Sending or Receiving Stations?: The Dual Influence of Railroads in Early 20th-Century Great Plains Settlement

Katherine J. Curtis White[1]

Center for Demography and Ecology
University of Wisconsin-Madison

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ABSTRACT

This study tests two theses on how railroads shaped settlement patterns in the twentieth century U.S. Great Plains using railroad, population census, and environmental data. Drawing from theories of transportation and development, I supplement standard regression procedures with spatially-oriented techniques to empirically test long-held claims about the relationship of railroads. The Great Plains is a region where settlement is commonly attributed to the railroad and I examine the period after the railroad heyday and before the widespread adoption of the automobile. Study results show a complex relationship between county population growth and the presence of railroads. Counter to the nineteenth-century pattern, the influence of railroads between 1900 and 1930 is negative and conditioned by county development; in the first decade, railroads are receiving stations for counties with greater population density and sending agents for less settled places. Spatial effects explain the conditional relationship in later decades. Theoretical and statistical implications for scholarship concerning transportation and spatial observations are discussed.

Sending or Receiving Stations?:

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Transcontinental railroads have been identified as a major contributor to the settlement of the western United States, especially the vast region occupying the continent's center: the Great Plains. Indeed, while quantitative analyses are absent, previous research and commentary concerning migration and population growth in the region has focused on the colonizing influence of the railroads and counts the railroads as the most significant factor in the region's settlement (Fogel 1962; Hedges 1926; Jenks 1944; Kirby 1983; Savage 1959). With the aid of federal land grants, nineteenth century entrepreneurs constructed transcontinental railroads that connected the east and west coasts, stimulating a significant transition in the U.S.'s economic and settlement potential. There is reason, however, to suspect that the influence of the railroads may have waned by the turn of the century. More than 90,000 miles of track were laid down in the U.S. between 1830 and 1880, yet construction had subsided by the 1890s and virtually halted by 1910.[2] And although additional mileage was added to lines serving the Great Plains after the 1910s, existing railroad lines were reinforced but no new major markets were accessed (Kirby 1983).

As railroad expansion quieted in the early twentieth century, the Great Plains continued to develop. Between 1900 and 1930, the region experienced considerable growth, expanding its population by approximately 45% compared to the U.S.'s 62%, with most of the growth concentrated in the western-most counties ([citation withheld]). The diminished construction of railroads and the distribution of population growth and loss motivate the present investigation of whether the railroads continued to promote population growth in the Great Plains during the early decades of the twentieth century and whether the nature of the relationship changed over time. The Great Plains is a case ripe for such

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[2] Railway Station Productions. 2001. 1942 Quiz Book on Railroads and Railroading. http://www.railwaystation.com/1942/about.html.

exploration given its unique and heavily embedded relationship with the railroad that spawned the region's first phase of large-scale settlement in the 1800s.

Earlier works contribute to theoretical discussions of the importance of transportation in shaping population development and social organization (e.g., Duncan 1964; Mark and Schwirian 1967; Schnore 1957); yet they do not offer systematic investigations of the proposed relationship. Further, while more contemporary, statistically-driven research about the impacts of transportation on population growth exists, it focuses on the influence of highways during the post-1970 period (with the exception of Guest 1977). The basic premises and findings reported in these respective bodies of literature can inform the historical case of railroads in the Great Plains at the beginning of the twentieth century. In general, transportation supports population growth by providing potential residents with a means to access a location and by stimulating the economic base which then attracts additional laborers and residents. In addition, two hypotheses can be gleaned from this literature. First, the influence of transportation may be conditioned by the initial population status; transportation may lead to growth in smaller, less developed areas relative to larger, more developed places (Bohm and Patterson 1972; Crane and Leatham 1990; Hale and Walters 1974; Hobbs and Campbell 1967; Lichter and Fuguitt 1980). Second, its direct influence may dissipate over time although its influence becomes inherited within other location characteristics that were initially shaped by the transportation system (Guest 1977; McKenzie 1929).

Data for this study are drawn from several historical sources on railroad, population, and environmental conditions to estimate the relationship between railroads and county population change in the Great Plains from 1900 to 1930. I apply standard and spatially-oriented regression techniques to analyze whether the nature of the relationship was conditioned on the original population state and whether the influence, additive or interactive, diminished over time. This study offers the first systematic analysis of the relationship at a pivotal point in the railroad's development and at a moment of marked population growth on the Great Plains. In addition to informing the particular historical case, this investigation also improves scholarly understanding of the broader relationship between transportation and population change, as well as insight into how stages of development, for both factors, might alter this relationship.

HISTORICAL AND THEORETICAL CONTEXT

The Railroad Revolution

The Great Plains provided the stage for the "railroad revolution" that began in the 1840s and lasted throughout most of the late-1800s (Fogel 1962, p. 163). Scholars have crowned the railroad as the most important innovation of the last two-thirds of the nineteenth century, claiming that "[the railroad] appears as the sine qua non of American economic growth, the prime force behind the westward movement of agriculture, the rise of the corporation, the rapid growth of modern manufacturing industry, the regional location of industry, the pattern of urbanization, and the structure of interregional trade" (Fogel 1962, p. 164). It is argued that the importance and influence of the railroad "can hardly be overemphasized"; it was the preeminent force driving economic development and settlement in the West (Savage 1959, p. 184; see also Kirby 1983).[3]

Indeed, the railway promoter, both as the individual and the larger idea, has been characterized quite romantically as not only a potential economic agent but also the embodiment of the dream of developing communities, the region, and the continent (Jenks 1944, p. 3). Railroad and land companies developed on an advertising campaign that extended beyond the U.S. borders and made its way into the consciousness of hopeful immigrants looking for a better life, even if it meant traveling to a distant, undeveloped place. Such advertisements offered "peace and plenty" as well as "sunshine and contentment," and they were hard to resist (Rawlings Land Company Advertisement (1925) in Lange and Taylor 1999, p. 91). In order to profit, or at least to avoid debt, railroad companies sold land along the tracks to prospective settlers, creating communities along the railroad's path to sunshine. As railroads expanded their lines connecting the east and west coasts of the U.S. in the nineteenth century, many

[3] See Dawson (1927) for a discussion of the pivotal role of the railroad in settling the Canadian Great Plains and bridging the geographically and socially distant provinces of Canada.

companies sold "exploration tickets" whose fare could be credited towards the price of any land bought from the company within sixty days after purchase (Hedges 1926, p. 320). The Northern Pacific also granted free transportation for the land purchaser and any family members en route to settle the purchased land.

The railroads stimulated economic development and, with it, population growth as the demand for construction labor initiated the founding of communities and markets. Laborers were paid wages that were used to purchase goods that supported farms, mills, and other producers both within and outside of the local market, thus further contributing to the spread of economic specialization (Jenks 1944, p. 6). Along with the settlers and laborers, the railroads brought economic development to areas that would not have otherwise had any commercial life.

