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Effects of Socioeconomic Factors and Forest Environments on Demand for Rural Residential Development

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ABSTRACT : This study investigates the effects of economic factors and forest environments on rural residential area development in seven north central states of the U.S. by focusing on the relative importance of not only economic factors but also forest environments by forest type as core drivers of residential development. An empirical model of locations and magnitudes of population changes since 1950 in the north central region is first constructed, and then a panel model with fixed effects for counties is used to explain population growth by age group over time at the county level. Then a set of three equations is estimated for three major age groups, and a cross-sectional model is estimated for the last time period that regresses county-level environmental amenity variables on fixed effects coefficients for counties. Finally, an equation explaining changes in rural housing density is estimated. The results imply that immigrant age is a key factor influencing the choice of the place of residence and that the effects of environmental amenity factors on population growth and subsequent housing development in a county vary according to the age group.

Keywords : Housing Demand, Economic Factors, Forest Amenities, Age Group, Population Change, Panel Model

JEL 분류 : C5, N5, R21

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농촌 주거지 개발 수요에 대한 사회경제적 요인 및 산림환경의 영향 분석

이요한* · 지성태**

요 약 : 이 연구에서는 미국의 북중부 7개주를 대상으로 농촌 주거지 개발에 영향을 미치는 주요 인자들을 분석하였다. 특히, 사회경제적 요인들과 산림유형에 따른 산림환경특성을 주거지 개발의 주요 요인으로 고려하여 상대적 중요도를 살펴보았다. 먼저, 1950년 이후 미 북중부 지역에서 나타난 인구변화에 대한 실증모델을 개발하였고, 고정효과 패널모델을 이용하여 인구변화에 영향을 미치는 주요 인자들을 분석하였다. 연령별로 인구변화패턴과 거주지를 선택하는 선호 요인이 상이하게 나타나기 때문에, 실증모형을 구성할 때 연령별로 모형을 설정하였다. 다음단계로, 인구변화에 영향을 미치는 요인들이 소득과 같은 가변요인 뿐 아니라 단기간에 거의 변화가 없는 지역의 특수한 환경 요인들을 포함할 것이라는 가정하에, 패널모형의 고정효과 값을 종속변수로 설정하여 각 카운티별 인구증감의 차이가 산림환경, 수자원 등 시간불변변수들에 의해 영향을 받는 것으로 설정하여 횡단면적 모델을 추정하였다. 마지막으로, 농촌 지역의 주거지 수요를 설명하는 모델을 추정하였다. 연구결과, 이주자의 나이가 주거지 선정에 영향을 미치는 핵심 인자로 나타났고, 특히 사회경제적 요인 뿐 아니라 산림유형, 수자원 등 환경 어메니티가 주거지 수요에 미치는 상대적 중요도도 나이 계층별로 상이한 것으로 나타났다.

주제어 : 주거지 수요, 경제적 요인, 산림 어메니티, 나이 계층, 인구 변화, 패널 모형

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I. Introduction

Population growth and shifting migration patterns can lead to new residential development in previously undeveloped locations and increased housing densities in existing residential areas. This trend is important for resource managers to understand and anticipate for at least two reasons: First, housing development can have various environmental impacts, and second, it can influence subsequent land-use decisions involving how remaining resource lands are managed (e.g., Radomski & Goeman, 2001; Wear et al., 1998; Munn et al., 2002). Although mitigating potential adverse impacts of housing development on environmental amenities is desirable, by discouraging development near sensitive resource areas, the interaction between housing and amenities may have multiple and conflicting policy implications. For example, the protection of forest areas can increase the value of existing housing units, thereby stimulating further development (e.g., Irwin, 2002; Geoghegan, 2002). On the other hand, an increase in the value of housing and accelerating development may encourage residents to place greater emphasis on protecting remaining forest areas (e.g., Kotchen & Powers, 2006). Anticipating development and understanding its relationships with forest resources and environmental amenities as well as with economic factors can help land-use planners develop policies that can better protect forest resources and desired environmental characteristics in light of landscape changes likely brought about by new development. Predicting changes in housing development can also help land-use planners and resource managers to allocate planning efforts to areas most likely to experience substantial changes.

