17.61)	(17.66)	(17.28)
N	3109	2023	1086

The average highway density for all U.S. counties is 4.1 (mile/$\sqrt{mile^2}$). Metropolitan counties have a higher average highway density than do nonmetropolitan counties. The average airport accessibility score is 4.01 for all U.S. counties, with metropolitan counties having higher average airport accessibility scores than nonmetropolitan counties. It is not surprising that metropolitan counties tend to have better transportation accessibility than nonmetropolitan counties.

For all U.S. counties, 16.51% of persons 25-34 years old have a bachelor's degree or higher credential. This value is 20.51% for metropolitan counties and 14.36% for nonmetropolitan counties. The average population density for all U.S. counties is 245 persons per square mile. As expected, metropolitan counties have 618 people per square mile, a value that is much higher than that of nonmetropolitan counties. For all U.S. counties, the average household income is 35,266.95 dollars. For metropolitan counties and nonmetropolitan counties the average household incomes are 41,638.95 dollars and 31,849.45 dollars, respectively.

The mean net migration rate for whites in all U.S. counties is 3.84 per 100 individuals. For metropolitan counties, this rate is 6.75 per 100 individuals, which is higher than that of nonmetropolitan counties, at 2.29 per 100 individuals. In contrast, the mean net migration rates for black and Hispanic are higher in nonmetropolitan counties than in metropolitan counties. For nonmetropolitan counties, the mean black and Hispanic net migration rates are 135.49 per 100 individuals and 116.1 per 100 individuals, respectively.

It should be noted that black and Hispanic net migration rates almost always exhibit higher values in nonmetropolitan counties than in metropolitan counties. This is because, in many nonmetropolitan counties, the expected black and Hispanic populations are very small; a very small number of net migrants in these race groups can yield large values of net migration rates. Therefore, the values of black and Hispanic net migration rates reflect positive net migration in both nonmetropolitan and metropolitan counties, but these values do not necessarily suggest that more black and Hispanic people migrate to nonmetropolitan counties than to metropolitan counties.[2]

The mean net migration rate for the middle age population for all U.S. counties is 11.61 per 100 individuals. Metropolitan counties have a higher average middle age net migration rate (13.47 per 100 individuals) than do nonmetropolitan counties (10.62 per 100 individuals). In contrast, the old age net migration rate in nonmetropolitan counties (10.58 per 100 individuals) is higher than that of metropolitan counties (7.11 per 100 individuals). For all U.S. counties, the average old age net migration rate is 9.37 per 100 individuals.

Table 4.3 shows the mean difference between metropolitan counties and nonmetropolitan counties for each variable. On average, both metropolitan and nonmetropolitan counties have positive net migration and population growth, and the difference between metropolitan counties and nonmetropolitan counties is statistically significant. The average natural amenity scale is higher in metropolitan counties than in nonmetropolitan counties, and the difference is statistically significant. The average proportion of forest coverage is similar in both metropolitan and nonmetropolitan counties, and the difference is not statistically significant. The average proportions of land developability and arts, entertainment, and recreation establishment density are lower in metropolitan counties than in nonmetropolitan counties, and the differences are statistically significant. The average highway density and airport accessibility are higher

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[2] This issue was discussed with Dr. Winkler, the principal investigator of the project http://www.netmigration.wisc.edu/, through Email (Oct 11-16, 2015).

in metropolitan counties than in nonmetropolitan counties, and the differences are statistically significant.

On the average, metropolitan counties have more educated populations, higher population density, and higher household income than do nonmetropolitan counties. On the average, the percentage of people between 25-34 years old who have a bachelor's degree or higher credential is 6.15% greater in metropolitan counties than in nonmetropolitan counties. Average population density is 574 more persons per square mile in metropolitan counties than in nonmetropolitan counties. Average household income is 9,789.50 dollars more in metropolitan counties than in nonmetropolitan counties. All of these differences are statistically significant.

Metropolitan counties have higher white and middle age net migration rates than do nonmetropolitan counties. In contrast, black, Hispanic, and old age net migration rates are higher in nonmetropolitan counties than in metropolitan counties. The net migration differences between metropolitan and nonmetropolitan counties are statistically significant.

The comparison reveals that metropolitan counties have significantly higher average net migration rates, population increases, natural amenity endowment (excluding arts, entertainment, and recreation establishments and forest), and transportation advantages than do nonmetropolitan counties.

Table 4.3 Comparison of Means for Nonmetropolitan and Metropolitan Counties

Variables	Mean Difference (Metropolitan counties-Nonmetropolitan counties
Net migration rate	6.28***
Population change	0.10***
Natural amenity scale	0.31***
Forest coverage	0.98
Land developability	-4.77***
Arts, entertainment, and recreation establishments	-0.08***
Highway density	2.28***
Airport accessibility	3.37***
Educational attainment	6.15***
Population density	574.21***
Household income	9789.50***
White net migration rate	4.46***
Black net migration rate	-67.53**
Hispanic net migration rate	-17.78*
Middle age net migration rate	2.85***
Old age net migration rate	-3.47***

Notes: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

4.2 Correlation Matrix for All Variables

Table 4.4 shows the correlations of all variables. Independent variables are not highly correlated. Some control variables with relatively high correlations are indicated by shading in Table 4.4. In the following analyses, all control variables are included in the models because no multicollinearity problem is detected and the model fit is improved compared to models with selected control variables. The models with selected control variables are presented in the appendix.

Table 4.4 Correlation Matrix for All Variables

	Net	Pop_c	Nat	For	Land	Rec	Hw	Aa	Edu	Pop_d	H_inc	Net_w	Net_b	Net_h	Net_m	Net_o
Net	1															
Pop_c	0.916**	1														
Nat	0.248**	0.269**	1													
For	0.200**	0.156**	0.196**	1												
land	-0.123**	-0.149**	-0.491**	-0.286**	1											
Rec	0.035	-0.005	0.162**	-0.066**	-0.229**	1										
Hw	0.069**	0.148**	0.040*	-0.012	-0.115**	-0.040*	1									
Aa	0.277**	0.385**	0.069**	0.046*	-0.114**	-0.053**	0.425**	1								
Edu	0.209**	0.303**	0.181**	-0.113**	-0.190**	0.352**	0.365**	0.379**	1							
Pop_d	-0.021	0.016	0.021	-0.073**	-0.164**	0.047**	0.245**	0.255**	0.212**	1						
H_inc	0.334**	0.449**	0.022	-0.106**	-0.057**	0.163**	0.377**	0.494**	0.659**	0.131**	1					
Net_w	0.645**	0.568**	0.302**	0.282**	-0.147**	0.123**	-0.080**	0.148**	0.104**	-0.076**	0.230**	1				
Net_b	-0.027	-0.046*	-0.040*	-0.012	0.001	0.019	-0.051**	-0.072**	-0.047*	-0.022	-0.012	0.061**	1			
Net_h	0.051**	0.044*	-0.073*	0.108**	0.062**	-0.049**	-0.031	-0.003	-0.085**	-0.028	-0.044*	0.103**	0.015	1		
Net_m	0.510**	0.436**	0.273**	0.156**	-0.136**	0.142**	-0.118**	0.073**	-0.028	-0.080**	0.224**	0.833**	0.139**	0.110**	1	
Net_o	0.507**	0.352**	0.370**	0.241**	-0.249**	0.109**	-0.136**	-0.052**	-0.106**	-0.105**	-0.110**	0.777**	0.054**	0.086**	0.674**	1

Notes: **Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).
Net = Net migration rate; Pop_c = Population change; Nat = Natural amenity scale; For = Forest coverage; Land = Land developability; Rec = Arts, entertainment, and recreation establishments; Hw = Highway density; Aa = Airport accessibility; Edu = Educational attainment; Pop_d = Population density; H_inc = Household income; Net_w = White net migration rate; Net_b = Black net migration rate; Net_h = Hispanic net migration rate; Net_m = Middle age net migration rate; Net_o = Old age net migration rate.

4.3 Spatial Weight Matrices

In order to assess the potential spatial dependence of the data, it is necessary to define a neighborhood structure via a spatial weight matrix for each location (Anselin, 1988). Researchers may use different spatial weight matrices based on their theoretical, empirical, and data interests. Table 4.5 lists the well-known spatial weight matrix conceptualizations. For lattice data, contiguity weight matrices are often used to specify neighboring structures. The classical contiguity weight matrices are the rook, the bishop, and the queen contiguity weight matrices (Fischer and Wang 2011). The higher order contiguity is defined in a recursive manner: "objects that are viewed to be second order contiguous to an object are first order contiguous to the first order contiguous ones" (Fischer and Wang 2011:9). This dissertation examines lattice data (county); thus, the contiguity-based spatial weight matrices selected are the first-order and second-order rook and queen weight matrices. In this study, the first-order rook weight matrix defines a county's neighbors as those areas with shared borders. The first-order queen weight matrix defines a county's neighbors as those with either a shared border or vertex. The second-order queen and rook contiguity weight matrices define a county's neighbors as neighbors of the county's first-order neighbors (Figure 4.1 illustrates the order of contiguity).

Table 4.5 Typical Spatial Weight Matrices

Well-known schemes
1. spatially contiguous neighbors
2. inverse distances raised to some power
3. lengths of shared borders divided by the perimeter
4. bandwidth as the n^{th} nearest neighbor distance
5. ranked distances
6. constrained weights for an observation equal to some constant
7 all centroids with distance *d*
8 *n* nearest neighbors
Newer schemes
1. bandwidth distance decay
2. Gaussian distance decline
3. "tri-cube" distance decline function

Source: Getis and Aldstadt (2004:91)