The railroad's importance as a pace setter and innovator, however, declined as time passed. The last cluster of new railway systems was completed during the first decade of the twentieth century, and although distances traveled by passengers increased by more than 100% between 1890 and 1940, passenger-miles did not expand after 1920 (Jenks 1944, pp. 12-13). Although passengers continued to travel via railroad, and do so even today, the railroad was overpowered by the automobile. In 1900, a mere 8,000 motor vehicles were on U.S. roads, 128,500 miles of which were surfaced. By 1940, more than 32 million automobiles could be found on the nations' 1.4 million miles of surfaced highways (Schnore 1957, p. 174; see also Burgess 1930, p. 992). The early decades of the twentieth century have been identified as a period between the conclusion of the railroad era and the start of the automobile age, since automobiles were not widely practical or affordable for the mainstream population until after World War II (McKenzie 1929; see also Guest 1977). The years between 1900 and 1930 provide scholars with a period of settlement worthy of investigation.

Perspectives on Population and Transportation

Populations can grow through four mechanisms: increase in fertility, reduction in mortality, increase in in-migration, and decrease in out-migration. It is through in-migration, rather than natural increase (the difference between births and deaths), that the Great Plains' population rapidly expanded during the first three decades of the twentieth century. One of the long-standing “laws of migration” (Ravenstein 1889; Lee 1966) states that “[t]he volume of migration is related to the difficulty of surmounting the intervening obstacles” (Lee 1966, p. 53). Railroads reduced the obstacles to migration into the Great Plains and West. Crossing the expansive plains was a daunting task, even by railroad. Yet, the iron horses diminished much of the risk associated with westward migration by providing higher levels of comfort, security, and time efficiency compared to other available modes of transportation, namely horseback or wagon.

A second long-standing law of migration states that “[e]ach main current of migration produces a compensating counter-current” (Lee 1966, p. 48) and that efficiency, or the balance between the “main current” and the “counter-current,” varies with economic conditions. Efficiency is high in prosperous periods and low in times of depression (1966, p. 56). As the agricultural industry expanded during the late-1800s and into the early-1900s, the Great Plains were considered a prime destination. Nevertheless, even the early part of the 1900s was marred by poor economic conditions mainly caused by harsh environmental circumstances. During these times, railroads may have disproportionately encouraged membership into the “counter-current” migration away from the region, and, therefore, population loss rather than growth.

The notion of dual roles, railroads as both population sending and receiving agents, is explored in contemporary research that examines the relationship between highways and population growth (for a thorough review of this literature see Chi, Voss, and Deller 2004). This literature treats transportation as a type of infrastructure that affects population change exclusively through migration and not natural increase. Researchers have investigated the influence of transportation on population change through the lenses of various regional economic theories. Each of these perspectives suggests that transportation operates indirectly through economic change. Among these, the growth pole theory (Thiel 1962) considers that the influence of transportation on population change varies according to what might be characterized as an urbanization scale that reflects population size or stage of development.[4]

The growth pole theory focuses on "spread" versus "backwash" in terms of population growth in the metropolitan area versus the hinterland. Increases in the hinterlands are supplemented by the "spread" effects of added employment, while decreases result from the "backwash" movement of rural laborers to the urban location (Briggs 1980; Henry, Barkley, and Bao 1997; Humphrey and Sell 1975; Lichter and Fuguitt 1980; Rephann 1992). A more dynamic process has also been proposed: one dependent on the stage of the region's development because backwash is characteristic at the earlier stages. Due to metropolitan spillover, backwash is later followed by spread. Empirical studies generally suggest a positive relationship between highways and population growth, but they clarify that this relationship is conditioned by development-oriented factors, including size of place, urban versus rural status, and centrality versus periphery status (Bohm and Patterson 1972; Crane and Leatham 1990; Hale and Walters 1974; Hobbs and Campbell 1967; Lichter and Fuguitt 1980).

In this research, the unit of analysis is the county rather than a smaller geographic unit such as a township or a city and the mode of transportation is the railroad rather than highway. The former difference implies that one cannot readily distinguish between metropolitan center and hinterland because county contains both place types. Yet, measures of population density and city status (described below in the *Data and Methods* section) are used to garner information about the stage of development or degree of urbanization which is reflected in the hinterland/metropolitan distinction. The latter difference is

[4] Mark and Schwirian (1967) offer an insightful study of the influence of transportation on population growth according to area level of development: settlement, industrialization, and metropolitanization. The authors test Christaller's (1933) central-place model and determine that the utility of the perspective is limited to the settlement stage, and has no application to the more advanced stages of development. The central-place model suggests that settlements are geographically distributed according to their position within a hierarchy of ecological position (i.e., niche) and functional differentiation.

arguably inconsequential, as both are prevailing modes of transportation during their respective time periods.

The greatest difference between the contemporary association examined in the research reviewed above and the historical relationship investigated in the present analysis concerns the assumed direction of population growth. The population stream for the Great Plains between 1900 and 1930 may have moved toward previously less inhabited counties (the "rural") rather than more populated counties (the "urban"). Therefore, the "dynamic" growth pole process might have spread at the earlier stage and contracted in later years instead of the reverse. Here, spread would be attributable to added employment through agricultural development and not necessarily through metropolitan spillover.

Historical research provides additional insight. When the nineteenth century concluded, the geographic distribution of population growth and urban centers across the U.S. coincided with railway intersections (Schnore 1957). In his analysis of population growth in the Puget Sound from the mid-1800s through the 1970s, Guest (1977) demonstrates that each wave of transportation technology offered unique contributions to settlement patterns including location and growth, although some systems have longer-lasting effects. For example, 70% of new developments were placed along railroad lines during the "railroad era," spanning 1898-1915 (1977, p. 192). The majority of the largest settlements were located near or on a railroad line. Moreover, much of the later highway development mimicked the system of settlement established by railways (1977). Although the railroad did not directly influence settlement location or the extent of population growth in the post-railroad era, it did establish the pattern that later development and systems of transportation continued to follow.

Two hypotheses concerning railroads in the Great Plains are drawn from the research on contemporary and historical transportation. First, railroads are anticipated to influence population change, although the direction and magnitude are expected to be conditioned by stage of development. Whether railroads act as sending or receiving agents is expected to depend on the initial county population density and the point in the period under analysis. Specifically, a more positive influence of railroads should be evidenced in less dense counties given the expanding agricultural market in the Great

Plains during the early 1900s. Second, the magnitude of the relationship is anticipated to dissipate over time as railroad expansion and its accompanying role as a "pace setter" diminishes. Other location characteristics are expected to attenuate the influence of railroads in later years because, as argued by Guest (1977), the influence of transportation is absorbed by other settlement attributes that were initially shaped by the system of transportation. Further, highway researchers (e.g., Thiel 1962) suggest that transportation indirectly impacts population change through its association with employment.