There are two general approaches in the literature on land economics to the examination of linkages between residential development and environmental amenities. One approach uses cross-sectional hedonic pricing models to estimate relationships between property values and attributes, including nearby environmental amenities, at a single point in time (McConnell & Walls 2005). Studies using this static hedonic approach have typically estimated the extent to which various environmental amenities increase property or house values. For example, Tyrävinen and Miettinen (2000) find that house prices are significantly higher for houses within walking distance of forest land. Average prices of houses having views of forest land were 4.9% higher than those of houses without such views. Garrod and Willis (1992) test whether different mixes of tree species influence contributions of forests to prices of nearby houses. Irwin (2002) and Geoghegan (2002) find that permanently preserved open-space environments are more likely to contribute to property values than developable agriculture and forestland areas because a preserved open-space environment provides a certain absence of future development. These and other hedonic studies have characterized positive financial contributions of environmental amenities on homeowners and provide an economic rationale for environmental amenity protection.

A drawback of the static hedonic approach is that it overlooks the dynamic nature of housing price adjustment and the endogeneity of employment, housing, and amenities. Recognizing this, Riddel (2001) estimates a dynamic regional economic model for the Boulder, Colorado, area for which the area of open space, the price and quantity of housing, and employment and earnings are endogenously determined. The integrated approach she employs has practical limitations. More specifically, almost everything is endogenous, and therefore there are very few variables with which predictions can be made and for which policy scenarios can be constructed. Nonetheless, the model provides some conceptual insights into structural linkages between housing and amenities. For example, Riddel (2001) finds that an active open-space purchase program can cause inflated house prices, a drop in average wages, and commercial and residential expansion.

The second and more direct approach to examining linkages between residential development and environmental amenities attempts to explain changes in land use over time as a function of economic and topographic factors typically associated with residential development as well as variables characterizing environmental amenities of interest. For example, Wear and Bolstad (1998) estimate a model to explain development characterized by increases in building density as a function of conditions in 1950, and slope and elevation. Lewis et al. (2002) analyze the effects of public conservation lands on employment growth in the Northern Forest region of the U.S. by estimating a model of simultaneous employment growth and net migration based on panel data from non-metropolitan counties. To measure the effects of environmental amenities in a more direct manner, Kline et al. (2007) create an econometric model of building density as a function of the population, proximity to urban centers, slopes, land-use zoning, and the existence of a panoramic view of any high peaks of the Oregon Cascade Range and find a significant positive effect of views on the likelihood of development over the study period. These studies approach the problem of residential development more directly than hedonic models by using measures of development as dependent variables. However, because they typically rely on relatively fine-scaled land-use data, their inclusion of economic factors is accomplished only indirectly (if at all) because of some difficulty in obtaining economic data at such fine scales. This limits the ability of these models to account for effects of socioeconomic changes influencing development.

This study investigates the relationships between economic factors, environmental amenities, and rural housing development in seven states covering the north central region of the U.S., namely Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin. In particular, the study focuses on the relative importance of amenity and economic variables as drivers of changes in housing density. For this, an empirical model of locations and magnitudes of population density changes since 1950 in the north central region is constructed, and then a panel model (i.e., a cross-sectional/time series model) for some key variables such as income and populations estimated with fixed effects for counties is used to explain population changes over time at the county level. A set of three equations is estimated for three major age groups: a young-age (mobile) group (18-25), a middle-age (working) group (25-65), and an old-age (retirement) group (over 65). Those factors driving migration are identified by age group to provide insights into changes in housing density for those factors through their effects on migration decisions by age group. Fixed effects coefficients reflect variations not explained in these equations for population growth across counties and then become dependent variables in a cross-sectional model of the last time period that analyzes the effects of forest cover and other county-level variables on differences in the population growth rate by county. Finally, an equation is estimated, explaining changes in housing density as a function of population changes and factors that may cause the two to differ.

II. Model

Housing density depends mainly on the population (e.g., Blanco, 1963; Lowry, 1966; Muth, 1971), which is determined by in-migration, out-migration, and birth and death rates. Population growth differs from net migration by net mortality (i.e., deaths less births). However, because birth and death rates are strongly influenced by age structures (Bennett & Olshansky, 1996), in-migration and out-migration often exist as more apparent determinants of population changes. Blanco (1963) and Lowry (1966) both suggest that changes in employment opportunities in a state can have significant effects on population changes. Therefore, a local labor market can be specified as two simultaneous equations: (1) a population growth equation to represent labor supply and (2) an employment growth equation to represent labor demand.

This study assumes that individuals hold the housing stock for two main reasons: as an input into the production of housing services and as an investment. An individual’s demand for the housing stock depends on attributes of a house, including those related to the location, such as proximity to recreational opportunities and services (e.g., medical facilities). These factors, together with variables influencing preferences for housing services, such as age, income, and technology, contribute to the housing stock’s ability to serve as a home. In addition, housing demand depends on household wealth as well as on variables influencing the value of housing as an asset.