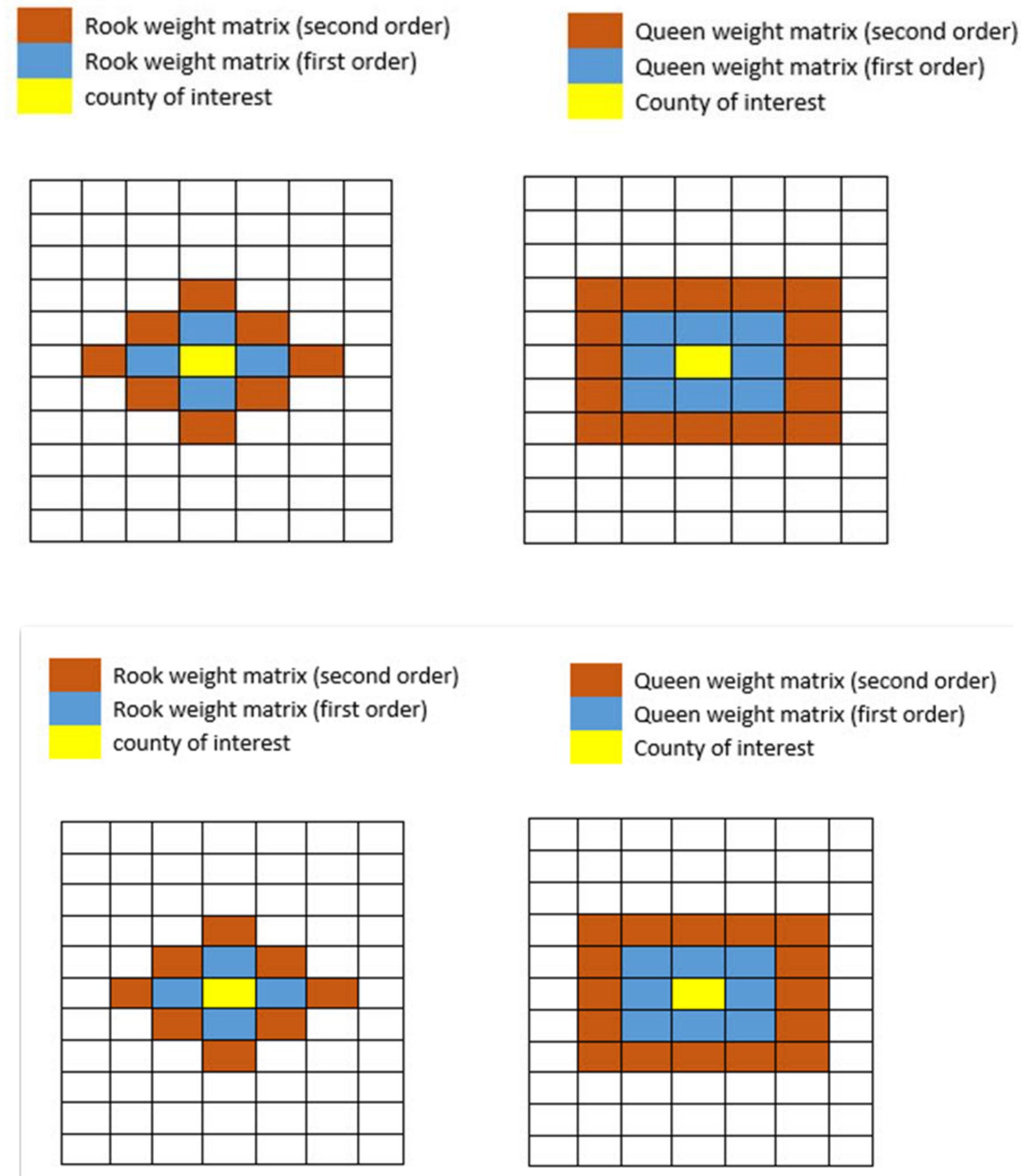


Figure 4.1 Rook and Queen Spatial Weight Matrices

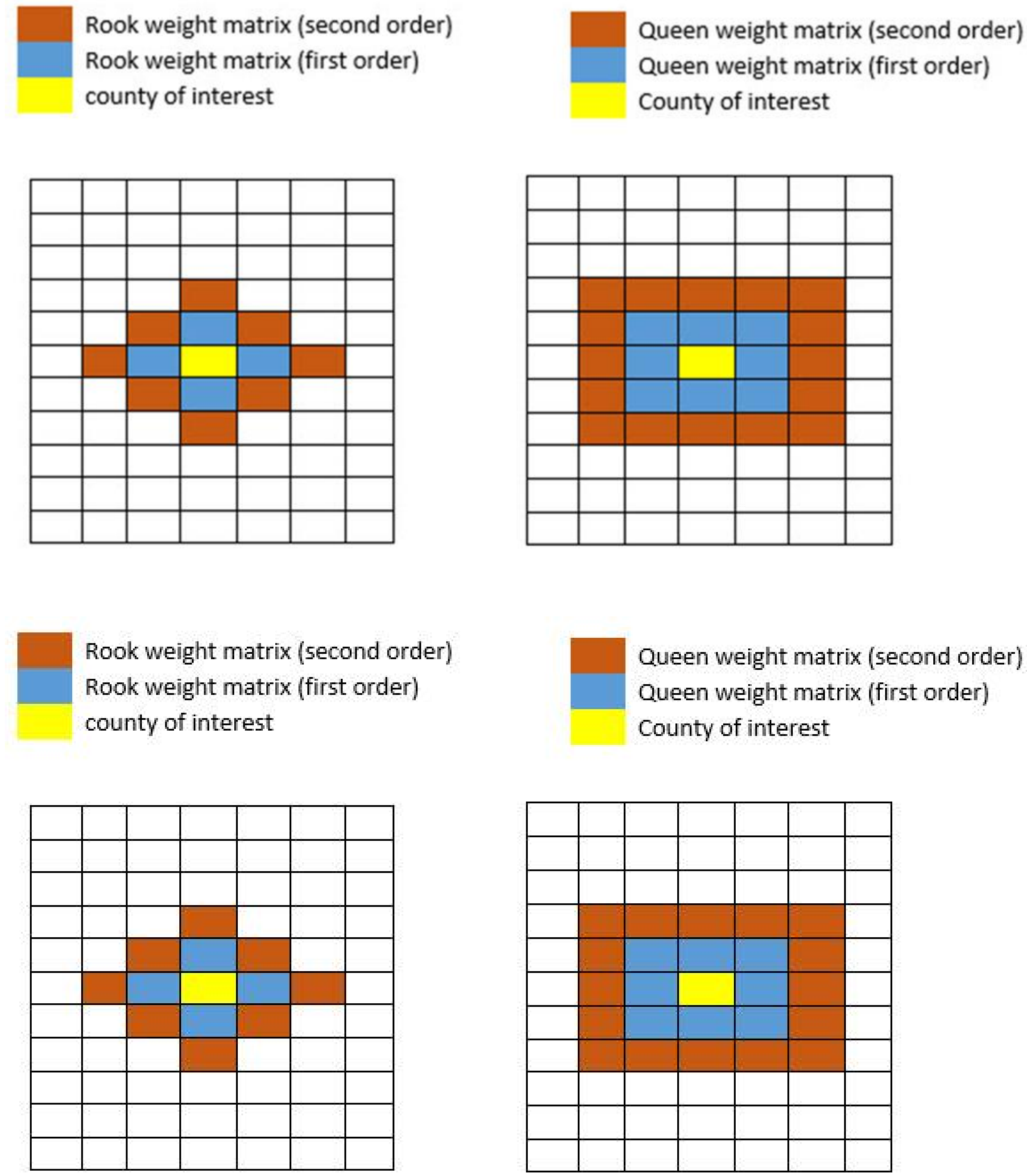


Figure 4.1 (Continued)

A visual examination of the dependent variables in Figure 3.2 suggests that the spatial autocorrelation of population change and net migration is plausible. In order to explore spatial autocorrelation in these variables, the specific spatial weight matrices for population change and net migration need to be determined. This dissertation compares four spatial weight matrices and selects the one that has the highest coefficient of spatial autocorrelation (Moran's I) along with a high level of statistical significance.

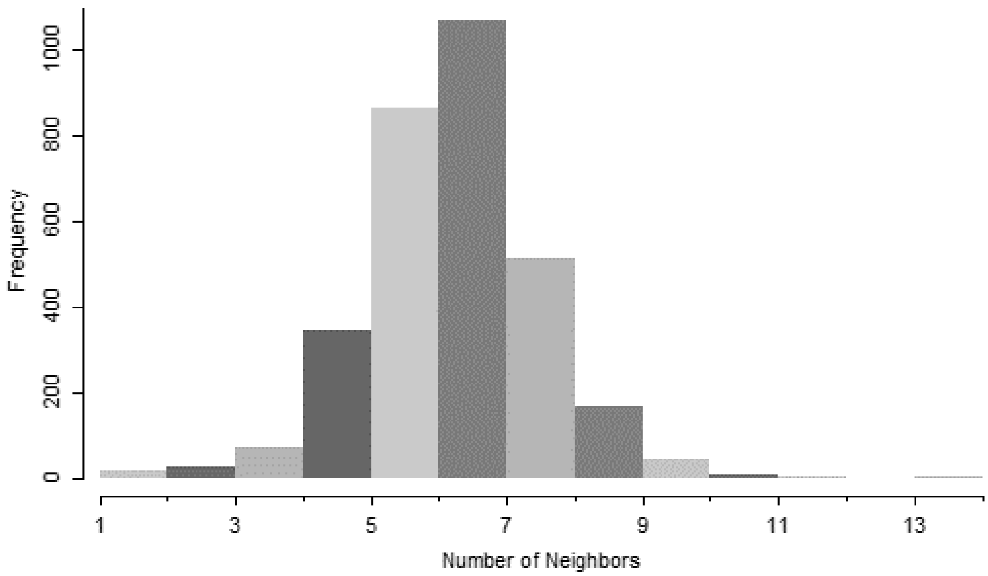
Table 4.5 shows the magnitudes and significances of the Moran's I statistics of the rook and queen contiguity weight matrices, with order 1 and order 2, for the dependent variables across all counties, metropolitan counties, and nonmetropolitan counties. The *p*-values are all less than 0.001 indicating that there are statistically significant spatial autocorrelations of population change and net migration rates, from 2000 to 2010, across different regional types. The specific spatial weight matrix is selected if it provides the highest Moran's I statistic. Therefore, as indicated by shading in Table 4.6, rook contiguity weight matrix order 1 is selected for the purpose of analyzing population change and net migration in all U.S. counties and nonmetropolitan counties. Queen contiguity weight matrix order 1 is selected for analyzing population change and net migration in metropolitan counties.

Table 4.6 Moran's I Values of the Dependent Variables

Spatial Weight Matrix	Moran's I (*p*-value)					
	Population Change			Net Migration		
	All	Metropolitan	Nonmetropolitan	All	Metropolitan	Nonmetropolitan
Queen, Order 1	0.454***	0.346***	0.456***	0.392***	0.297***	0.415***
Queen, Order 2	0.314***	0.224***	0.329***	0.278***	0.197***	0.294***
Rook, Order 1	0.456***	0.345***	0.458***	0.393***	0.295***	0.417***
Rook, Order 2	0.318***	0.229***	0.334***	0.282***	0.201***	0.298***

Notes: * p≤0.05; ** p≤0.01; *** p≤0.001

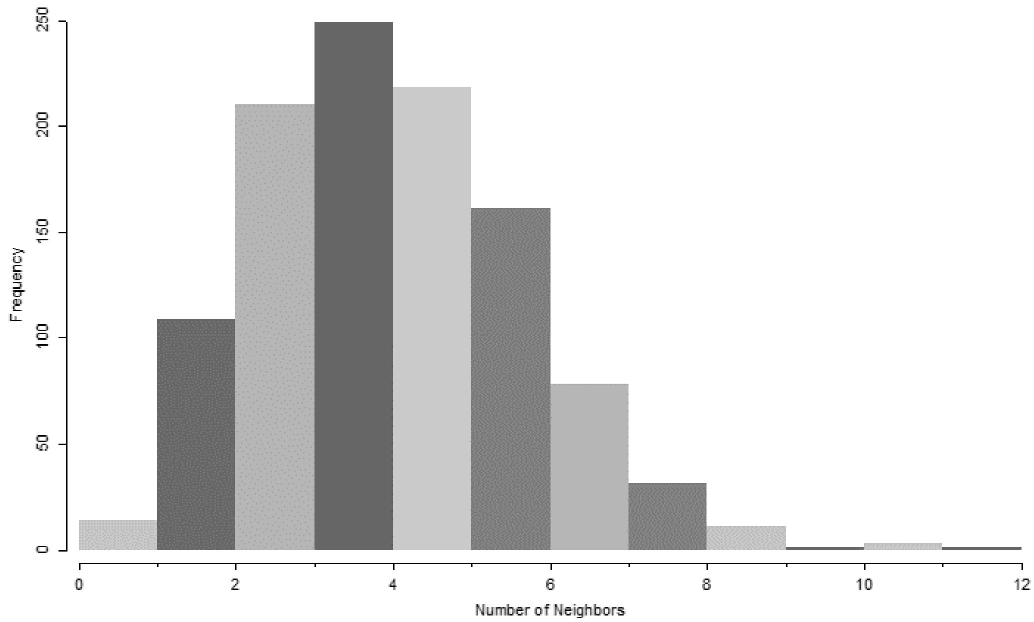
Figures 4.2, 4.3, and 4.4 show neighbor characteristics for each selected spatial weight matrix. Using rook contiguity weight matrix order 1, the average number of neighbors for each county is 6 for all U.S. counties. The maximum number of neighbors for a county is 13. The average number of neighbors defined by queen contiguity weight matrix order 1, is 3 for metropolitan counties. The maximum number of neighbors for a county is 11. There are 14 metropolitan counties that are neighborless because they are adjacent to only nonmetropolitan counties. The average number of neighbors defined by rook weight matrix order 1, is 5 for nonmetropolitan counties. The maximum number of neighbors for a county is 10. There are 8 nonmetropolitan counties that are neighborless because they are adjacent to only metropolitan counties. Based on these selected weight matrices, spatial autocorrelation, model specification, and estimation can be conducted.



from	1	2	3	4	5	6	7	8	9	10	11	12	13
to	2	3	4	5	6	7	8	9	10	11	12	13	14
#obs	14	26	69	343	860	1068	512	165	41	9	1	0	1
% of total	0.45	0.836	2.22	11	27.7	34.4	16.5	5.31	1.32	0.289	0.0322	0	0.0322
sd from mean	-2.89	-2.11	-1.33	-0.551	0	0.229	1.01	1.79	2.57	3.35	4.13	4.91	5.69

min: 1, max: 13, median: 6, mean: 5.70601, s.d.: 1.28215, #obs: 3109

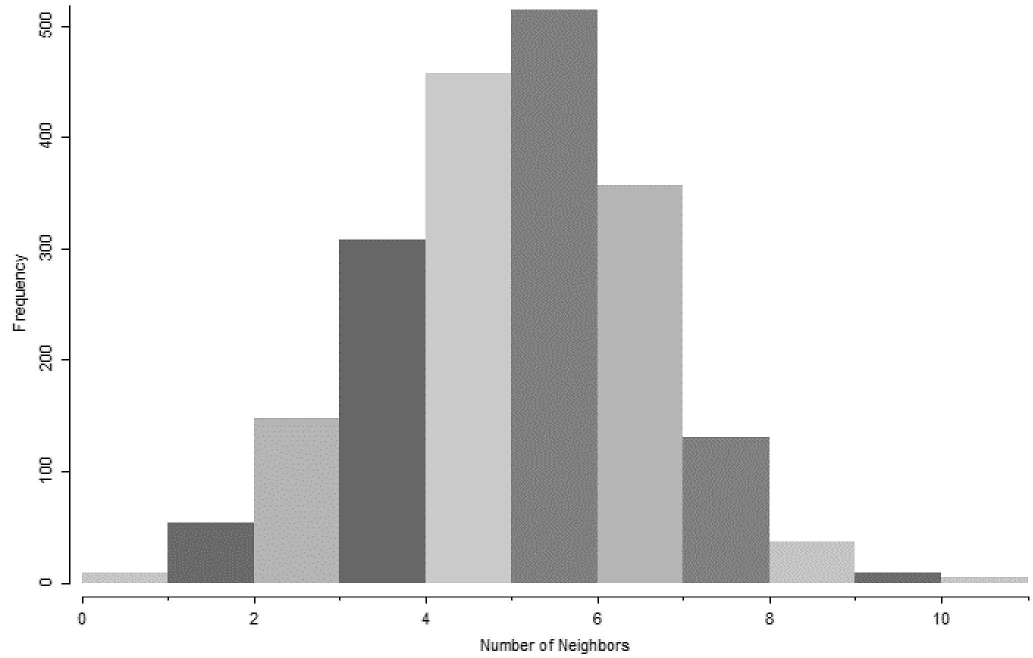
Figure 4.2 Rook Weight Matrix Order 1 Connectivity Histogram for All U.S Counties



from	0	1	2	3	4	5	6	7	8	9	10	11
to	1	2	3	4	5	6	7	8	9	10	11	12
#obs	14	109	210	249	218	161	78	31	11	1	3	1
% of total	1.29	10	19.3	22.9	20.1	14.8	7.18	2.85	1.01	0.0921	0.276	0.0921
sd from mean	-1.46	-0.873	-0.282	0	0.309	0.9	1.49	2.08	2.67	3.26	3.85	4.45

min: 0, max: 11, median: 3, mean: 3.47698, s.d.: 1.6922, #obs: 1086

Figure 4.3 Queen Weight Matrix Order 1 Connectivity Histogram for Metropolitan Counties



from	0	1	2	3	4	5	6	7	8	9	10
to	1	2	3	4	5	6	7	8	9	10	11
#obs	8	53	148	308	457	514	356	130	36	9	4
% of total	0.395	2.62	7.32	15.2	22.6	25.4	17.6	6.43	1.78	0.445	0.198
sd from mean	-2.23	-1.59	-0.958	-0.324	0	0.31	0.944	1.58	2.21	2.85	3.48

min: 0, max: 10, median: 5, mean: 4.51112, s.d.: 1.57715, #obs: 2023

Figure 4.4 Rook Weight Matrix Order 1 Connectivity Histogram for Nonmetropoltian Counties