DATA AND ANALYTICAL APPROACH

Sample

There is no consistent geographical definition of the Great Plains among historians, geographers, demographers, or sociologists. Inclusion ranges from six U.S. states in their entirety to counties within 13 states plus Canadian and Mexican territories. The eastern border is sometimes drawn at the 98th meridian, the 100th meridian, or the iso-line following 20 inches or less of rainfall, and the western boundary is typically demarcated at the base of the Rocky Mountains. Yet, all scholars agree that the Great Plains is distinct from its surrounding areas by its semi-arid quality. In some years the Great Plains region is dry and desert-like, while in other years it is very wet. Still, in other years, it is wet or dry at the wrong time from the viewpoint of agricultural production (Kraenzel 1955, p. 12). It is this unpredictability and annual variation that separates the Great Plains from its more predictable eastern and western neighbors. The sample for this study follows the U.S. Geological Survey definition and includes approximately 876 counties within 13 states that are aggregated into 742 county clusters described below in greater detail.[5]

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[5] A broader definition is employed in the present analysis compared to other studies of the Great Plains (see http://www.epa.gov/ecoplaces/part1/site9.html). Minnesota, Iowa, and Missouri often are omitted from studies of this region due to the variation in precipitation, grass length, and altitude. For example, The Great Plains Population and Environment Project excludes most counties within these three states and Missouri entirely, thereby creating a sample of 450 counties (Gutmann et al. 1998). Other Great Plains research has restricted analysis to 396 (Adcock 1995) or 478 (Cromartie 1998) counties, while

The relationship between transportation and population change in this region provides an intriguing case to study particularly given the extent of variation in population growth among counties and between decades. Further, the widely discussed role of the railroad companies in shaping early white settlement on the Great Plains provides additional reasons for an empirical analysis of the railroad and its association with continued settlement patterns.

Counties are analyzed because they are governmental units that unify the populations within their boundaries (Stephan 1971). They also are geographical units rich with social and economic data that remain reasonably consistent over time. Government taxes and programs involving agriculture, social welfare, education, and transportation construction and maintenance operate at the county level. Because few large metropolitan centers are found within the Great Plains, concerns regarding metropolitan overflow that are incessantly bothersome in studies of more urban locations do not apply to the present analysis.

County borders, however, change over time and they tend to change for reasons mainly associated with population growth (Stephan 1971). Using a template developed by Horan, Hargis, and Killian (1989), each county is converted into its 1900 form and given a unique county cluster code, which produces 742 county clusters for analysis.[6] Some counties did not change their shape while others were dramatically different in 1930 than they were in 1900. For example, while most of the counties in Iowa

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others have limited it to 294 non-metropolitan counties (Albrecht 1986). Although places within these states may receive more than 20 inches of rainfall, evaporation maintains semi-arid conditions among the western counties of these states (Kraenzel 1955).

[6] Use of the template has the following implications: if county A and B are not involved in the formation of a new county, then there would be no change in the county code and each county would be assigned a separate county cluster code. But if a portion of county A split off to produce county B, then the counties would share the same county cluster code. Similarly, if county B merged with county A, then they would share the same county cluster code.

have not changed their boundaries since 1900, almost every county in Oklahoma has because by 1900, Oklahoma had not yet become a state and was largely considered "Indian Territory."

Measures

Decadal population change for 1900-10, 1910-20 and 1920-30 serve as the dependent variables in the present analysis. The measure of county population is drawn from the Historical, Demographic, Economic, and Social Data: The United States, 1790-1970, made available by the Inter-University Consortium for Political and Social Research (ICPSR 1976). Population change, or the transformed growth rate, is derived by taking the natural log of the value obtained by dividing the difference between county population in Time 1 and Time 2 by the value at Time 1 ($\log[1+(P_{1910}-P_{1900})/P_{1900}]$), where 1 is added to adjust for negative values. Reported in Table 1, the average percent change is the natural log of 0.38 (46%) for 1900-10, -0.11 (-10%) for 1910-20, and 0.31 (36%) in 1920-30. These averages suggest that growth characterizes the beginning and end of the period with notable loss during the middle decade. Others have described 1910-20 as a decade plagued with drought, poor crop yields, and out-migration (Ottoson et al. 1966).

Figure 1 illustrates the spatial distribution of population change across the three decades under analysis. The majority of the Great Plains counties experienced growth between 1900 and 1910 (7.0 + 51.2 = 58.2%), most of which grew by more than 10%. As evidenced in Figure 1, settlement at the turn of the century was still occurring on the Great Plains. Much of the growth was spatially concentrated in the western counties while loss was concentrated among the eastern-most counties. Between 1910 and 1920, the distribution reversed, and nearly three-quarters of the counties suffered loss. Spatially, the few cases of growth (15.4%) remained mostly restricted to the western counties; while the eastern and central counties were riddled with varying levels of decline. The region rebounded during the 1920s, where nearly 93% of all Great Plains counties grew by more than 5%, 85% of which grew by more than 10%. This observation is consistent with the previously documented expansion of dryland farming during the years leading up to the Great Depression.[7] In this decade, growth was distributed across the Great Plains, with pockets of decline emerging in the eastern counties.

[Table 1 About Here]

[Figure 1 About Here]

There are two key independent variables in the present analysis: railroad presence and county population density. Railroad data are drawn from Modelski's (1975) Railroad Maps of the United States made available through the Library of Congress and historical atlases published by Rand McNally. Modelski's collection includes a map originally published in 1898 by Charles P. Gray that contains all railroads, by company name, within the continental United States, southern Canada and northern Mexico. The Rand McNally Commercial Atlas for 1911 and 1920 contains comparable information and are used for the most closely corresponding decennial census year. These maps were cross-checked with Poor's Manual of Railroads (Poor 1900, 1910, and 1920), an annual publication containing railroad companies' financial reports, short histories, and maps.

Counties were originally coded as either having a railroad, neighboring a railroad, or not having or neighboring a railroad. Given low frequencies of the latter two categories, the data are coded "1" if they contained a railroad and "0" if they did not contain a railroad, regardless of whether they neighbored one. Railroads were largely present at the beginning of the twentieth century, as reported in Table 1, with 87% of the counties containing a railroad in 1900. The percentage increased to 90% in 1910 and 96% in 1920. Although the vast majority of counties contained a railroad, not nearly as many shared the same degree of growth. It is reasonable to anticipate that if the railroad is to have a relationship with population change during this period, then it is likely conditioned by its association with some other county characteristic, arguably one reflecting the stage of population development.

[7] U.S. Department of Agriculture. 2003. "A History of US Agriculture, 1776-1990: Agricultural Trade and Development." Washington, DC: Economic Research Service (http://www.usda.gov/history2/text7.htm).

Population density is the second central independent variable and is measured as the reported number of people per square mile at the beginning of the decade (i.e., 1900, 1910, or 1920). The conditioned relationship between railroad presence and population change is the focus of this analysis, and this conditioned relationship is measured by the interaction between railroad presence and initial county population density. Drawing from previous research on the influence of highways, population density is expected to condition the relationship between railroads and county population. Railroads are anticipated to serve as sending agents in counties with high population density and receiving stations for counties beginning the decade with lower density.

Several additional co-variates are included to measure the influence of various demographic, economic, and environmental factors. Measures for the demographic and economic co-variates are taken from the Historical, Demographic, Economic, and Social Data: The United States, 1790-1970 (ICPSR 1976). The proportion of the county population engaged in farm work at the beginning of the decade is included as an indicator of the economic base; however complete and comparable census estimates of county employment in other economic sectors are not available until 1930. Theories addressing the influence of transportation on population growth suggest that economic base may reduce the influence of transportation on population change.

The potentially spurious influence of the county settlement date also is considered. Settlement date is operationalized as the year in which the county first appeared within the U.S. published census reports, with dates ranging from 1860 to 1900. Whether a county contains a city of 10,000 or more is measured in the initial year of the respective decade; the presence of a city generally is associated with continued population growth. Population age structure is measured as the proportion of the male population age 21 and older in 1900 and as the proportion of both the male and female population age 21 and older in 1910 and 1920. The age structure measures are admittedly crude but reflect the most accurate indicator available for these census years. Young populations typically are associated with positive population growth whereas older populations generally are related to population decline.