In particular, age is a key demographic variable that influences demand for location attributes of the housing stock. Depending on the age group — such as a young-age (mobile) group (18-25), a middle-age (working) group (25-65), and an old-age (retirement) group (over 65) – the pace of residence is required to satisfy different needs in terms of employment, education, public and health facilities, and environmental amenities. For example, in counties characterized by abundant environmental amenities, previous studies have shown that immigration is higher in the retirement-age group (over 65) than in the working-age group because retirees are attracted to amenity-rich areas and may not be concerned about employment opportunities (Blomquist et al., 1988).

To investigate the key drivers of population changes, the following equation is proposed as a reduced form (Lee et al. 2015):

$$PC_{it} = f(P_{it}, E_{it}, \boldsymbol{X}_{it}, \boldsymbol{Y}_{it}, \boldsymbol{Z}_{i}). \tag{1}$$

The terms P_{it} and E_{it} denote population and employment at the beginning of period t, respectively; $\boldsymbol{X}_{it}$, $\boldsymbol{Y}_{it}$, and $\boldsymbol{Z}_{it}$ denote the sets of exogenous variables specific to each of population and employment, and the set of exogenous variables that impact both population and employment, respectively.

In addition, changing preferences for household size, occupancy rates, and second-home ownership can influence changes in housing density and may cause some divergence between population and housing density changes. Shifts in income or demographic factors such as the age structure of the population can have considerable influence on people's preferences and demand for housing. These relationships should be taken into account in any housing density model. If the total housing stock H_{it} at time t in county i is denoted as the product of the population P_t and the per capita housing stock h_{it} as

$$H_{it} = P_{it} \times h_{it}. \tag{2}$$

Then, the rate of change in the housing stock HG_{it} has two components (Lee et al. 2015) as follows:

$$HG_{it} = \frac{\frac{\partial H_{it}}{\partial t}}{H_{it}} = \frac{\frac{\partial P_{it}}{\partial t} \times h_{it}}{P_{it} \times h_{it}} + \frac{P_{it} \times \frac{\partial h_{it}}{\partial t}}{P_{it} \times h_{it}} = \frac{\frac{\partial P_{it}}{\partial t}}{P_{it}} + \frac{\frac{\partial h_{it}}{\partial t}}{h_{it}} = PG_{it} + hG_{it}. \quad (3)$$

Hence, we can derive equation 3-1 as follows:

$$HG_{it} = PG_{it} + hG_{it} \quad (3\text{-}1)$$

where the first term on the right-hand side of equation 3 is the rate of population change and the second term hG_t is the rate of change in individuals' holding of housing. As described later, this study's data represent the housing stock HG_t as the number of housing units such that the per capita housing stock h_t is the average number of housing units per person. If preferences for housing are static and the economy is in equilibrium, the change in the housing stock equals the change in population. That is, hG_t=0, and equation 1 is sufficient to predict changes in housing density on the landscape because the rate of change in housing stocks is identical with the rate of population change. Some divergence between population growth and changes in the housing stock results if $hG_t \neq 0$, and this is a function of those variables influencing individuals' housing demand.

III. Empirical Model

1. Specification

Preferences and income changes over individuals' life cycles give rise to differences between population changes and housing density. Because of the importance of age in preferences for both housing and environmental amenities and as well as the divergence of the population from the housing stock, a three-age-class specification is used to model population changes as follows:

$$PC^{18}_{it} = f^{18}(P_{it}, \boldsymbol{X}_{it}) + \varepsilon^{18}_{it} \quad (4)$$

$$PC^{25}_{it} = f^{25}(P_{it}, \boldsymbol{X}_{it}) + \varepsilon^{25}_{it} \quad (5)$$

$$PC^{65}_{it} = f^{65}(P_{it}, \boldsymbol{X}_{it}) + \varepsilon^{65}_{it} \quad (6)$$

where PC^{18}_{it}, PC^{25}_{it} , and PC^{65}_{it} indicate net population growth rates, containing in-migration, out-migration, natural up-growth, and death and birth rate, by age group in county i in period t; P_{it}, P_{it}, and P_{it} indicate total population density; $\boldsymbol{X}_{it}$ is a set of exogenous variables that affect both migration and employment(i.e., $\boldsymbol{X}$ = (*STCH, UE, INC, PC18, PC65, and EDHS*)). Here we assume that the error terms (ε^{18}_{it}, ε^{25}_{it}, and ε^{65}_{it}), which are spherical disturbances, have zero mean.