CHAPTER V

ANALYSES OF RESULTS

This chapter explores the spatial autocorrelations of the dependent variables. First, global and local Moran's I statistics for the dependent variables are examined. Then, an ordinary least-squares (OLS) regression model, a spatial error model, and a spatial lag model will be estimated, to analyze the effects of natural amenities and transportation on population change and net migration rates for all U.S. counties, metropolitan counties, and nonmetropolitan counties. Each set of models is first estimated by OLS regression. The spatial dependence of the model residuals is then diagnosed. The Lagrange Multiplier (LM) test and the robust LM test will determine the use of the spatial regression model. Finally, the OLS model, spatial error model, and spatial lag model are evaluated on the basis of Akaike Information Criterion (AIC) and Schwartz's Bayesian Information Criterion (BIC) (Kuha 2005). Natural amenities variables can be highly correlated, since forests and wetlands (one measure of land developability) overlay one another. Multicollinearity condition numbers will therefore be examined.

5.1 Spatial Autocorrelation Analyses

In randomly distributed data, Pearson's *r* is generally used to measure linear association between variables. In spatially dependent data, for example, as illustrated in Figure 3.2, the high (or low) net migration rates and population increase (or decrease) are very dense in some counties and quite sparse in others. To measure such correlation between feature locations and feature values, the Moran's I statistic is introduced (Moran 1950). The Moran's I statistic is a global autocorrelation statistic, providing one value to measure spatial autocorrelation (association) for an attribute in a region as a whole.

The Moran scatter plots in Figures 5.1 and 5.2 illustrate population change from 2000 to 2010 for each county (*x*-axis) in relation to the average population change of each county's neighbors weighted by rook weight matrix order 1 (*y*-axis) and the net migration rate from 2000 to 2010 for each county (*x*-axis) in relation to the average net migration rate of each county's neighbors weighted by rook weight matrix order 1 (*y*-axis). The quadrants in the scatter plots suggest four types of spatial autocorrelation: high-high (upper right) and low-low (lower left) for positive spatial autocorrelation, high-low (lower right) and low-high (upper left) for negative spatial autocorrelation. As the two scatter plots show, the majority of U.S. counties fall into two quadrants: the upper-right and the lower-left. The upper-right quadrant indicates counties with population growth (or positive net migration rates) surrounded by counties with population growth (or positive net migration rates). The lower-left quadrant indicates counties with population decline (or negative net migration rates) surrounded by counties with population decline (or negative net migration rates). In contrast, the upper-left quadrant indicates counties with population decline (or negative net migration rates) surrounded by counties with population growth (or positive net migration rates). The lower-right indicates counties with population growth (or positive net migration rates) surrounded by counties with population decline (or negative net migration rates). Fewer counties fall into these two quadrants. The respective slopes of the regression lines in the Moran scatter plots are 0.456 for population change and 0.393 for net migration rates, which reflect positive spatial autocorrelations of these variables from 2000 to 2010.

Figures 5.3 and 5.4 display the LISA cluster maps for population change and net migration rates from 2000 to 2010, by the combinations of local clusters[3] and spatial outliers with different colors: high-high, low-low, low-high, and high-low regions, where the local Moran statistic is significant at the 0.05 level, by randomization procedure. High-high regions are represented by red color. Low-low regions are represented by blue color. Spatial outliers (low-high and high-low regions) are represented by yellow and green colors. For population changes from 2000 to 2010, the high-high counties are mostly found, for example, in Washington, southern California, eastern Nevada, Arizona, Utah, Wyoming, Colorado, Texas (Dallas, Austin, and Houston areas), Florida, Tennessee, Georgia, North Carolina, and Virginia. In these areas, high population growth counties are surrounded by high population growth counties. The cold spots counties are mostly found, for example, in the Mississippi delta, Arkansas (adjacent to Mississippi delta), Louisiana (southeast corner), northern Texas, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, Wisconsin, Michigan, western Pennsylvania, and the junction areas of Western Virginia and Kentucky. In these areas, low population growth or declining counties are surrounded by low population growth or declining counties. The distributions of high-high cluster and low-low cluster for net migration rates from 2000 to 2010 demonstrate a geographic pattern similar to population changes from 2000 to 2010.

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[3] "The LISA cluster map only shows the center of the cluster in color. The actual extent of the cluster includes the center and the surrounding neighbors as defined by the weights matrix" (GeoDa Center, n.d.).

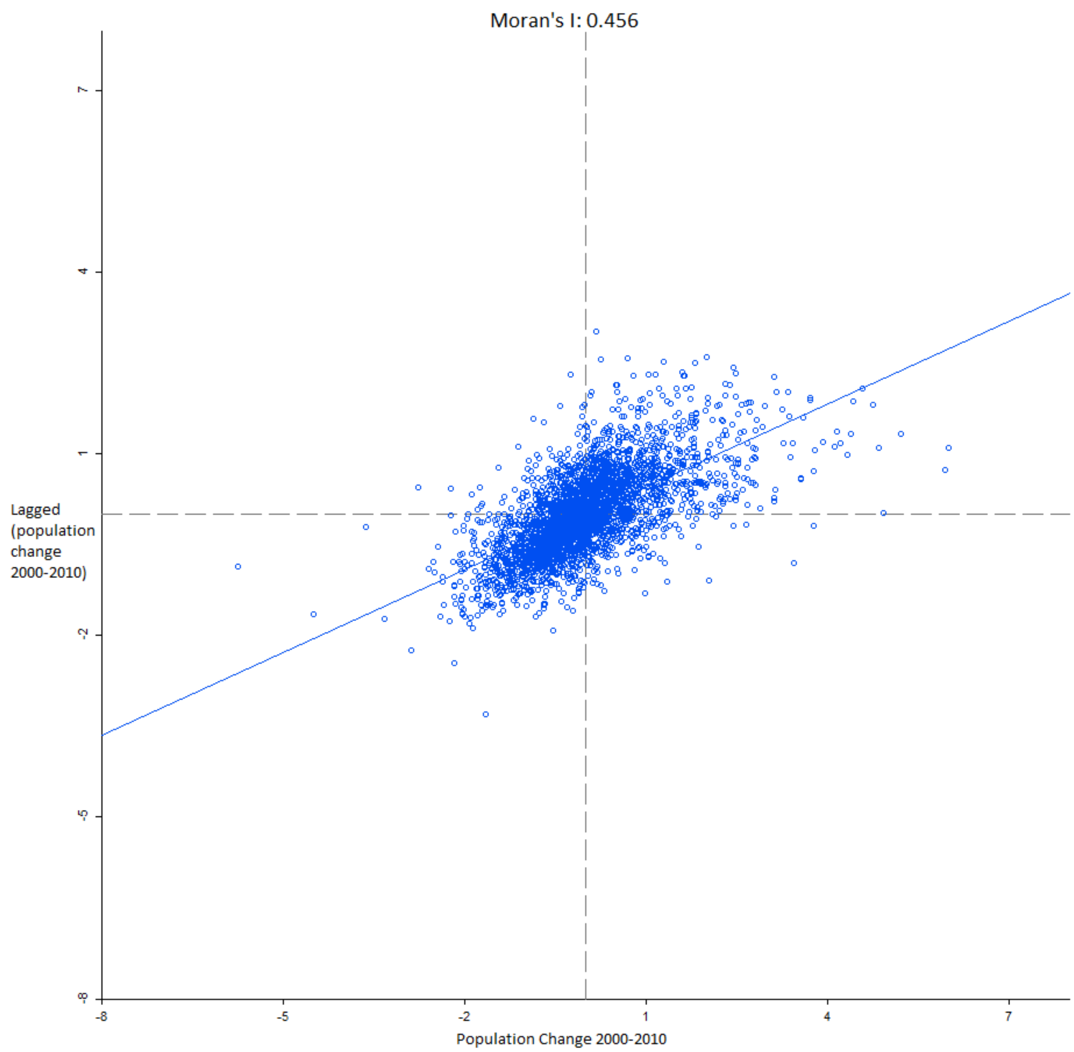

Figure 5.1 Moran's I Scatter Plot of Population Change from 2000-2010 for all U.S. Counties

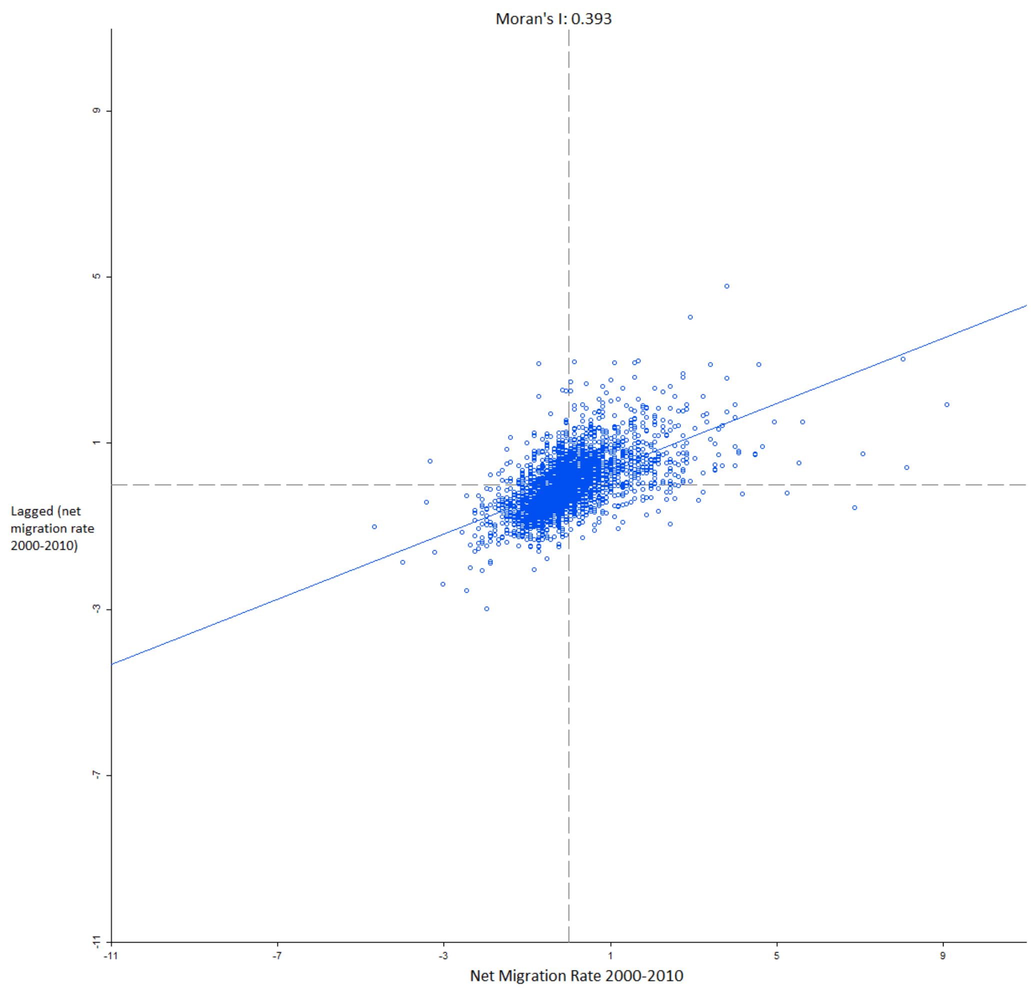

Figure 5.2 Moran's I Scatter Plot of Net Migration Rate from 2000 to 2010 for all U.S. Counties

The spatial outliers are represented by yellow and green colors. Yellow color counties with negative local Moran's I values indicate low-high outliers, where low population growth (or low net migration rate) counties are surrounded by high population growth (or high net migration rate) counties. For example, Millard County in Utah experienced low population growth from 2000 to 2010, when its neighboring (defined by first-order rook weight matrix) counties experienced high population growth from 2000 to 2010. Green color counties with negative local Moran's I values indicate high-low outliers where high population growth (or high net migration rate) counties are surrounded by low growth or declining population (or low net migration rate) counties. For example, Lincoln and Garfield counties in Nebraska experienced high population growth from 2000 to 2010 compared to their neighboring low population growth and population declining (defined by first-order rook weight matrix) counties. Such spatial outliers highlight interesting counties, indicative of spatial anomalies, which suggest these counties have quite different population change patterns from those of their spatial neighbors.