Precipitation and temperature range are included in the analysis to account for any spurious effects that the environment might have on population change through its relationship with agricultural production (Boserup 1981; Galloway1986) or population preferences for tepid climates (Cromartie 1998; Heaton, Clifford, and Fuguitt 1981). Climate data are made available through the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP), provided by the VEMAP data group within the Ecosystem Dynamics and the Atmosphere Section, Climate and Global Dynamics Division, National Center for Atmospheric Research (Kittel et al. 1997; Schimel et al. 2000).[8] Precipitation is measured as the average rainfall in inches during the decade's initial census year, while temperature range is the difference in degrees Fahrenheit between the January and July temperature for the corresponding census year. Greater temperature ranges and lower precipitation are negatively associated with population change.

Methods

Standard ordinary least square (OLS) and two spatial methods of analysis, geographically weighted regression (GWR) and spatial lag regression, are employed to examine the relationship between railroads and population change from 1900 to 1930. Spatial methods of analysis are used because the data are georeferenced and tests for spatial correlation are large and significant across each decade. The estimated global Moran's I for the dependent variable is reported for each decade in Table 1 (0.65 in 1900-10; 0.36 in 1910-20; and 0.53 in 1920-30). The positive correlation suggests that counties experiencing growth tend to neighbor other counties experiencing growth, whereas counties suffering loss tend to neighbor other counties losing population. Like temporal autocorrelation, spatial autocorrelation introduces dependence into the regression error structure which can produce biased standard errors of parameter estimates if left unresolved.

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[8] The data are derived from historical time series and projected scenarios by applying spatial interpolation methods to inputs from weather sources spanning the years between 1895 and 1994. Estimates are available at the annual, monthly, and daily level. In this analysis, monthly data are aggregated for the decadal years between 1900 and 1930.

Several analytical steps precede the selection of a spatial regression model. Standard OLS regression and GWR techniques are first employed to discern the nature of the relationship and whether the relationship varies across space in a systematic pattern. GWR is similar to the more familiar OLS regression model, but it also incorporates a spatial weights matrix that allows the researcher to fit a separate "local" regression model for each county (Fotheringham, Brunsdon, and Charlton 2002). The parameter values of the local regressions can be mapped to provide insight into the spatial patterning of the relationship of interest. In the current analysis, GWR is employed to test whether the bivariate association between railroads and population change varies across space or whether the relationship can be generalized to the entire study region. Analysis results are also useful in assessing the specific nature of the spatial correlation: spatial heterogeneity, spatial dependence, or both.

The software packages SpaceStat and GeoDa are used in diagnosing the type of spatial effects existing within the Great Plains data. Spatial heterogeneity can be conceptualized as a large-scale effect. This is indicated by variation in the moments of a spatial process in an area resulting from spatial location or from relationships with explanatory variables that vary regularly in their values across the spatial unit under analysis. Such a drifting process is indicative of spatial non-stationarity. In contrast, spatial dependence is a small-area effect and, according to Anselin, "can be considered to be the existence of a functional relationship between what happens at one point in space and what happens elsewhere" (1988, p.11). In this context, a spatial process underlies the relationship between an independent variable and co-variates of interest in a stationary fashion. For example, the deviations in values of the process from its mean tend to follow each other in neighboring sites. The reader is referred to Cliff and Ord (1973, 1981) for a more thorough discussion of the various forms and issues accompanying spatial autocorrelation. It is difficult to determine whether heterogeneity or dependence is operating or whether both are at play.

Several steps to address potential heterogeneity were taken before fitting a dependence model; although in the interest of space and the primary focus on the theorized relationship, the details of the various iterations are not reported here (results are available from the author at request). The steps consist of including additional variables to reduce the amount of heterogeneity prevalent in the data and then re-estimating the extent of spatial correlation. One iteration includes a polynomial trend surface to de-trend the data of existing spatial heterogeneity and reduce heteroskedasticity that could otherwise bias the interpretation of model diagnostics. The trend surface captures the linear and non-linear influence of the respective county's location and is expressed as the county centroid's longitude, latitude, the squared values of each, and the multiplicative value of both.

Inclusion of the substantive co-variates and a polynomial trend surface reduce much of the correlation attributable to heterogeneity. Diagnostics suggest that the remaining spatial correlation is attributable to a dependence process; the residual spatial correlation is a product of a functional relationship between the social processes experienced in different spatial observations. For example, what happens in county A influences what happens in neighboring county B. Spatial lag regression is the selected dependence model, represented in matrix notation as $y = (I - \rho W)^{-1} X\beta + (I - \rho W)^{-1} \varepsilon$. In addition to the basic building blocks of the OLS equation, the spatial lag regression satisfies the assumption of independent errors and includes an additional parameter capturing the strength of the spatial process, represented as ρ, and yields unbiased estimates of railroad presence and other predictors of population change.

FINDINGS

The Direct Influence of Railroads

Two important implications are drawn from the bivariate analysis of railroads and population change in the Great Plains, reported in the upper part of Table 2. First, unlike the positive relationship presented in historical accounts of railroads and population expansion during the nineteenth century, the relationship between railroad presence and county population change is negative or non-significant during the early decades of the twentieth century. Second, the strength of the relationship varies between decades; it is strongly significant and negative in 1900-10 and 1920-30, while no relationship is evidenced in 1910-20. It is worth noting that this decade witnessed considerable loss relative to the bracketing years (illustrated in Figure 1), and model fit is relatively low for this and the remaining analysis of 1910-20.

[Table 2 About Here]

The population implications of railroad presence can be estimated by exponentiating the solution to the regression equation, where the value of the railroad parameter is multiplied by 1 for counties with railroads and 0 for counties without railroads. Among counties of average population density, those with railroads are estimated to have experienced a 28% increase in population between 1900 and 1910. By comparison, counties without railroads are estimated to have grown by 234%, a more than 200 percentage-point difference. Between 1920 and 1930, the difference persisted at a reduced 120 percentage-point disparity; counties with railroads have an estimated 32% change in population, while counties without railroads are estimated to have grown by 152%. To put these percent changes in perspective, national averages are 19% between1900 and 1910, 13% between 1910 and 1920, and 14% between 1920 and 1930 (U.S. Census Bureau 2000).

The relationship between population growth and railroads is different from that depicted in studies considering the railroad as a colonizing agent during the nineteenth century. If historical accounts are to be trusted, this study’s findings indicate that the railroad's role in settlement appears to have changed by the early 1900s. Results from the GWR analysis, also reported in the upper part of Table 2, suggest no evidence of spatial variation in the relationship. The global estimates produced in the regression analysis adequately reflect the relationship across the Great Plains and can be generalized to the entire study region. By the beginning of the twentieth century, railroads appear to act as sending agents for all Great Plains counties. But, as purported by transportation theory, is this role conditioned by county population density?

The Conditioned Influence of Railroads

Tests for an interactive relationship between railroads and county population density are conducted and reported in the lower part of Table 2. Results indicate that the nature of the relationship varies according to population density; the negative influence of railroad presence is tempered by population density. In the bivariate analysis, counties with railroads experienced an estimated 120 to 200 percentage-points less growth than counties without railroads. The estimates reverse when considering the conditioning influence of population density. The difference between counties of average density without and with railroads is an estimated 70 and 110 percentage-points revealing that counties with railroads have a growth advantage.

Previous research on transportation and population growth suggests that transportation has a greater positive growth impact on less populated places. This proposition is challenged in the case of the historical Great Plains. Figure 2 illustrates the estimated percent change in population derived from the interaction regression equations for 1900-10 and 1920-30 reported in Table 2, where the railroad and density values are permitted to vary. Percent change is estimated for less densely populated counties (2 people per square mile) and more densely populated counties (100 people per square mile), respectively. Here, the complexity of railroad presence is demonstrated. Among less densely populated counties, those without railroads have five to six times the estimated growth in both 1900-10 and 1920-30. Thus in counties with railroads, the railroads act as sending agents. In contrast, among more densely populated counties, counties without a railroad experience greater loss in both decades (16 times in 1900-10 and four times the loss in 1920-30); railroads act as receiving stations.

[Figure 2 About Here]

Results from the spatial lag regression analysis are reported in Table 3 and indicate that the conditioned influence of the railroads persists in the first decade of the twentieth century independent of the predictive influence of other factors commonly associated with population growth. Further, the direct influence of railroads persists. This is not the case in the remaining two decades. No relationship emerges in 1910-20, and while a direct association persists in 1920-30, the conditioning influence of population density is no longer evidenced. The smaller parameter values for railroads in all years and the statistically non-significant interaction in 1920-30 are attributable to specifying spatial effects in two ways. First, much of the direct association between railroads and population change is attenuated by the polynomial trend surface. For example, the 1900-10 parameter estimate for the presence of railroads is -

0.88 (SE 0.07) after accounting for the influence of all substantive co-variates (results not reported), but this same parameter is reduced to -0.51 (SE 0.07) after including the trend surface. The estimate is further reduced to the reported -0.26 (SE 0.06), Table 3, when accounting for the spatial dependence in the outcome variable. The two observed reductions in parameter values are indicative of the spatial effects embedded within both the predictor (attributed to the trend surface and characteristic of spatial heterogeneity) and the outcome (attributed to the spatial parameter, ρ, and characteristic of spatial dependence). Properly specifying the model to account for the spatial effects yields a more accurate estimate of the relationship between railroads and population change.

[Table 3 About Here]

Second, in 1920-30, the density and railroad interaction is attenuated by the spatial lag parameter and not the co-variates or the trend surface. This finding suggests the existence of a spatial dependence process rather than spatial heterogeneity. The way density and the interaction between density and railroads influenced population change in 1920-30 corresponds with the spatial co-variation in the errors of population change; the predictor and the outcome share a similar spatial distribution, and the two variables are closely related in a spatial way. The spatial lag of the dependent variable, therefore, accounts for the influence of the predictor. The conditioning influence of population density is no longer evidenced once the error structure of population change is specified. The Lagrange Multiplier estimate on spatial error in the data confirms the selection of the spatial lag model; the LM estimates are low and statistically non-significant.

Turning to the relative influence of the county characteristics in 1900-10, all of the co-variates behave as anticipated, except for precipitation. The proportion of the county employed in farm jobs is positively associated with population growth and is consistent with the notion that the region as a whole experienced considerable population growth and agricultural expansion during the first decade of the century. The distribution of growth during this decade was especially high in the western-most counties, counties with later settlement dates. The presence of cities and population age structure also are related in the expected directions. Thus, counties with cities tend to experience growth; and lower proportions of older populations are associated with growth. Although there is no evidence of a statistical influence of precipitation, counties with lower temperature ranges are more likely to experience positive population change.

These results imply that even though other county characteristics are associated with population change from 1900 to 1910, railroad presence maintained a direct influence on growth conditioned by population density. Of particular relevance to previous research in contemporary settings, farm employment does not account for the influence of railroads on population change. Railroads influenced county population change in 1900-10 as illustrated in Figure 3. Estimates of county population change are derived from solving the multivariate spatial regression equation, where the values of railroad and population density are varied to demonstrate the differential impacts on population change. The values of county population density reflect the observed range in 1900-10, reported in Table 1, with the minimum equal to less than one person per square mile, the average equal to 23 people per square mile, and the maximum equal to 512. Results show that the influence of having a railroad did not vary by county density but that all counties with railroads are estimated to increase by 100% regardless of density. The influence of not having a railroad, however, does vary according to county density: less densely populated counties without a railroad have a higher estimated population change (160%) than counties with comparable density that have a railroad; counties with average density and no railroad have a lower estimated population change (33%) than comparable counties with a railroad; and more densely population counties are estimated to experience population loss (-100%) whereas comparable counties with a railroad experience growth (100%).

[Figure 3 About Here]

This relationship is restricted to the first decade of the twentieth century. Railroads do not appear to influence population change in 1910-20, but few variables do and the model fit is poor. (This decade differs from the surrounding decades on a number of points and calls for further exploration in future work.) Moreover, the interactive association in the 1920-30 period is reduced to statistical non-significance when accounting for spatial effects. In some ways, prior research suggesting that the railroad lost its influence in later decades is supported, yet through different mechanisms than previously specified. Farm employment and other indicators of the county structure do not attenuate the direct influence of railroads in any decade: the relationship persists in 1900-10 and 1920-30; and there is no bivariate relationship in 1910-20 to explain. Further, the conditioning influence of density is explained by spatial effects and not by other county characteristics. In 1920-30, railroads maintain a direct influence on county population change, and the way in which this influence varies by density is spatially correlated with the variance of population change. When accounting for the spatial correlation in the dependent variable's error structure, the closely, spatially-related interactive relationship between railroads and density is no longer statistically significant.

SUMMARY AND DISCUSSION

The railroad has been identified as the most significant contributor to the settlement of the western U.S. during the nineteenth century:

> The story of the colonization of the West is not altogether the story of fearless men pushing at random into an uncharted country, nor of bands of settlers traveling in covered-wagon trains, desperately withstanding one dire calamity after another. It is also a story of farmers from the older states, crowded into uncomfortable railroad trains, moving, undisturbed by spectacular adventure, into the fertile middle-western farm lands, already surveyed and partially settled. It is a story of colonies of Mennonites and sects from South Russia, journeying out to the prairies of Kansas, not with wagons and ox-teams, but in the drab passenger coaches of the early western railroads. It is the story of Swedes and Norwegians in Minnesota, of Germans in Dakota, Bohemians in Nebraska, and of Hollanders in Iowa, who sought new homes where the railroads led them. (Hedges 1926, p. 311).

This passage suggests that while the migrants were eager to head west, it was the railroad that dictated where they would settle. Two factors cast doubt on this nineteenth-century characterization of the impact of railroads on population growth in the twentieth-century Great Plains: the near saturation of the presence of railroads in Great Plains counties by 1900; and the observed population loss among some counties despite the presence of railroads. This study asks whether railroads act as sending agents or receiving stations during the twentieth-century settlement of the Great Plains and finds that railroads served a dual role: they enabled population growth as well as population decline.