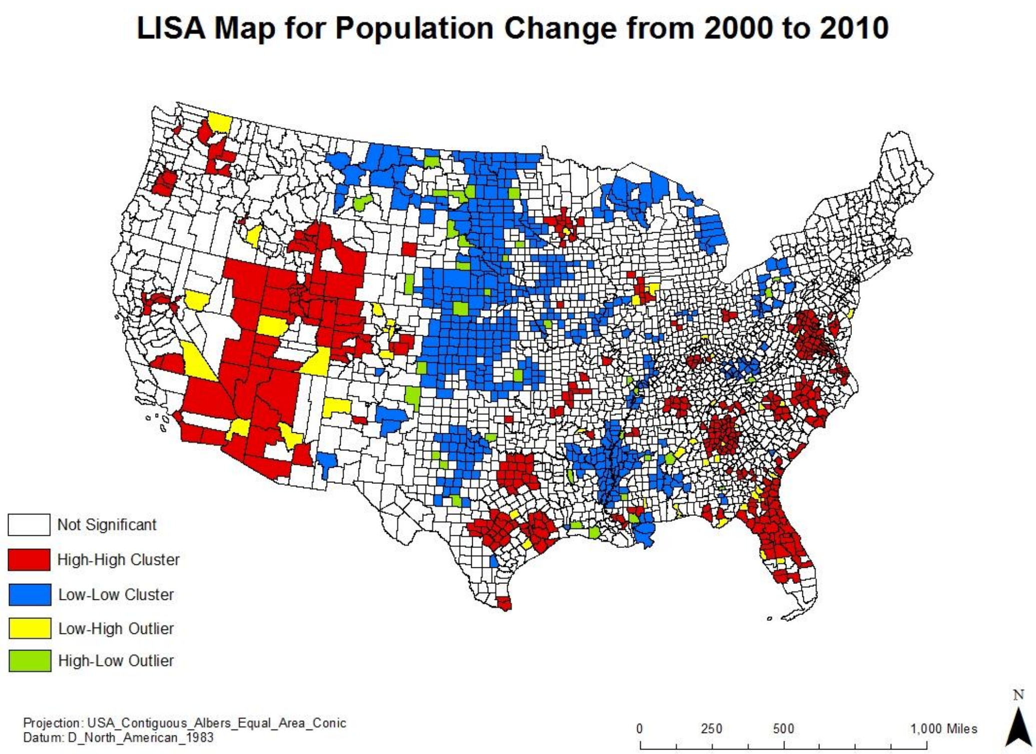

Figure 5.3 LISA Cluster Map for Population Change from 2000 to 2010

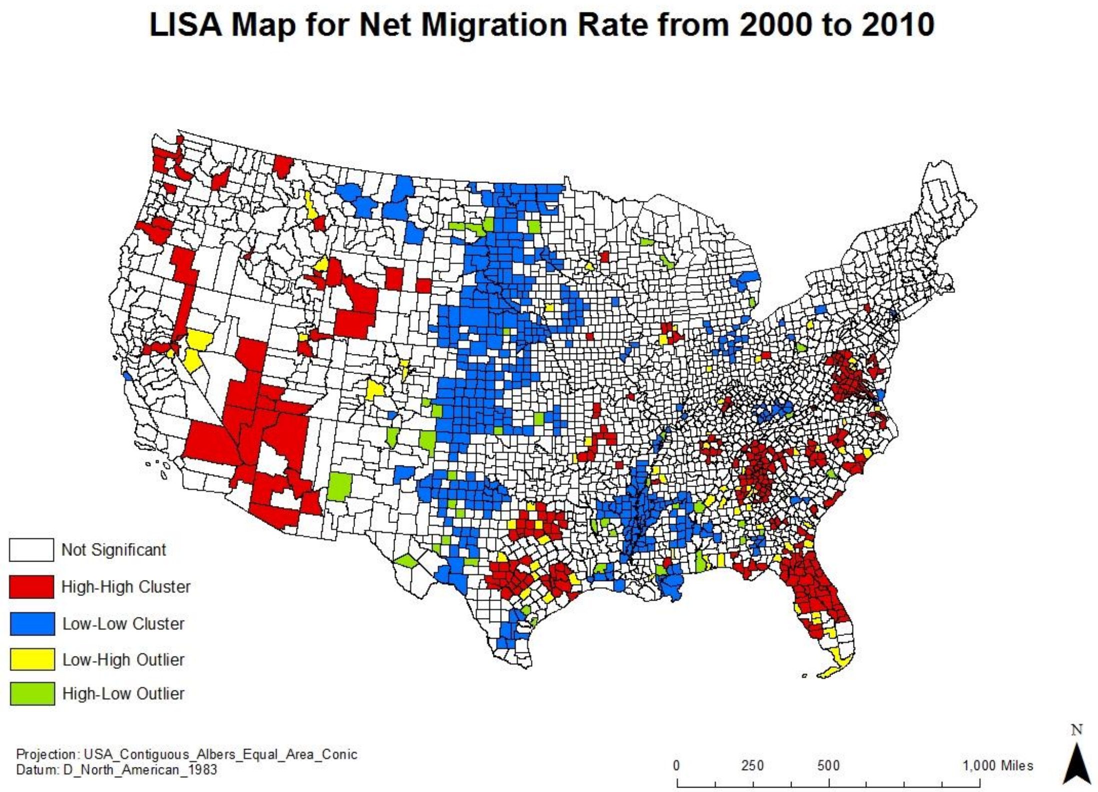

Figure 5.4 LISA Cluster Map for Net Migration Rate from 2000 to 2010

5.2 Spatial Regression Analyses

5.2.1 Analyses of Population Change and Net Migration

The results of the standard linear regression model, spatial error model, and spatial lag model are shown in Table 5.1. In the standard OLS regression model, the natural amenity scale has a positive and statistically significant ($p \leq 0.001$) association with population change from 2000 to 2010. A higher amenity scale indicates population growth. Arts, entertainment, and recreation establishments have a statistically significant ($p \leq 0.001$) negative association with population change from 2000 to 2010. However, forest coverage and land developability are not associated with population change from 2000 to 2010. Highway density does not significantly predict population change from

2000 to 2010; however, airport accessibility has a statistically significant association with population change from 2000 to 2010.

Social economic and demographic conditions also play an important role in predicting population change from 2000 to 2010. In the OLS regression model, population density has a negative and statistically significant ($p \leq 0.05$) association with population change from 2000 to 2010. Household income has a positive and statistically significant ($p \leq 0.001$) association with population change from 2000 to 2010. Educational attainment does not predict population change from 2000 to 2010 in the OLS regression model.

Previous migration trends show substantial associations with population change. The white net migration rate in the previous decade is positive and statistically significant ($p \leq 0.001$) associated with population change from 2000 to 2010. The black net migration rate and middle age net migration rate in the previous decade have negative and significant ($p \leq 0.01$ and $p \leq 0.001$) associations with population change from 2000 to 2010. The Hispanic net migration rate and old age net migration rate do not predict population change from 2000 to 2010.

In addition, the regression diagnostic showed that the multicollinearity condition number is 25.174 meaning that the OLS regression model has reasonably stable regression estimates. This number over 30 is suggestive of problems (Anselin 2005). The explanatory variables are not too correlated with each other.

In the spatial error model, the natural amenity scale and arts, entertainment, and recreation establishments remain statistically significant, but the natural amenity scale became less statistically significant in comparison to the OLS results. Similar to the OLS results, airport accessibility is statistically significantly and positively associated with population change from 2000 to 2010. Educational attainment is statistically significant ($p \leq 0.01$); however, population density and the black net migration rate in the previous decade are no longer statistically significant. Household income and the white net migration rate in the previous decade are still positive and statistically significantly ($p \leq 0.001$) associated with population change from 2000 to 2010, and the middle age net migration rate remains negative and statistically significantly ($p \leq 0.001$) associated with population change from 2000 to 2010.

The results of the spatial lag model are similar to those of the spatial error model regarding the coefficients' signs and statistical significance levels. Two variables that are statistically significant in the spatial lag model but not in the spatial error model are population density ($p \leq 0.05$) and the black net migration rate ($p \leq 0.05$).

In terms of spatial dependence, the Moran's I test for the OLS regression model is 0.27 and is highly significant statistically ($p \leq 0.001$), strongly indicating spatial autocorrelation. Thus, the estimates of the OLS regression model may be unreliable. The spatial error model and the spatial lag model are used to reanalyze the data in order to account for the spatial autocorrelation. The Lagrange Multiplier tests decide which model is more appropriate. According to the spatial regression model selection decision rule (Anselin 2005), when both the Lagrange Multiplier error and lag statistics are statistically significant statistically, the Robust Lagrange Multiplier statistics should be examined. If both the Robust Lagrange Multiplier error and lag statistics are highly significant statistically, the researcher must choose the model with the largest value for the test statistic. Therefore, in this study, the tests suggest that in order to control for spatial dependence, a spatial error model is appropriate for the analysis of U.S. counties' population change from 2000 to 2010.

Moreover, in terms of model fit, the values of the Log-Likelihood, AIC, and BIC are compared among the OLS model, the spatial error model, and the spatial lag model. Both the spatial error and spatial lag models provide a better fit than the OLS model. However, the spatial error model has the highest Log-Likelihood value and the lowest AIC and BIC values, which suggest an improvement of fit due to the spatial error specification. Thus, the spatial error model is superior for interpreting the associations of natural amenities and transportation with population change from 2000 to 2010 for all U.S. counties.

The OLS results indicate that all natural amenities variables have statistically significant associations with the net migration rate from 2000 to 2010. The natural amenity scale has a statistically significant ($p \leq 0.01$) positive association with the net migration rate. A high natural amenity scale predicts a high net migration rate. The percentage of forest coverage is positively associated with the net migration rate ($p \leq 0.01$). Land developability is also statistically significantly ($p \leq 0.05$) and positively associated with the net migration rate. However, arts, entertainment, and recreation establishments have a statistically significant ($p \leq 0.001$) negative association with the net migration rate. Highway density is not significantly associated with the net migration rate, but airport accessibility is positively associated with the net migration rate ($p \leq 0.001$) suggesting that the net migration rate is higher in counties with greater airport accessibility.

Household income is positively associated with net migration rate from 2000 to 2010 ($p \leq 0.001$). Neither educational attainment nor population density has significant associations with the net migration rate. The white and old age net migration rates in the previous decade have statistically significant ($p \leq 0.001$) and positive associations with the net migration rate from 2000 to 2010, while the black and middle age net migration rates in the previous decade have statistically significant ($p \leq 0.01$) and negative associations with the net migration rate from 2000 to 2010. However, the Hispanic net migration rate in the previous decade is not significantly associated with the net migration rate from 2000 to 2010. The diagnostics of the OLS regression model do not indicate multicollinearity.

Some variables become statistically non-significant or less statistically significant after controlling for the spatial structure. In the spatial error model, the natural amenities scale and the forest coverage variable are no longer significant. Arts, entertainment, and recreation establishments ($p \leq 0.01$), the black net migration rate ($p \leq 0.05$), and the middle age net migration rate ($p \leq 0.05$) become less statistically significant. The signs and significance levels of land developability, airport accessibility, household income, the white net migration rate, and the old age net migration rate in the spatial error model do not change relative to the OLS regression estimates. However, educational attainment becomes statistically significant in the spatial error model compared to the OLS regression model. The results of the spatial lag model are similar to those of the spatial error model regarding signs and statistical significance levels. The only major difference is that the middle age net migration rate is no longer statistically significant in the spatial lag model.

In terms of spatial dependence, the Moran's I test for the OLS regression model is 0.23 and highly statistically significant ($p \leq 0.001$), suggesting spatial autocorrelation. The Lagrange Multiplier tests and Robust Lagrange Multiplier tests indicate that the spatial error model is appropriate for analyzing the associations of natural amenities and transportation with the net migration rate from 2000 to 2010 for all U.S counties. Furthermore, comparisons of the Log Likelihood, AIC, and BIC statistics indicate that the spatial error model is the best fitting model.

The results can be summarized as follows. The natural amenity scale is positively associated with population change but is not related to the net migration rate. Forest coverage does not have a statistically significant relationship with either population change or the net migration rate. Land developability is positively associated with the net migration rate but is not associated with population change. Arts, entertainment, and recreation establishments are negatively related to both population change and the net migration rate. Highway density is not significantly associated with either population change or the net migration rate. However, airport accessibility is positively associated with both population change and the net migration rate. Population change and the net migration rate are also associated with a variety of other factors, such as educational attainment, household income, and the net migration rate of the racial and age groups in the model.