Four conclusions with implications for additional inquiry and theoretical development can be drawn from this analysis. First, the influence of railroads on population change is opposite of that noted for nineteenth-century growth. Railroads negatively impacted population change, and the relationship varies in its statistical strength between decades. Throughout the analysis, a direct relationship persists in 1900-10 and 1920-30, yet no association is evidenced in 1910-20. In contrast to the bracketing decades, 1910-20 is marked with average population loss rather than decline and is poorly estimated by the county characteristics that perform well in the other studied decades. Research on the Great Plains has paid only minor attention to this downward glitch in the general upward trend in regional growth prior to WWII and industrialization. Some research suggests that scattered drought led to poor crop yields which, in turn, led to out-migration (Ottoson et al. 1966). Although measures of farm employment and temperature range capture some of the observed variation in population change, model performance is modest. This period is worthy of additional study. For example, would a localized analysis of climate and farm dependence more adequately explain variation in population change? Are other factors, not included in this analysis or other previous studies, driving the anomaly? Did the nation's involvement in WWI differentially affect population growth in the Great Plains?

Second, the influence of railroads was conditioned by population density. Research on the relationship between contemporary highways and population growth suggests that highways are generally advantageous for growth and tend to be more influential in less developed places (Bohm and Patterson 1972; Crane and Leatham 1990; Hale and Walters 1974; Hobbs and Campbell 1967; Lichter and Fuguitt 1980). In the bivariate context, counties with railroads experienced an estimated 200 and 120 percentage-point disadvantage in population growth relative to counties without a railroad in 1900-10 and 1920-30, respectively. This observation is challenged when accounting for the interactive relationship between railroad presence and population density, as well as other co-variates and spatial effects. The interactive association only persists in 1900-10 while spatial effects explain the relationship in 1920-30. In 1900-10, whether counties with railroads had an estimated growth advantage over counties without railroads depended on population density. For counties with average density, those with railroads have an advantage. For counties with very high density, those with railroads also had an advantage. Yet for counties with very low density, those with railroads had a disadvantage. The conditioned influence of railroads reveals the complexity and duality of its impact on population change; railroads act as sending agents in low density counties and receiving stations in high density counties. These findings support the notion that the influence of transportation differentially influences population growth according to the degree of existing settlement. The direction of the variation, however, is the opposite of that found in studies of contemporary periods, and it only pertains to the first decade of the twentieth century.

Perhaps the opposite direction of the direct and interactive associations implies that railroads were already outmoded by other forms of transportation by the early 1900s, namely the automobile. Unfortunately, county-level data on automobiles does not become available until 1940 thus posing a serious challenge to tests of this thesis. Yet national statistics and previous research on historical periods provide some insight. Part of this study period's intrigue is that it falls after the railroad era and before the automobile era; hence it is truly a pivotal moment in the railroad's history. National statistics reveal that automobiles were gaining acceptance in the 1900s, but they were not widespread until 1920. This implies that the findings pertaining to the 1900-10 decade are not attributable to the unaccounted use of the automobile. Further, previous analyses of the different modes of transportation suggest that patterns of population growth in the automobile era mimicked the patterns established in the railroad era (Guest 1977). If automobiles rather than railroads were shaping population change on the Great Plains in the early decades of the twentieth century, then the relationship should be approximated by the influence of railroads; in the absence of an indicator of automobile presence, an indicator of railroad presence would be a reasonable proxy.

Third, employment and other county characteristics commonly associated with population growth do not explain the direct influence of railroads. Early research in contemporary settings indicates that transportation indirectly influences population change through its influence on employment (Briggs 1980; Henry et al. 1997; Humphrey and Sell 1975; Lichter and Fuguitt 1980; Rephann 1992). Other work implies that the direct influence of transportation might be absorbed by other location characteristics that were initially influenced by the mode of transportation (Guest 1977). Counter to these arguments, these study results show that the direct relationship between railroad presence and population change persists even when accounting for employment and other county characteristics, including the presence of a city and population age structure. This finding suggests that the railroad era may have persisted through the early 1900s and that it is not until later stages of development, extending beyond the time scope of this study, that the direct influence of transportation is eclipsed by other attributes it helped shape in earlier years.

Finally, this analysis demonstrates the need to consider the potential influence of spatial autocorrelation when analyzing areal units of analysis. One implication of the spatial analysis concerns the attenuation of the interactive relationship between railroads and population density in 1920-30. Had the dependence in the outcome error structure not been accounted for, study conclusions would indicate that the relationship persists during this period rather than it being restricted to 1900-10. A second repercussion is the exaggerated magnitude of the railroad parameter. The parameter value of railroad presence is reduced when accounting for the potential influence of spatial heterogeneity through the polynomial trend surface (e.g., -0.88 vs. -0.51 in 1900-10 and -0.91 vs. -.29 in 1920-30). Clearly, the proper specification of spatial data has both statistical and theoretical repercussions.

There is a growing interest in spatial aspects of social processes within sociological research that is likely due to recent developments in computing technology (see [citation withheld] for further discussion). These advances have equipped sociologists, in addition to economists and geographers, with the statistical tools necessary to more accurately analyze spatial data. As demonstrated in this study, the application of the economists' and geographers' tools has both statistical and theoretical implications for sociological research.

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Table 1. Descriptive Statistics of the Dependent Variable and Covariates by Decade, 1900-1930 (N = 742)

	1900-1910		1910-1920		1920-1930	
	Mean	SD	Mean	SD	Mean	SD
Dependent Variable						
Population Change (ln)	0.38	0.69	-0.11	0.25	0.31	0.45
Moran's I	0.65	0.02	0.36	0.02	0.53	0.02
Covariates						
Railroad Present	0.87	0.34	0.90	0.30	0.96	0.19
Density (per square mile)	22.56	33.65	24.76	40.90	22.80	43.63
Prop. Farm Jobs	0.27	0.19	0.13	0.04	0.14	0.05
Settlement Date	1869.91	15.86	† -	-	-	-
City Present	0.05	0.22	0.07	0.26	0.10	0.30
Prop. Age 21+	0.39	0.16	0.33	0.03	0.35	0.04
Annual Precipitation (in)	28.61	10.75	18.68	8.94	27.53	9.57
Temperature Range (^oF)	95.13	11.56	102.92	11.43	102.48	8.36

† The values for Settlement Date are the same in all decades

Table 2. Results from OLS and GWR Regression Analysis of Population Change by Decade, 1900-1930 (N = 742)

	1900-1910		1910-1920		1920-1930	
	β	SE	β	SE	β	SE
Bivariate OLS Model						
Railroad Present	-0.96 ***	0.07	-0.03	0.03	-0.64 ***	0.08
Intercept	1.21 ***	0.06	-0.08 **	0.03	0.92 ***	0.08
Log Likelihood	-688.6		-26.8		-430.4	
AIC	1381.2		57.6		864.7	
Moran's I (errors)	0.463		0.360		0.471	
Spatial Variation (GWR)						
Bandwidth	722		722		461	
P-Value (Monte Carlo)	0.27		0.10		0.84	
Interaction Model						
Railroad Present	-1.12 ***	0.07	-0.06	0.04	-0.94 ***	0.10
Density (per square mile)	-0.09 ***	0.01	-0.005	0.00	-0.12 ***	0.02
Railroad*Density	0.08 ***	0.01	0.01	0.00	0.12 ***	0.02
Intercept	1.48 ***	0.07	-0.06	0.35	1.23 ***	0.10
Log Likelihood	-639.09		-25.75		-414.65	
AIC	1286.17		59.51		837.30	
Moran's I (errors)	0.37		0.36		0.43	

Table 3. Results from Spatial Regression Analysis of Population Change by Decade, 1900-1930 (N = 742)

	1900-1910		1910-1920		1920-1930	
	β	SE	β	SE	β	SE
Railroad Present	-0.26 ***	0.06	-0.06	0.04	-0.21 **	0.08
Density (per square mile)	-0.03 ***	0.01	-0.002	0.00	-0.03	0.02
Railroad*Density	0.03 ***	0.01	0.001	0.00	0.03	0.02
Prop. Farm Jobs	1.03 ***	0.12	-1.44 ***	0.23	2.37 ***	0.32
Settlement Date	0.00 ***	0.00	0.0002	0.00	0.001 **	0.00
City Present	0.29 ***	0.08	0.01	0.04	0.09 *	0.05
Prop. Age 21+	-1.63 ***	0.15	-0.17	0.34	-2.90 ***	0.36
Annual Precipitation (in)	0.00	0.00	-0.001	0.01	-0.001	0.00
Temperature Range (°F)	-0.004 *	0.00	-0.003 **	0.00	0.003	0.00
Latitude	-0.03 *	0.01	-0.01	0.00	-0.06 ***	0.01
Longitude	-0.02 **	0.01	0.005	0.00	-0.01	0.00
$Latitude^2$	0.001	0.00	-0.001	0.00	0.00	0.00
$Longitude^2$	0.001 *	0.00	-0.001 *	0.00	0.002 ***	0.00
Latitude*Longitude	0.001	0.00	-0.002 *	0.00	0.01 ***	0.00
Spatial Parameter (ρ)	0.55 ***	0.04	0.56 ***	0.04	0.48 ***	0.04
Intercept	-0.63	0.38	0.31	0.20	-0.52	0.30
Log Likelihood	-369.95		113.85		-168.88	
AIC	771.90		-195.69		369.77	
Heteroskedasticity †	892.98 ***		777.48 ***		1917.82 ***	
LM on Spatial Error	0.15		0.11		2.69	