Table 5.1 Regression Analyses of Population Change and Net Migration

Variables	Population change 2000-2010			Net migration rate 2000-2010		
	OLS regression model	Spatial error model	Spatial lag model	OLS regression model	Spatial error model	Spatial lag model
Natural amenity scale	0.0063***	0.0029*	0.0025**	0.0024**	0.0008	0.0002
	(0.0008)	(0.0011)	(0.0008)	(0.0007)	(0.0010)	(0.0007)
Forest coverage	1.9646E-5	3.5046E-5	-5.7671E-5	0.0002**	0.0001	6.5609E-5
	(6.7914E-5)	(0.0001)	(6.2205E-5)	(6.0565E-5)	(8.5376E-5)	(5.7063E-5)
Land developability	-7.3553E-5	3.3114E-5	2.5584E-5	0.0001*	0.0002*	0.0002**
	(7.1265E-5)	(8.9480E-5)	(6.5199E-5)	(6.3554E-5)	(7.8877E-5)	(5.9647E-5)
Arts, entertainment, and	-0.0345***	-0.0241***	-0.0286***	-0.0172***	-0.0109**	-0.0145***
recreation establishments	(0.0040)	(0.0039)	(0.0037)	(0.0036)	(0.0036)	(0.0033)
Highway density	-0.0004	0.0003	-0.0008	-0.0004	-0.0007	-0.0010
	(0.0007)	(0.0007)	(0.0006)	(0.0006)	(0.0006)	(0.0005)

Table 5.1 (Continued)

Airport accessibility	0.0067***	0.0060***	0.0037***	0.0041***	0.0041***	0.0024***
	(0.0007)	(0.0008)	(0.0006)	(0.0006)	(0.0007)	(0.0006)
Educational attainment	0.0005	0.0008**	0.0011***	0.0004	0.0007*	0.0008**
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0430)
Population density	-2.2636E-6*	-1.1251E-6	-1.9512E-6*	-1.1523E-6	-5.6108E-7	-6.9195E-7
	(9.6315E-7)	(1.1044E-6)	(8.8079E-7)	(8.5893E-7)	(9.8512E-7)	(8.0620E-7)
Household Income	3.6587E-6***	4.1180E-6***	2.5041E-6***	2.5808E-6***	2.4880E-6***	1.9046E-6***
	(2.8413E-7)	(3.1975E-7)	(2.6813E-7)	(2.5338E-7)	(2.8573E-7)	(2.4117E-7)
White net migration rate	0.0044***	0.0040***	0.0037***	0.0034***	0.0034***	0.0030***
	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0434)

Table 5.1 (Continued)

Black net migration rate	-7.9551E-6**	-4.4000E-6	-5.7587E-6*	-7.1156E-6**	-4.6780E-6*	-5.5813E-6**
	(2.5774E-6)	(2.2531E-6)	(2.3575E-6)	(2.2985E-6)	(2.0842E-6)	(2.1575E-6)
Hispanic net migration rate	8.1813E-6	2.8145E-6	3.4958E-6	1.0050E-6	-3.0811E-6	-2.5697E-6
	(5.7597E-6)	(5.1273E-6)	(5.2692E-6)	(5.1365E-6)	(4.7295E-6)	(4.8224E-6)
Middle age net migration rate	-0.0006***	-0.0007***	-0.0004**	-0.0004**	-0.0004*	-0.0003
	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
	Population change 2000-2010			Net migration rate 2000-2010		
Variables	OLS regression model	Spatial error model	Spatial lag model	OLS regression model	Spatial error model	Spatial lag model

Table 5.1 (Continued)

Old age net migration rate	0.0001	0.0002	-2.5785E-5	0.0013***	0.0011***	0.0010***
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)
Constant	-0.1096***	-0.1426***	-0.0891***	-0.1141***	-0.1164***	-0.0932***
	(0.0108)	(0.0128)	(0.0101)	(0.0097)	(0.0113)	(0.0092)
Spatial lag effects	–	–	0.4173***	–	–	0.3577***
			(0.0190)			(0.0196)
Spatial error effects	–	0.5398***		–	0.4734***	
		(0.0209)			(0.0225)	
Measures of fit						
Log Likelihood	3315.45	3567.26	3532.07	3671.47	3853.24	3822.75
AIC	-6600.89	-7104.61	-7032.17	-7312.95	-7676.48	-7613.5
BIC	-6510.26	-7013.88	-6935.46	-7222.32	-7585.85	-7516.83

Table 5.1 (Continued)

Tests for spatial dependence		
Moran's I	0.27***	0.23***
Lagrange Multiplier (error)	613.544***	439.744***
Robust Lagrange Multiplier (error)	113.427***	99.876***
Lagrange Multiplier (lag)	524.487***	352.176***
Robust Lagrange Multiplier (lag)	24.371***	12.308***
Regression Diagnostic		
Multicollinearity condition number	25.174	25.174

Note: * p≤0.05; ** p≤0.01; *** p≤0.001; standard errors in parentheses;
AIC = Akaike's Information Criterion. BIC = Bayesian Information Criterion

5.2.2 Analyses of Population Change and Net Migration in Nonmetropolitan Counties

The associations of natural amenities and transportation with population change and the net migration rate from 2000 to 2010 for nonmetropolitan counties are examined in the OLS regression model, the spatial error model, and the spatial lag model (Table 5.2). In the OLS regression model, both the natural amenity scale and forest coverage have positive and statistically significant ($p \leq 0.001$) associations with population change from 2000 to 2010. Both land developability and arts, entertainment, and recreation establishments have negative and statistically significant ($p \leq 0.05$ and $p \leq 0.001$) associations with population change from 2000 to 2010. Highway density does not significantly predict population change; however, airport accessibility has a statistically significant ($p \leq 0.001$) association with population change.

Household income and the white net migration rate in the previous decade are positively associated with population change from 2000 to 2010 ($p \leq 0.001$ for both). The black and middle age net migration rates in the previous decade are inversely related to population change from 2000 to 2010 ($p \leq 0.01$ for both). However, educational attainment, population density, and the Hispanic and old age net migration rates do not predict population change from 2000 to 2010 in the OLS regression analysis. The diagnostics of the OLS regression model indicate an acceptable stability of the estimates.

In the spatial error model, the results for the natural amenity scale, forest coverage, land developability, and arts, entertainment, and recreation establishments, remain statistically significant with the same signs. Highway density becomes statistically significant ($p \leq 0.05$) and has a positive association with population change.

Airport accessibility is also positively associated with population change. Educational attainment ($p \leq 0.01$) and household income ($p \leq 0.001$) are statistically significantly related to population change. Higher educational attainment and household income predict a larger population change. Regarding the net migration trends of the previous decade, the white ($p \leq 0.001$) and old age ($p \leq 0.05$) net migration rates have positive associations with population change; however, the middle age ($p \leq 0.01$) net migration rate has a negative association with population change.

Most of the coefficients in the spatial error model and the spatial lag model are similar regarding the signs and levels of statistical significance. However, in the spatial lag model, forest coverage, land developability, highway density, and the old age net migration rate are no longer significantly associated with population change, and the black net migration rate has a statistically significant negative association with population change.

In terms of spatial dependence, the Moran's I test statistic for the OLS regression model is 0.29 and highly statistically significant ($p \leq 0.001$), providing strong evidence of spatial autocorrelation. The Lagrange Multiplier tests and Robust Lagrange Multiplier tests indicate that the spatial error model controls for spatial dependence. The model fit statistics also show that the spatial error model has a higher Log-Likelihood value and lower AIC and BIC values than do the OLS regression model and the spatial lag model, suggesting a reasonably good fit for the spatial error specification. The spatial error model is the superior model for analyzing how natural amenities and transportation are associated with population change from 2000 to 2010 in nonmetropolitan counties.

The OLS regression estimates indicate that the natural amenities scale ($p \leq 0.001$) and forest coverage ($p \leq 0.001$) have positive associations with the net migration rate, but arts, entertainment, and recreation establishments ($p \leq 0.05$) are negatively associated with the net migration rate. Land developability is not significantly related to the net migration rate. Airport accessibility has a positive and statistically significant ($p \leq 0.01$) relationship with the net migration rate. However, highway density does not predict the net migration rate. Population density ($p \leq 0.01$), household income ($p \leq 0.001$), the white net migration rate in the previous decade ($p \leq 0.001$), and the old age net migration rate in the previous decade ($p \leq 0.001$) have positive associations with the net migration rate from 2000 to 2010. The black net migration rate in the previous decade ($p \leq 0.05$) has a negative association with the net migration rate from 2000 to 2010. However, educational attainment, the Hispanic net migration rate in the previous decade, and the middle age net migration rate in the previous decade do not have significant associations with the net migration rate from 2000 to 2010. In addition, the OLS regression model does not have a noticeable problem with multicollinearity.

The results of the spatial error model are similar to those of the OLS regression model. The natural amenity scale ($p \leq 0.05$) and population density ($p \leq 0.05$) become less statistically significant. The signs and significance levels of forest coverage, arts, entertainment, and recreation establishments, airport accessibility, household income, the white net migration rate in the previous decade, and the old age net migration rate in the previous decade are similar to those in the OLS regression model. Educational attainment is not statistically significant in the OLS regression model but is statistically significant

($p \leq 0.05$) in the spatial error model. The black net migration rate is statistically significant in the OLS regression model but not in the spatial error model.

In the spatial lag model, the natural amenity scale and population density are no longer significantly associated with the net migration rate from 2000 to 2010. Airport accessibility is less statistically significant ($p \leq 0.05$). However, land developability ($p \leq 0.05$) and the black net migration rate in the previous decade ($p \leq 0.05$) are statistically significant, and arts, entertainment, and recreation establishments are more statistically significant ($p \leq 0.01$) than in the spatial error model. The signs and significance levels of forest coverage, educational attainment, household income, the white net migration rate in the previous decade, and the old age net migration rate in the previous decade are similar to those in the spatial error model.

In terms of spatial dependence, the Moran's I test statistic for the OLS regression model is 0.25 and highly statistically significant ($p \leq 0.001$), strongly indicating spatial autocorrelation. The Lagrange Multiplier tests and Robust Lagrange Multiplier tests suggest that the spatial error model is appropriate for analyzing the associations of natural amenities and transportation with the net migration rate. In addition, based on the measures of fit tests, the spatial error model provides a better fit than the OLS regression model and spatial lag model. The spatial error model has the highest Log Likelihood value and the smallest AIC and BIC values.

In summary, for nonmetropolitan counties, the natural amenities and transportation variables are significantly associated with population change from 2000 to 2010. The natural amenity scale, forest coverage, highway density, and airport accessibility are positively related to population change, while land developability and arts, entertainment, and recreation establishments are negatively related to population change. In contrast, land developability and highway density are not associated with the net migration rate from 2000 to 2010. It is worth noting that the coefficients in the analyses of the net migration rate are larger in magnitude than the corresponding coefficients in the analyses of population change. The larger coefficients suggest stronger associations.

Table 5.2 Regression Analyses of Population Change and Net Migration in Nonmetropolitan Counties

Variables	Population change 2000-2010			Net migration rate 2000-2010		
	OLS regression model	Spatial error model	Spatial lag model	OLS regression model	Spatial error model	Spatial lag model
Natural amenity scale	0.0083***	0.0055***	0.0040***	0.3963***	0.2571*	0.1550
	(0.0010)	(0.0012)	(0.0009)	(0.0854)	(0.1074)	(0.0808)
Forest coverage	0.0003***	0.0002*	0.0001	0.0428***	0.0362***	0.0254***
	(8.0240E-5)	(0.0001)	(7.2987E-5)	(0.0072)	(0.0093)	(0.0068)
Land developability	-0.0002*	-0.0002*	-7.1635E-5	0.0122	0.0108	0.0153*
	(7.9458E-5)	(9.6427E-5)	(7.2034E-5)	(0.0071)	(0.0085)	(0.0067)
Arts, entertainment, and recreation	-0.0253***	-0.0215***	-0.0242***	-0.9615*	-0.7744*	-0.9415**
establishments	(0.0042)	(0.0040)	(0.0038)	(0.3793)	(0.3650)	(0.3542)
Highway density	0.0008	0.0030*	0.0010	-0.0274	0.0733	-0.0443
	(0.0011)	(0.0012)	(0.0010)	(0.1025)	(0.1118)	(0.0958)
Airport accessibility	0.0053***	0.0057***	0.0044***	0.2012**	0.2652**	0.1804*
	(0.0009)	(0.0009)	(0.0008)	(0.0771)	(0.0828)	(0.0721)

Table 5.2 (Continued)

Educational attainment	0.0004	0.0013**	0.0015***	0.0201	0.0820*	0.0864*
	(0.0004)	(0.0004)	(0.0004)	(0.0381)	(0.0389)	(0.0357)
Population density	3.3111E-5	1.5596E-5	6.6542E-6	0.0044**	0.0035*	0.0029
	(1.7642E-5)	(1.6118E-5)	(1.5990E-5)	(0.0016)	(0.0015)	(0.0015)
Household Income	3.8801E-6***	3.6922E-6***	2.5471E-6***	0.0003***	0.0002***	0.0002***
	(3.7788E-7)	(4.3246E-7)	(3.5088E-7)	(3.3862E-5)	(3.8718E-5)	(3.2123E-5)
White net migration rate	0.0029***	0.0026***	0.0022***	0.1854***	0.1949***	0.1520***
	(0.0003)	(0.0003)	(0.0003)	(0.0298)	(0.0299)	(0.0280)
Black net migration rate	-6.9126E-6**	-3.6379E-6	-5.0495E-6*	-0.0006*	-0.0004	-0.0005*
	(2.6494E-6)	(2.3045E-6)	(2.3977E-6)	(0.0002)	(0.0002)	(0.0002)
Hispanic net migration rate	3.2267E-6	2.2805E-7	1.2444E-6	-0.0002	-0.0005	-0.0004
	(5.4427E-6)	(4.8111E-6)	(4.9254E-6)	(0.0005)	(0.0004)	(0.0005)
Middle age net migration rate	-0.0005**	-0.0006**	-0.0003*	-0.0326	-0.0295	-0.0188
	(0.0002)	(0.0002)	(0.0002)	(0.0171)	(0.0165)	(0.0160)

Table 5.2 (Continued)

	Population change 2000-2010			Net migration rate 2000-2010		
	OLS regression	Spatial error	Spatial lag	OLS regression	Spatial error	Spatial lag
Variables	model	model	model	model	model	model
Old age net migration rate	0.0003	0.0005*	0.0003	0.1653***	0.1539***	0.1406***
	(0.0002)	(0.0002)	(0.0002)	(0.0170)	(0.0170)	(0.0160)
Constant	-0.1261***	-0.1370***	-0.1018***	-12.9545***	-12.6371***	-10.5081***
	(0.0142)	(0.0158)	(0.0130)	(1.2683)	(1.4135)	(1.2009)
Spatial error effects	–	0.4817***		–	0.4151***	
		(0.0236)			(0.0253)	
Measures of fit						
Log Likelihood	2362.19	2521.40	2510.21	-6732.17	-6618.95	-6632.2
AIC	-4694.39	-5012.79	-4988.55	13494.3	13267.9	13296.4
BIC	-4610.2	-4928.61	-4898.75	13578.5	13352.1	13386.2

Table 5.2 (Continued)

Tests for spatial dependence		
Moran's I	0.29***	0.25***
Lagrange multiplier (error)	353.829***	254.766***
Robust Lagrange multiplier (error)	36.441***	43.015***
Lagrange multiplier (lag)	326.375***	215. 711***
Robust Lagrange multiplier (lag)	8.987**	3.960*
Regression Diagnostic		
Multicollinearity condition number	28.587	28.587

Note: * p≤0.05; ** p≤0.01; *** p≤0.001; standard errors in parentheses;
AIC = Akaike's Information Criterion. BIC = Bayesian Information Criterion

5.2.3 Analyses of Population Change and Net Migration in Metropolitan Counties

The OLS regression analysis shows that the natural amenities variables have statistically significant associations with population change. The natural amenity scale ($p \leq 0.001$) and land developability ($p \leq 0.05$) are positively associated with population change from 2000 to 2010. Forest coverage ($p \leq 0.001$) and arts, entertainment, and recreation establishments ($p \leq 0.001$) are negatively associated with population change from 2000 to 2010. Airport accessibility ($p \leq 0.001$) has a positive relationship with population change but highway density does not.

Educational attainment and household income have positive and statistically significant ($p \leq 0.05$ and $p \leq 0.001$) associations with population change. The white ($p \leq 0.001$), Hispanic ($p \leq 0.001$), and old age ($p \leq 0.01$) net migration rates are also positively associated with population change. The middle age net migration rate ($p \leq 0.05$) is negatively associated with population change. The black net migration rate is not associated with population change. Based on the regression diagnostics, the OLS regression model does not show a noticeable problem with multicollinearity.

The results of the spatial error model and spatial lag model are very similar to those of the OLS regression model. In the spatial error model, the natural amenity scale ($p \leq 0.05$) and forest coverage ($p \leq 0.01$) are less statistically significant; however, land developablility is more statistically significant ($p \leq 0.001$). The Hispanic ($p \leq 0.05$) and old age ($p \leq 0.05$) net migration rates are also less statistically significant. In the spatial lag model, both airport accessibility and Hispanic net migration rate are less statistically significant; and the middle age net migration rate is more statistically significant relative to the OLS regression estimates.

The tests for spatial dependence show that the OLS regression model has spatial autocorrelation among the residuals (Moran's I = 0.23; $p \leq 0.001$), which violates the independence assumption of the error terms. Thus, the Lagrange Multiplier statistics suggest that the spatial lag model is appropriate for analyzing the associations of natural amenities and transportation with population change from 2000 to 2010 in metropolitan counties, although the model fit statistics indicate that the spatial error model has a slightly better fit than the spatial lag model (the Log Likelihood value of the spatial error model is slightly higher and the values of AIC and BIC are slightly lower than those of the spatial lag model).

The OLS regression analysis shows that the natural amenity scale and forest coverage are not associated with the net migration rate from 2000 to 2010. Land developability ($p \leq 0.01$) has a positive association and arts, entertainment, and recreation establishments ($p \leq 0.01$) have a negative association with the net migration rate from 2000 to 2010. Airport accessibility ($p \leq 0.001$) is positively associated with the net migration rate. However, highway density does not predict the net migration rate. Household income ($p \leq 0.001$) is positively related to the net migration rate but neither educational attainment nor population density have statistically significant relationships with the net migration rate. The white ($p \leq 0.001$), Hispanic ($p \leq 0.05$), and old age ($p \leq 0.001$) net migration rates in the previous decade are positively associated with the net migration rate from 2000 to 2010. Conversely, the middle age ($p \leq 0.01$) net migration rate in the previous decade is negatively associated with the net migration rate from 2000 to

2010. The black net migration rate in the previous decade is not associated with the net migration rate from 2000 to 2010. The regression diagnostics do not indicate a noticeable problem with muticollinearity.

The spatial error and spatial lag models provide results that are similar to those of the OLS regression model. In the spatial error model, the signs and significance levels of the natural amenities and transportation variables are not substantially different from those in the OLS regression model. The control variables also have signs and significance levels that are similar to those of the OLS regression model. But the Hispanic net migration rate in the previous decade is not statistically significant and the middle age net migration rate in the previous decade is less statistically significant. In the spatial lag model, the natural amenity scale and forest coverage are not statistically significant; land developability ($p \leq 0.05$) and airport accessibility ($p \leq 0.01$) are less statistically significant. The signs and significance levels of the control variables in the spatial lag model are similar to those in the OLS regression model.

The Moran's I test statistic for the OLS regression model is 0.19 and highly statistically significant ($p \leq 0.001$), suggesting a problem with spatial autocorrelation. The Lagrange Multiplier tests indicate that the spatial error model should be selected because the Robust Lagrange Multiplier error is more statistically significant than the Robust Lagrange Multiplier lag. In addition, the values of the Log Likelihood, AIC, and BIC demonstrate that the spatial error model has a better fit than the spatial lag model.

In summation, in the metropolitan counties, all natural amenities and transportation variables have statistically significant associations with population change from 2000 to 2010. However, only land developability and arts, entertainment, and recreation establishments have statistically significant associations with the net migration rate from 2000 to 2010. Airport accessibility is related to both population change and the net migration rate. It is worth noting that the Hispanic net migration rate in the previous decade has a statistically significant association with population change, but it is not associated with the net migration rate. The larger coefficients in the net migration rate analysis indicate that the associations of land developability, arts, entertainment, and recreation establishments, and airport accessibility with net migration are stronger than the associations of these variables with population change.

Table 5.3 Regression Analyses of Population Change and Net Migration in Metropolitan Counties

	Population change 2000-2010			Net migration rate 2000-2010		
Variables	OLS regression model	Spatial error model	Spatial lag model	OLS regression model	Spatial error model	Spatial lag model
Natural amenity scale	0.0052***	0.0043*	0.0035*	0.1362	0.0942	0.0458
	(0.0015)	(0.0018)	(0.0009)	(0.1323)	(0.1544)	(0.1280)
Forest coverage	-0.0005***	-0.0004**	-0.0004***	-0.0204	-0.0233	-0.0201
	(0.0001)	(0.0002)	(0.0001)	(0.0115)	(0.0134)	(0.0111)
Land developability	0.0003*	0.0006***	0.0003*	0.0345**	0.0450**	0.0296*
	(0.0001)	(0.0002)	(0.0001)	(0.0127)	(0.0140)	(0.0123)
Arts, entertainment, and recreation	-0.0624***	-0.0501***	-0.0560***	-3.1678**	-2.7430**	-2.9527**
establishments	(0.0117)	(0.0113)	(0.0111)	(1.0457)	(1.0310)	(1.0094)
Highway density	-0.0004	-7.9692E-5	-0.0003	-0.0108	-0.0294	-0.0197
	(0.0009)	(0.0009)	(0.0008)	(0.0799)	(0.0848)	(0.0771)

Table 5.3 (Continued)

Airport accessibility	0.0053***	0.0058***	0.0039**	0.4552***	0.4865***	0.3469**
	(0.0012)	(0.0013)	(0.0012)	(0.1113)	(0.1169)	(0.1087)
Educational attainment	0.0010*	0.0012*	0.0011*	0.0485	0.0708	0.0477
	(0.0005)	(0.0005)	(0.0005)	(0.0445)	(0.0447)	(0.0430)
Population density	-8.3273E-7	-3.6370E-7	-5.1358E-7	-5.8567E-5	-3.6117E-5	-2.2206E-5
	(1.0959E-6)	(1.1897E-6)	(1.0389E-6)	(9.7938E-5)	(0.0001)	(9.4617E-5)
Household Income	3.0982E-6***	3.2384E-6***	2.9158E-6***	0.0002***	0.0002***	0.0002***
	(4.8048E-7)	(5.0692E-7)	(4.5628E-7)	(4.2938E-5)	(4.5334E-5)	(4.1444E-5)
White net migration rate	0.0049***	0.0044***	0.0047***	0.4426***	0.4300***	0.4338***
	(0.0005)	(0.0005)	(0.0005)	(0.0298)	(0.0440)	(0.0434)
Black net migration rate	-7.1301E-6	-4.9679E-6	-5.5535E-6	-0.0007	-0.0005	-0.0006
	(6.0061E-6)	(5.5699E-6)	(5.6927E-6)	(0.0005)	(0.0005)	(0.0005)
Hispanic net migration rate	7.5870E-5***	4.8724E-5*	5.6650E-5**	0.0048*	0.0034	0.0036
	(2.2053E-5)	(2.1612E-5)	(2.0932E-5)	(0.0020)	(0.0020)	(0.0019)

Table 5.3 (Continued)

Variables	Population change 2000-2010			Net migration rate 2000-2010		
	OLS regression model	Spatial error model	Spatial lag model	OLS regression model	Spatial error model	Spatial lag model
Middle age net migration rate	-0.0008*	-0.0006*	-0.0008**	-0.0834**	-0.0574*	-0.0773**
	(0.0003)	(0.0003)	(0.0003)	(0.0287)	(0.0284)	(0.0277)
Old age net migration rate	0.0009**	0.0008*	0.0006*	0.1832***	0.1525***	0.1532***
	(0.0003)	(0.0003)	(0.0003)	(0.0273)	(0.0283)	(0.0265)
Constant	-0.0942***	-0.1273***	-0.1022***	-10.4007***	-11.0889***	-10.1764***
	(0.0201)	(0.0218)	(0.0191)	(1.7965)	(1.9429)	(1.7356)
Spatial error effects	–	0.3297***		–	0.2723***	
		(0.0309)			(0.0323)	
Measures of fit						
Log Likelihood	1075.56	1119.81	1115.65	-3803.56	-3775.00	-3779.14
AIC	-2121.12	-2209.62	-2199.3	7637.12	7580	7590.28
BIC	-2046.26	-2134.77	-2119.45	7711.97	7654.85	7670.13

Table 5.3 (Continued)

Tests for spatial dependence		
Moran's I	0.23***	0.19***
Lagrange Multiplier (error)	85.665***	54.465***
Robust Lagrange Multiplier (error)	7.731**	7.512**
Lagrange Multiplier (lag)	88.624***	52.001***
Robust Lagrange Multiplier (lag)	10.691**	5.049*
Regression Diagnostic		
Multicollinearity condition number	27.683	27.683

Note: * p≤0.05; ** p≤0.01; *** p≤0.001; standard errors in parentheses;
AIC = Akaike's Information Criterion. BIC = Bayesian Information Criterion

CHAPTER VI

DISSCUSSION AND CONCLUSIONS

6.1 Summary

Research on amenity-led and transportation-led population change in the U.S. is relatively new. We know that amenity-led population change is occurring in many places such as the European Alps (Perlik 2006), Norway (Flognfeldt 2006), Philippines (Glorioso 2006), and New Zealand (Hall 2006). Natural amenities by themselves cannot influence migration. The role of transportation technology and networks is also important. Previous studies of the U.S. population distribution analyzed the changes in the 1970s, 1980s, and 1990s. Few of these studies integrated natural amenities and transportation related variables into their analyses (Johnson et al. 2005; Frey 1990; Long 1981; Fuguitt 1985; Frey and Speare 1992; Johnson and Beale 1994; and Johnson 1999). The present study investigated U.S. population size change and net migration in the 2000s and focused on detailed natural amenities and transportation variables for all U.S. counties, nonmetropolitan counties, and metropolitan counties. The findings are discussed in section 6.2. Section 6.3 discusses the public policy implications and contributions of the study. The limitations of the analysis are outlined in 6.4, and the chapter concludes with directions for future research in section 6.5.

6.2 Discussion

The theoretical expectations of this research were that population change and net migration in the U.S. are positively associated with natural amenities and transportation indicators such as the natural amenity scale, forest coverage, land developability, arts, entertainment, and recreation establishments, highway density, and airport accessibility. Guided by these theoretical expectations, six hypotheses were proposed in Chapter 2. The spatial analyses tested these six hypotheses across all U.S. counties, nonmetropolitan counties, and metropolitan counties. The summary of the hypothesis testing is presented in Table 6.1.