† Breusch-Pagan Test for Heteroskedasticity

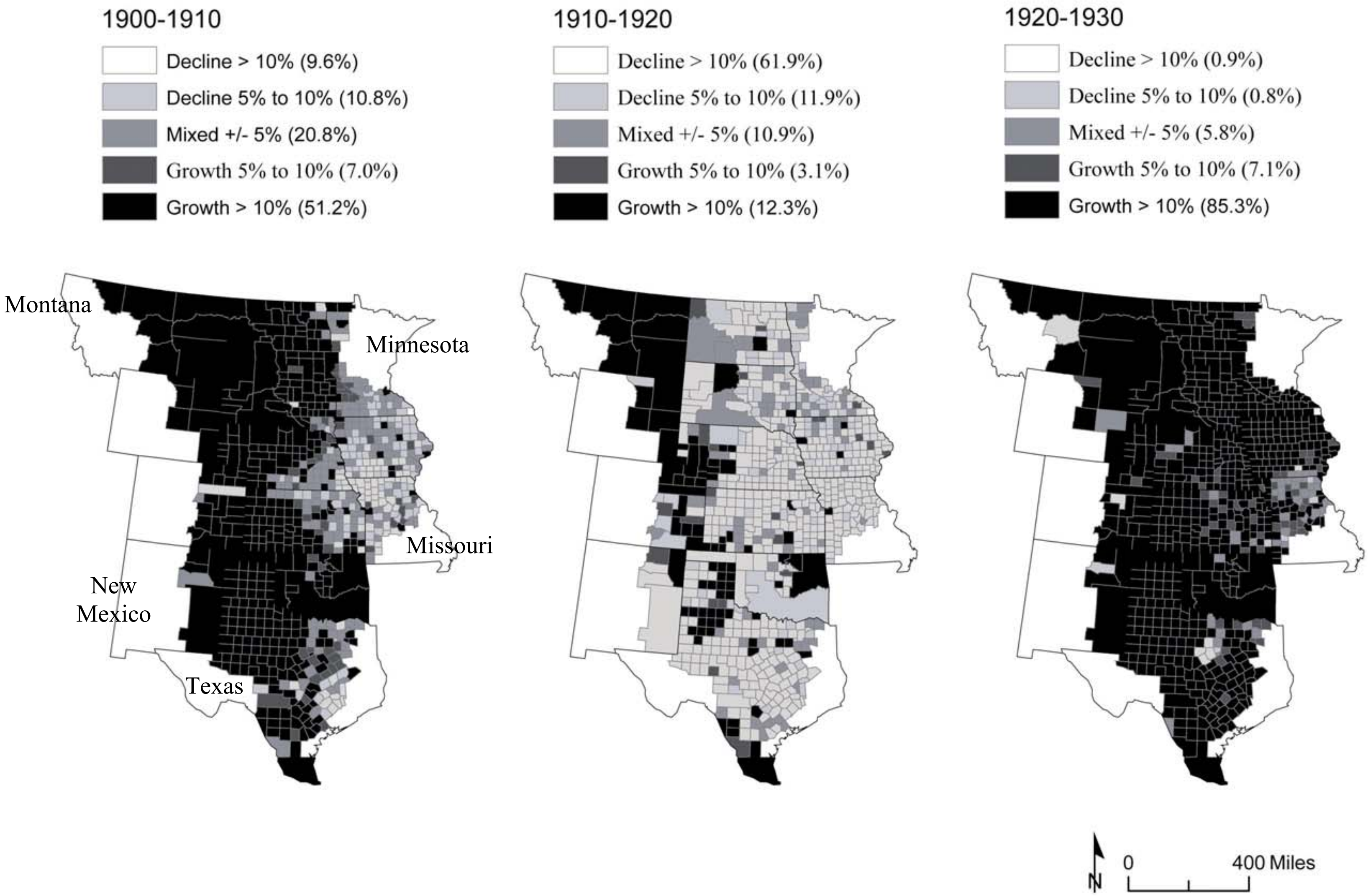

Figure 1. Spatial Distribution of County Population Change by Decade, 1900-30

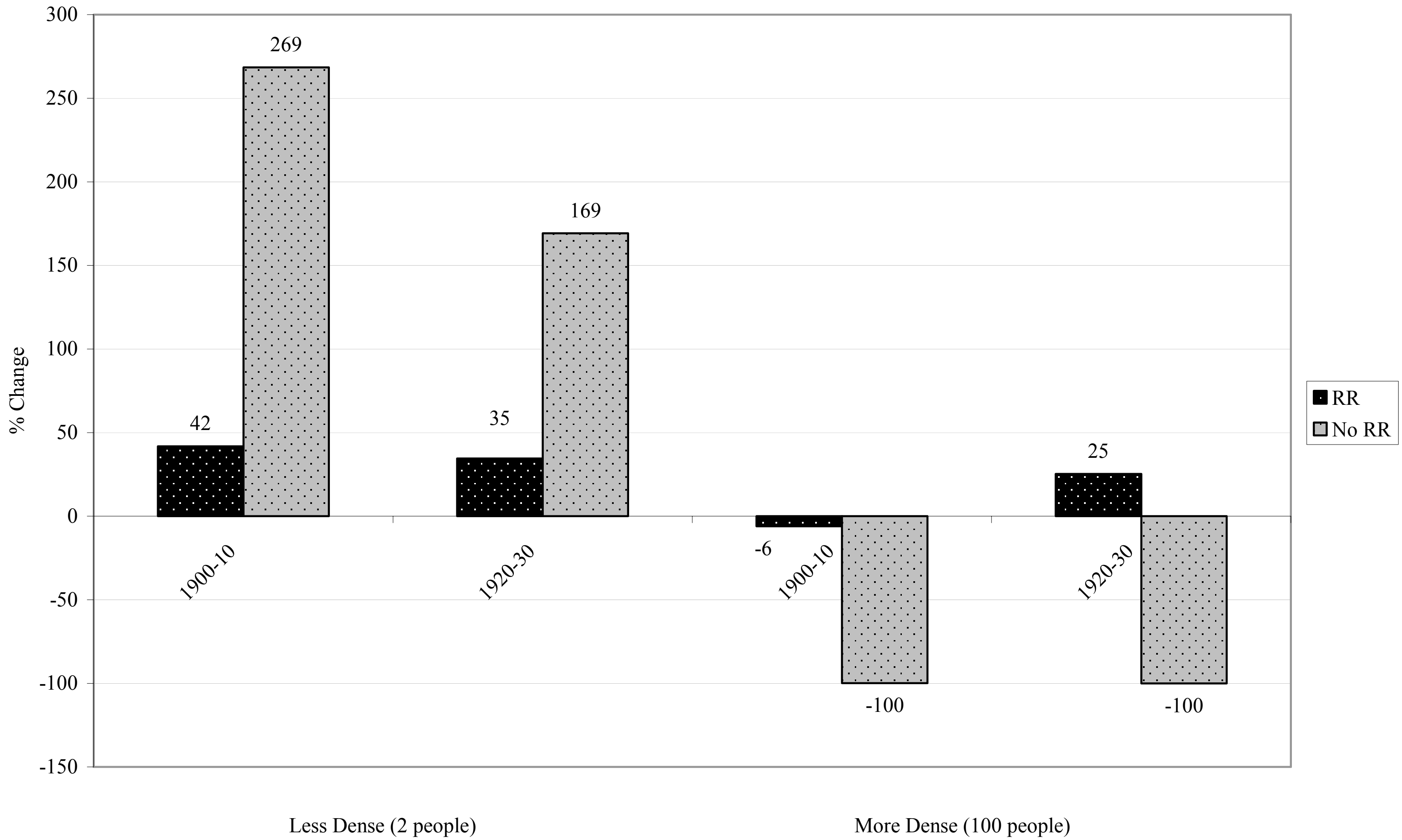

Figure 2. Estimated Percent Change in County Population by Varying Population Density, 1900-10 and 1920-30

Note: Parameter values and model diagnostics are reported in the lower panel of Table 2

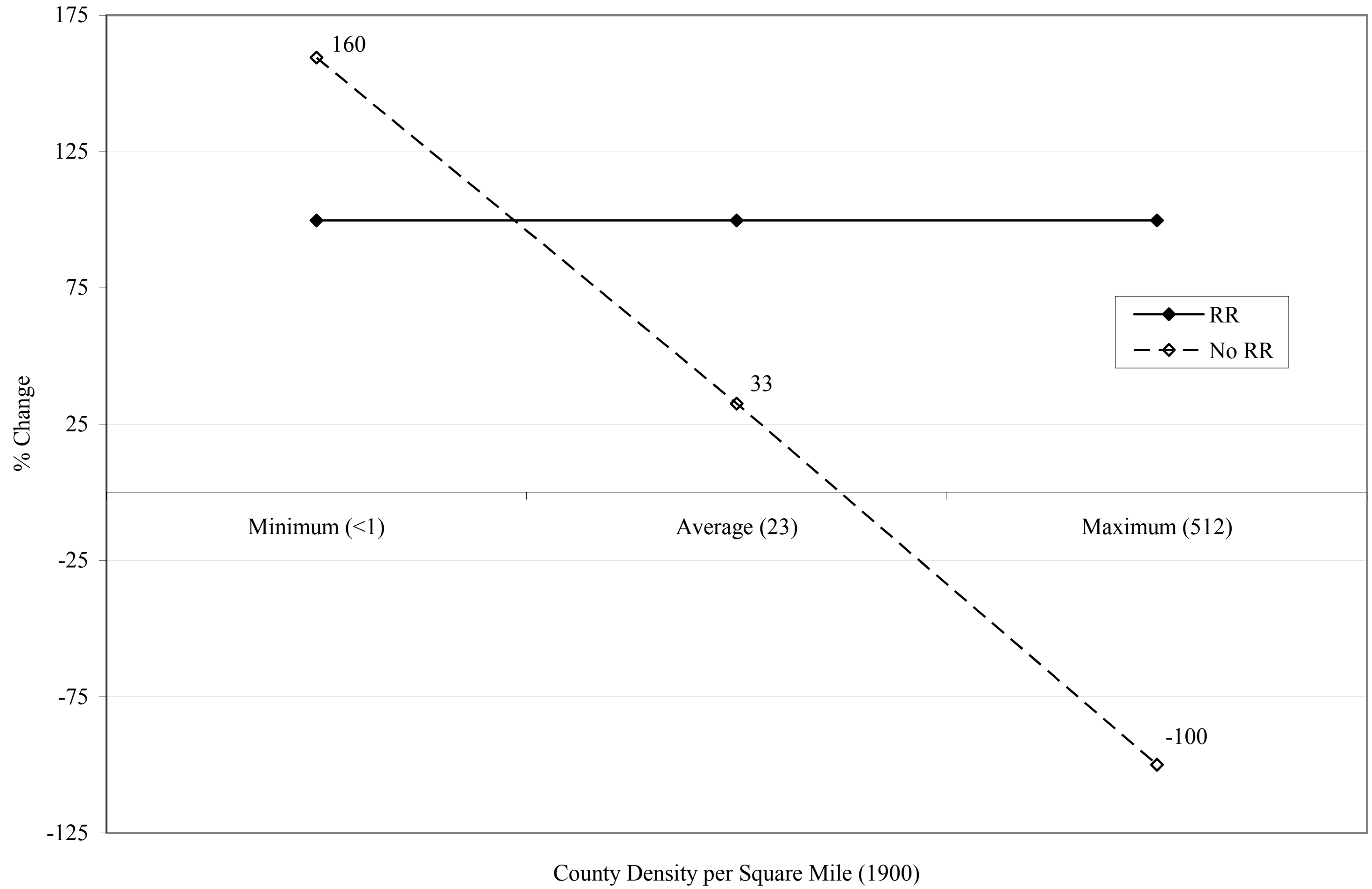

Figure 3. Estimated Percent Change in County Population from Spatial Regression Analysis, 1900-10

Note: Parameter values and model diagnostics are reported in Table 3