Hypothesis 1, higher natural-amenity-ranking counties have a higher net migration rate and population growth than lower natural-amenity-ranking counties, was partially supported. Population growth was higher in counties with higher natural-amenity-ranking values in both metropolitan and nonmetropolitan areas. However, natural-amenity-ranking is positively associated with the net migration rate in nonmetropolitan counties only, a finding consistent with previous studies (Hunter et al. 2005; Rickman and Rickman 2011; Chi and Marcouiller 2013b). The dynamic of population change is complex. It includes tradeoffs of death, birth, in-migration, and out-migration. Although the role of natural amenities is difficult to identify, one possibility is that a high quality of natural amenity has a twofold relationship with the overall population change process. Greater natural amenities such as a high proportion of land in forest, farmland, rangeland, water bodies, and mild climate, are positively related to people's life expectancy (Poudyal et al. 2009). Natural amenities are also negatively associated with certain diseases such as obesity and positively associated with physical activity (Jilcott Pitts et al. 2013; Jilcott et al. 2011; Michimi and Wimberly 2012). In addition, natural amenities play an important role in in-migration, especially for rural and nonmetropolitan areas (Hunter et al. 2005; Rickman and Rickman 2011; Chi and Marcouiller 2013b). Counties with desirable natural amenities are more likely to attract migrants with long life expectancies, thus increasing the population. Since few studies have examined the how the birth rate and death rate are associated with natural amenities, further investigation is warranted.

Hypothesis 2, counties with higher forest coverage have a higher net migration rate and population growth than counties with lower forest coverage, was support only in nonmetropolitan counties. The level of population change and the net migration rate were high in nonmetropolitan counties with high forest coverage. In metropolitan counties, the association of forest coverage with population change was negative, meaning that a high forest coverage in a metropolitan county predicted low population change.

Hypothesis 3, counties with lower values of land developability have a higher net migration rate and population growth than counties with higher values of land developability, was partially supported. Only nonmetropolitan counties with lower land developability had higher levels of population growth. However, in metropolitan counties, more developable lands were positively associated with population change and the net migration rate. These results may reflect two different preferences for rural and urban migration. Undevelopable characteristics in rural areas such as water, wetlands, public lands, Indian reservations, and varied topographies are appealing landscapes, attracting people to move in. Scenic landscapes are strongly associated with rural migration (McGranahan 2008, 1999). However, developable land in metropolitan areas provides space for new development and economic opportunities which encourage in-migration.

Hypothesis 4, counties with greater human-made amenities (establishments of arts, entertainment, and recreation) have a higher net migration rate and population growth than counties with fewer human-made amenities, was not supported. On the contrary, amenities, such as the establishments of arts, entertainment, and recreation are negatively associated with population change and the net migration rate. This finding is inconsistent with research indicating that historical and cultural amenities, such as arts, festivals, museums, entertainment sports, and memorials are positively associated with population growth (Kahsai et al. 2011); in fact, total population growth is higher in counties with more natural amenities and constructed amenities, such as opera, research libraries, used and rare book stores, juice bars, Starbucks, and bicycle events (Clark 2004). Since the definitions of human-made amenities vary across different studies, a more comprehensive index of such amenities should be created in future research.

Hypothesis 5, counties with better airport accessibility have a higher net migration rate and population growth than counties with worse airport accessibility, was supported, regardless of county type. Population growth and the net migration rate were higher in counties with greater airport accessibility. To some extent, these findings are consistent with literature showing that airports are a positive predictor of population growth in metropolitan areas (Green 2007) and that airport accessibility promotes population growth in both rural and suburban areas (Chi 2012).

Hypothesis 6, counties with higher density of highways have a higher net migration rate and population growth than counties with lower density of highways, was partially supported. The association of highway density with population change existed in nonmetropolitan counties only. Highway density was not associated with the net migration rate. These results support previous studies of highway impacts on population change in rural areas (Chi 2010; Perz et al. 2010).

Additionally, the present study examined the associations of natural amenities and transportation with population change and net migration, controlling for socioeconomic and demographic variables. The findings indicate that population growth is more likely in nonmetropolitan counties with a high percentage of educated people, a high level of household income, a high previous migration rate for whites and old people, and a low previous migration rate for middle age people. Net migration to nonmetropolitan counties also increases if the counties have high levels of educated people, population density, household income, and previous white and old age migration rates. The pattern of associations was similar to metropolitan counties. However, the positive relationship between population change and the Hispanic net migration rate was observed in metropolitan counties only, indicating the importance of understanding how Hispanic migration affects metropolitan areas.

In summation, the results suggest that natural amenities, transportation, socioeconomic factors, and previous in-migration trends work together to influence population change and migration. The influence of these variables differs between nonmetropolitan and metropolitan counties. For example, the results imply that high forest coverage and low land developability are positively associated with population growth in nonmetropolitan counties but are negatively associated with population growth in metropolitan counties.

Although patterns of population change and migration in rural and urban settings have received considerable attention, much of this attention focuses on socio-economic explanations of these patterns. However, population change and migration patterns are also linked to spatial variation in the characteristics of land use and natural resources. In rural and nonmetropolitan settings especially, the ways of life are closely tied to natural resources and studies find significant relationships between noneconomic amenity variables, like climate, topography and proximity to water, and population growth (Brehm et al. 2004; Johnson and Beale 1994; McGranahan 1999). The present study reaffirms the importance of natural amenities, forest coverage, and land developability as correlates of population growth in nonmetropolitan America from 2000 to 2010.

The possible reasons for nonmetropolitan population growth and in-migration are the high valuation of the natural environment, quality of life, leisure, and socially constructed ideals of rural landscapes and life styles (Gosnell and Abrams 2011; Smutny 2002; McCarthy 2008; Nelson 2002). Other possible reasons are the improved conditions of mobility, increased wealth, and advanced communication and transportation technology. Studies also show that nonmetropolitan population change is strongly associated with road and airport accessibility (Kotavaara et al. 2012). The nonmetropolitan communities adjacent to metropolitan areas or within commuting distance of urban areas experience population growth, because such locations take advantage of both rural natural amenities and urban amenities, such as health facilities and job opportunities (Brown et al. 1997; Johnson and Fuguitt 2000; Johnson and Beale 1998). However, airports are more important for resident retention in more remote regions (Halpern and Bråthen 2011).

Table 6.1 Summary of Hypothesis Testing (✓=supported)

Hypotheses	Population change			Net migration rate		
	All U.S. Counties	Nonmetropolitan Counties	Metropolitan Counties	All U.S. Counties	Nonmetropolitan Counties	Metropolitan Counties
Higher natural-amenity-ranking counties have higher net migration rate and population growth than lower natural-amenity-ranking counties	✓	✓	✓	no association	✓	no association
Counties with higher forest coverage have higher net migration rate and population growth than counties with lower forest coverage.	no association	✓	negative association	no association	✓	no association
Counties with lower values of land developability have higher net migration rate and population growth than counties with higher values of land developability.	no association	✓	negative association	negative association	no association	negative association
Counties with greater human-made amenities (establishments of arts, entertainment, and recreation) have higher net migration rate and population growth than counties with fewer human-made amenities.	negative association	negative association	negative association	negative association	negative association	negative association

Table 6.1 (Continued)

Counties with better airport accessibility have higher net migration rate and population growth than counties with worse airport accessibility.	✓	✓	✓	✓	✓	✓
Counties with higher density of highways have higher net migration rate and population growth than counties with lower density of highways.	no association	✓	no association	no association	no association	no association

6.3 Contributions and Implications

First, this study contributes to the literature on natural amenities, transportation, and U.S. population change by comparing metropolitan and nonmetropolitan counties. Previous studies have been conducted mainly on a regional level (examining the Intermountain West, Northeast, and natural-amenities-rich states) and focused only on rural settings without considering spatial dependency (Green et al. 2005; Krannich et al. 2011). The maps of this dissertation provide clear images of how counties vary by natural amenities and transportation conditions. Moreover, the spatial analyses highlight the importance of considering spatial structure, indicating that the relationship between county characteristics and population change varies considerably over space.

Second, the LISA Cluster maps (Figure 5.3 and Figure 5.4) of population change and net migration are a valuable reference for future research that examines clustered regions with positive and negative spatial dependences. This future research might address such questions as, what other factors contribute to population growth or decline in specific regions besides the natural amenities characteristics studied in this dissertation? In particular, the outlier counties deserve in-depth study because their population change is the opposite of that of their neighbors.

Finally, the study demonstrates the application of GIS methodology to analyzing spatial aspects of social processes. GIS methodology and advanced computing technology supplement conventional data analysis with more accurate and innovative spatial data analysis. This dissertation illustrates the transformation of a satellite image of forest coverage, highway lines, and airport points into analyzable data for population change research. The ability of GIS methodology and spatial analysis to combine such geographic data based upon the researcher's interest advance the understanding of the social and physical contexts of a particular geographic region.

Several implications are suggested by the study's results. First, from a theoretical standpoint, this study shows that biophysical features like natural amenities, landscapes, forests, highways, and airports can significantly influence population change and the influence varies across space. An integrated theory is needed to incorporate both social factors and these biophysical features into a comprehensive explanation of population change and the interaction of humans with the environment. Additionally, since natural amenities include a wide range of characteristics and change over space and time, a multi-scale georeferenced longitudinal database needs to be developed so the measurement of natural amenities can be consistent across studies.

Second, this study implies that the perception of natural resources is shifting. Natural resources were previously viewed as raw materials for production, but now they are valued for their beauty and recreational opportunities. The relationship between humans and natural resources extends beyond economic pursuits into aesthetic appreciations and cultural meanings. Many natural amenities-rich areas are undergoing this value restructuring process. Therefore, policy-makers, entrepreneurs, and nonprofit leaders should fully recognize such change, so they can integrate the role of natural amenities into their decisions.

Third, the findings of this study have important implications for local economic development policies because natural amenities attract tourists and in-migrating residents, who in turn, can drive jobs, capital, and economic opportunities. For example, the economic development of rural areas can be enhanced by sustaining and strengthening the quality of the natural environment. Rural development strategies thus need to realize the importance of place attachments, the value of good neighbors, social interactions, and the values people place on their social/physical environments (Rudzitis 1999). In addition, with the increase of amenity-led migration, questions about the tradeoffs between population growth and environmental protection need to be carefully considered. Such questions include the following: How does population change threaten or benefit natural amenities? How can the quality of amenities, as well as local development, be managed? How can the management of natural amenities be maintained and who bears the cost, since natural amenities are public goods (Samuelson 1969) for which the public does not have to directly pay? Given that public demand for natural amenities is increasing, all these questions offer great challenges for policy planners to consider: like Daniels (1999:3) said, "In the new knowledge economy, an area's quality of life translates into economic growth. Yet the places with the highest quality of life are always at risk of being loved to death."

Fourth, in this study, low land developability was found to be positively associated with population growth in nonmetropolitan counties but negatively associated with population growth in metropolitan counties. This finding suggests that different land-use policies should be implemented for nonmetropolitan and metropolitan counties. Nonmetropolitan in-migrants prefer high natural amenities areas with low developable land for commercial development. However, increasing nonmetropolitan in-migrantion inevitably creates demand for housing and supporting development, which in turn, changes the land for commercial use. This paradox needs to be carefully evaluated by land-use planners. Much research shows that growth control and land-use planning are not very effective in protecting rural community environments and open space (Beyers and Nelson 2000; Warner and Molotch 2000). In metropolitan areas, the amount of land available for development is still a predictor of population growth. Therefore, land-use planning should reconcile the need for supporting development with concerns for the environment.

Last but not least, findings from this study have implications for transportation planning. Natural amenities are positively associated with population growth when these amenities are relatively accessible to people. The results show that airport accessibility is positively related to population change and the net migration rate in both nonmetropolitan and metropolitan counties; however, highway density is positively associated with population change in nonmetropolitan counties only. Accessibility to airports becomes increasingly important in promoting regional economic development and population growth. Building a commercial airport may be unrealistic; however, it is feasible to enhance the accessibility of nearby airports by improving roads and highways to these airports and thereby increase airport passenger flow. Both highways and airports are important for nonmetropolitan areas. Rural transportation planners should therefore consider the improvements of highways and airports together, in order to implement an optimal transportation system.

6.4 Limitations and Future Studies

The limitations of this study are primarily related to the data and methods. Some independent variables like land developability, highway density, and airport accessibility are calculated from data collected after 2010. Since the dependent variables are based on data from year 2000 to 2010, causal inferences are not appropriate.

A second problem relates to model selection. The results of the spatial lag and the spatial error models show that both Robust Lagrange Multiplier statistics are statistically significant, which indicate that other spatial weights and/or spatial models might be considered (Anselin 2005). Since the results show different associations among the variables in nonmetropolitan counties and metropolitan counties, geographically weighted regression (GWR) might be considered. Unlike the spatial error and the spatial lag models used to find generalizable relationships, GWR can be used to identify local patterns. As Ali et al. (2007:301) claim, "regional scientists would expect not only that the explanatory variables differ across space, but also that the marginal responses to changes in the explanatory variables can also vary across space." Therefore, spatially varying associations among natural amenities, transportation, and population change can be examined in GWR.

A third limitation concerns the Modifiable Areal Units Problem (MAUP) (Tobler 1989). Scale matters in spatial analysis, meaning that choosing different sizes of units of analysis can yield different conclusions. The interpretations of independent variables can be affected by the MAUP. The associations of natural amenities and transportation with population change and the net migration rate may change if a researcher uses other spatial aggregations, such as the zip code, census tract, or the state as the unit of analysis instead of the county. Therefore, the results of this study can help researchers understand relationships among variables at the county level but not at other levels of analysis.

This study can be expanded in many ways in the future. First, the evidence from this study suggests that population change patterns vary by population subgroups; therefore, future research should examine how natural amenities and transportation variables are associated with population change for different racial groups, age groups, and social economic classes in both rural and urban settings. Additionally, future efforts should examine how the changes of birth rate, death rate, and life expectancy are associated with natural amenities. Third, future studies should investigate the interactions, attitudes, and perceptions of natural amenities among newcomers, long-term residents, and seasonal landowners. These studies will help us to understand the conflicts between newcomers and long-term residents with regard to local growth, land use planning, and community change. Last, by reclassifying the 2003 Urban-Rural Continuum codes (USDA ERS, 2003), future research should compare the associations of natural amenities and transportation with population change between rural regions that are, and are not, adjacent to metropolitan areas.

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APPENDIX A

MODELS WITH SELECTED CONTROL VARIABLES

Table A.1 Regression Analyses of Population Change and Net Migration

	Population change 2000-2010			Net migration rate 2000-2010		
	Spatial error model			Spatial error model		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Independent variables						
Natural amenity scale	0.0059***	0.0045***	0.0031**	0.0046***	0.0031**	0.0015
	(0.0012)	(0.0012)	(0.0011)	(0.0011)	(0.0011)	(0.0010)
Forest coverage	0.0004***	0.0004***	3.0362E-5	0.0004***	0.0005***	6.8356E-5
	(0.0001)	(0.0001)	(9.9904E-5)	(9.5047E-5)	(9.5440E-5)	(8.7083E-5)
Land developability	0.0002	0.0002*	2.1068E-5	0.0003**	0.0003***	0.0001
	(9.4981E-5)	(9.4388E-5)	(8.8865E-5)	(8.6882E-5)	(8.6664E-5)	(7.9473E-5)
Arts, entertainment, and	-0.0160***	-0.0256***	-0.0238***	-0.0017	-0.0111**	-0.0091*
recreation establishments	(0.0040)	(0.0041)	(0.0039)	(0.0038)	(0.0039)	(0.0036)
Highway density	-0.0004	-0.0012	0.0004	-0.0013	-0.0021**	-0.0003
	(0.0008)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0006)

Table A.1 (Continued)

Airport accessibility	0.0072***	0.0066***	0.0059***	0.0052***	0.0046***	0.0038***
	(0.0008)	(0.0008)	(0.0008)	(0.0007)	(0.0007)	(0.0007)
Control variables:						
Educational attainment		0.0028***	0.0008**		0.0027***	0.0006*
		(0.0003)	(0.0003)		(0.0003)	(0.0003)
Population density	-1.9555E-7	-1.0050E-6	-1.2037E-6	-1.6799E-7	-9.0514E-7	-9.9185E-7
	(1.1827E-6)	(1.1740E-6)	(1.1024E-6)	(1.0920E-6)	(1.0863E-6)	(9.9645E-7)
Household Income	5.1378E-6***	3.4586E-6***	4.0020E-6***	2.8008E-6***	1.1900E-6***	1.8028E-6***
	(2.6163E-7)	(3.2135E-7)	(3.0336E-7)	(2.4188E-7)	(2.9742E-7)	(2.7434E-7)
White net migration rate			0.0042***			0.0045***
			(0.0002)			(0.0002)
Black net migration rate	-6.4835E-6**	-6.9004E-6**	-4.4585E-6*	-7.3003E-6**	-7.6332E-6***	-4.9677E-6*
	(2.3919E-6)	(2.3588E-6)	(2.2532E-6)	(2.2701E-6)	(2.2322E-6)	(2.0975E-6)
Hispanic net migration rate	2.0319E-6	1.4747E-6	2.7106E-6	-4.4777E-6	-5.1015E-6	-3.8331E-6
	(5.4594E-6)	(5.3844E-6)	(5.1279E-6)	(5.1701E-6)	(5.0865E-6)	(4.7625E-6)

Table A.1 (Continued)

	Population change 2000-2010			Net migration rate 2000-2010		
	Spatial error model			Spatial error model		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Middle age net migration rate	0.0014***	-0.0017***	-0.0007***	0.0020***	0.0023***	-0.0003
	(9.4984E-5)	(0.0001)	(0.0002)	(8.9333E-5)	(9.4005E-5)	(0.0001)
Old age net migration rate						
Constant	-0.1975***	-0.1829***	-0.1366***	-0.1425***	-0.1291***	-0.0807***
	(0.0123)	(0.0123)	(0.0117)	(0.0112)	(0.0112)	(0.0104)
Spatial lag effects						
Spatial error effects	0.5609***	0.5675***	0.5394***	0.5105***	0.5263***	0.4856***
	(0.0204)	(0.0202)	(0.0209)	(0.0216)	(0.0213)	(0.0222)
Measures of fit						
Log Likelihood	3358.58	3397.65	3566.60	3556.90	3599.12	3825.23
AIC	-6693.17	-6769.29	-7105.21	-7089.8	-7172.24	-7622.46
BIC	-6620.66	-6690.75	-7020.62	-7017.3	-7093.70	-7537.87

Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; standard errors in parentheses;
AIC = Akaike's Information Criterion. BIC = Bayesian Information Criterion

Table A.2 Regression Analyses of Population Change and Net Migration in Nonmetropolitan Counties

	Population change 2000-2010			Net migration rate 2000-2010		
	Spatial error model			Spatial error model		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Independent variables						
Natural amenity scale	0.0088***	0.0068***	0.0058***	0.6367***	0.4600***	0.3325**
	(0.0012)	(0.0013)	(0.0012)	(0.1135)	(0.1171)	(0.1099)
Forest coverage	0.0005***	0.0005***	0.0002	0.0628***	0.0654***	0.0293**
	(0.0001)	(0.0001)	(0.0001)	(0.0098)	(0.0099)	(0.0096)
Land developability	-0.0002	-0.0001	-0.0002*	0.0075	0.0108***	0.0002
	(9.9255E-5)	(9.9278E-5)	(9.5666E-5)	(0.0092)	(0.0092)	(0.0087)
Arts, entertainment, and recreation establishments	-0.0149***	-0.0242***	-0.0210***	-0.1286	-0.9988*	-0.6013
	(0.0039)	(0.0041)	(0.0040)	(0.3720)	(0.3897)	(0.3715)
Highway density	0.0037**	0.0036**	0.0032*	0.2174	0.2008	0.1391
	(0.0013)	(0.0013)	(0.0012)	(0.1212)	(0.1206)	(0.1140)

Table A.2 (Continued)

Airport accessibility	0.0067***	0.0066***	0.0057***	0.3814***	0.3794***	0.2589**
	(0.0010)	(0.0009)	(0.0009)	(0.0897)	(0.0891)	(0.0846)
Control variables:						
Educational attainment		0.0030***	0.0012**		0.2778***	0.0685
		(0.0004)	(0.0004)		(0.0392)	(0.0396)
Population density	3.4892E-5*	1.6544E-5	-1.4742E-5	0.0051**	0.0035*	0.0031*
	(1.6752E-5)	(1.6664E-5)	(1.6139E-5)	(0.0016)	(0.0016)	(0.0015)
Household Income	4.6809E-6***	3.1835E-6***	3.4643E-6***	0.0003***	0.0001**	0.0002***
	(3.8905E-7)	(4.3813E-7)	(4.2241E-7)	(3.6325E-5)	(4.0985E-5)	(3.8647E-5)
White net migration rate			0.0031***			0.3604***
			(0.0003)			(0.0241)
Black net migration rate	-5.2073E-6*	-5.4157E-6*	-3.8844E-6	-0.0006**	-0.0006**	-0.0004*
	(2.4176E-6)	(2.3717E-6)	(2.3071E-6)	(0.0002)	(0.0002)	(0.0002)

Table A.2 (Continued)

	Population change 2000-2010			Net migration rate 2000-2010		
	Spatial error model			Spatial error model		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Hispanic net migration rate	-8.3766E-7	-7.5273E-7	2.0087E-8	-0.0007	-0.0007	-0.0006
	(5.0573E-6)	(4.9665E-6)	(4.8194E-6)	(0.0005)	(0.0005)	(0.0005)
Middle age net migration rate	0.0009***	0.0011***	-0.0005**	0.1523***	0.1748***	-0.0190
	(0.0001)	(0.0001)	(0.0002)	(0.1523)	(0.0111)	(0.0168)
Old age net migration rate						
Constant	-0.1731***	-0.1690***	-0.1237***	-13.8124***	-13.5204***	-8.0721***
	(0.0149)	(0.0148)	(0.0148)	(1.3804)	(1.3824)	(1.3513)
Spatial lag effects						
Spatial error effects	0.4703***	0.4938***	0.4797***	0.4164***	0.4453***	0.4250***
	(0.0239)	(0.0233)	(0.0237)	(0.0252)	(0.0245)	(0.0250)

Table A.2 (Continued)

Measures of fit						
Log Likelihood	2424.83	2451.19	2518.46	-6788.44	-6764.32	-6658.82
AIC	-4825.67	-4876.39	-5008.93	13600.9	13554.6	13345.6
BIC	-4758.32	-4803.42	-4930.35	13668.2	13627.6	13424.2

Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; standard errors in parentheses;
AIC = Akaike's Information Criterion. BIC = Bayesian Information Criterion

Table A.3 Regression Analyses of Population Change and Net Migration in Metropolitan Counties

	Population change 2000-2010			Net migration rate 2000-2010		
	Spatial lag model			Spatial error model		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Independent variables						
Natural amenity scale	0.0061***	0.0048**	0.0041**	0.5377**	0.4048*	0.2327
	(0.0015)	(0.0015)	(0.0014)	(0.1790)	(0.1775)	(0.1573)
Forest coverage	-0.0003*	-0.0003*	-0.0005***	-0.0073	-0.0058	-0.0297*
	(0.0001)	(0.0001)	(0.0001)	(0.0158)	(0.0156)	(0.0139)
Land developability	0.0004**	0.0005***	0.0002	0.0639***	0.0747***	0.0355*
	(0.0001)	(0.0001)	(0.0001)	(0.0157)	(0.0154)	(0.0141)
Arts, entertainment, and recreation establishments	-0.0330**	-0.0570***	-0.0559***	-0.7549	-2.8977*	-2.7464**
	(0.0116)	(0.0119)	(0.0111)	(1.1185)	(1.1309)	(1.0432)
Highway density	-0.0014	-0.0021*	-0.0001	-0.1736	-0.2590**	-0.0088
	(0.0009)	(0.0009)	(0.0008)	(0.0944)	(0.0931)	(0.0864)

Table A.3 (Continued)

Airport accessibility	0.0037**	0.0024	0.0037**	0.4683***	0.3205*	0.4478***
	(0.0013)	(0.0013)	(0.0012)	(0.1312)	(0.1301)	(0.1189)
Control variables:						
Educational attainment		0.0033***	0.0010*		0.3295***	0.0735
		(0.0005)	(0.0005)		(0.0453)	(0.0453)
Population density	-6.8352E-7	-1.1065E-6	-7.0220E-7	-2.3396E-5	-6.5155E-5	-8.1941E-5
	(1.1319E-6)	(1.1096E-6)	(1.0371E-6)	(0.0001)	(0.0001)	(0.0001)
Household Income	2.7169E-6***	7.7965E-7	2.5824E-6***	0.0002***	-5.2422E-5	0.0001**
	(3.4390E-7)	(4.3562E-7)	(4.3071E-7)	(3.5804E-5)	(4.5855E-5)	(4.3519E-5)
White net migration rate			0.0052***			0.5452***
			(0.0004)			(0.0383)

Table A.3 (Continued)

	Population change 2000-2010			Net migration rate 2000-2010		
	Spatial lag model			Spatial error model		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Black net migration rate	-1.0155E-5	-1.0543E-5*	-5.6773E-6	-0.0009	-0.0009	-0.0005
	(6.2237E-6)	(6.0919E-6)	(5.7027E-6)	(0.0006)	(0.0006)	(0.0005)
Hispanic net migration rate	6.4882E-5**	5.6114E-5*	5.4835E-5**	0.0035	0.0023	0.0027
	(2.2891E-5)	(2.2432E-5)	(2.0955E-5)	(0.0022)	(0.0022)	(0.0020)
Middle age net migration rate	0.0022***	0.0026***	-0.0007*	0.2620***	0.3072***	-0.0370
	(0.0002)	(0.0002)	(0.0003)	(0.0155)	(0.0164)	(0.0285)
Old age net migration rate						
Constant	-0.0967***	-0.0694***	-0.0831***	-9.6846***	-6.6130***	-6.6624***
	(0.0181)	(0.0180)	(0.0169)	(1.9589)	(1.9737)	(1.7814)

Table A.3 (Continued)

Spatial lag effects	0.2719***	0.2688	0.2459***			
	(0.0282)	(0.0278)	(0.0266)			
Spatial error effects				0.3447***	0.3592***	0.3040***
				(0.0306)	(0.0302)	(0.0316)
Measures of fit						
Log Likelihood	1013.05	1036.67	1113.25	-3906.07	-3880.30	-3788.86
AIC	-2000.1	-2045.35	-2196.50	7836.14	7786.6	7605.72
BIC	-1935.23	-1975.48	-2121.65	7896.02	7851.48	7675.59

Note: * p≤0.05; ** p≤0.01; *** p≤0.001; standard errors in parentheses;
AIC = Akaike's Information Criterion. BIC = Bayesian Information Criterion