Here choose three age groups for analysis purposes to account for differences between young people in their mobile years (18 to 25), people in their working and family years (25 to 65), and people in their retirement years (over 65). The age-specific population growth equation is extended to include in-growth from the next younger age group to replace births in the youngest age group and up-growth in the next older age group. Equations (4), (5), and (6) include a set of exogenous variables hypothesized to influence migration and employment. Each equation includes the average growth rate for its age group for the state (STCH). This means the coefficients for other variables indicate how the county-level population growth rate deviates from the state-level population growth rate. Exogenous variables influencing migration include the unemployment rate (UE) and median family income in 1989 dollars (INC), which are assumed indicate the potential attractiveness of counties to potential immigrants and current residents. The unemployment rate represents economic opportunities in a county. Median family income is a proxy for a number of economic factors, including the range of consumer and cultural amenities offered by a county and the extent of social problems stemming from poverty (Lewis et al., 2002). The level of unemployment and that of median family income by age are expected to be significantly different, reflecting each age group's ability to afford a house, and they may also reflect differences in housing demand by age group. In addition, the set of exogenous variables influencing migration and employment include the portion of the population in the county that includes young adults (PC18) and elderly individuals (PC65). The percentage of the population by age group matters because each age group has different migration and employment characteristics. Young people in their mobile years (18-25) tend to move frequently to find jobs, which is likely to influence both migration and employment. People in their retirement years also relocate frequently after retiring, which is also likely to influence both migration and employment in the county. In addition, the portion of the educated population (EDHS) represents a variable influencing employment because education can reflect workforce quality.

The relationship between population and housing density changes (equation (4)) provides a theoretical basis for the empirical study. The empirical model of housing density changes is specified as follows:

$$HC_{it} = f^h(PC^{18},\ PC^{25},\ PC^{65},\ X^h) + \varepsilon_{it} \qquad (7)$$

where PC^{18}, PC^{25}, and PC^{65} indicate the net population growth rate by age group and X^h represent vectors of variables influencing housing density changes(i.e., $\boldsymbol{X}$ = (*DS, WR, FR, and OCRATE*)).

Equation (7) includes the explanatory variables influencing differences between population and housing changes.[1)] These differences can be represented by the elasticity form of the individual housing stock. Regardless of whether the average individual holding of housing changes, $hG \neq 0$ depends not only on long-term changes from changing

1) Difference between net migration and housing density changes can also be mathematically derived from equation (4) as follows: $HG_{it} = PG_{it} + hG_{it} = f(PG, X)$.

wealth, amenities, and age class structures but also on short-term disequilibrium phenomena from fluctuations in the local economy (e.g., a housing bubble in the short term). In general, there is a lag in the housing stock response to resulting fluctuations in demand. To the extent that the positive rate of change in the individual holding of housing, $hG > 0$, is due to owners of second homes or vacation home construction, it arises from attributes of people who live elsewhere.

This study uses the variable of the distance from a large city (DS) to represent proximity to populations who may want to own second homes in the county and amenity variables including the proportion of the water area (WR) and the proportion of the forest area (FR) to represent recreational opportunities and other environmental services. Because county-level housing prices are not available, the occupancy rate of the housing stock (OCRATE) is used to represent any disequilibrium in the housing market or a lag in housing stock adjustment to short-term fluctuations in the local economy. Preferences of homeowners for housing services are influenced by these factors, but the magnitude of their influence on homeowner preferences varies according to the age group.

2. Data and Estimation Methods

The theoretical model assumes that economic opportunities and location-specific environmental amenities drive migration and thus population changes to a large extent. Independent variables consist of proxy variables intended to represent these factors. However, the analysis is constrained by available data. County-level data are available in time series for key demographic and economic variables but are available for other variables of interest only in more recent years. In addition, some variables of interest are time-invariant and thus remain constant throughout the analysis period. To take advantage of all available information, a two-step modeling approach is taken.

Equations (4) ~ (7) include the full model in the analysis. To explain what drives population changes by age group, equations (4) through (6) are estimated in two steps as follows: The housing density model (equation 7) is estimated separately using OLS and 2SLS to account for potential simultaneity in the housing stock and population growth. If housing density changes have no effects on migration patterns but migration influences housing density changes, then it is not necessary to use the 2SLS estimator because the system is recursive.

First, equation (4) − (6) are estimated using panel data with observations both across counties and over time. The panel consists of six decadal observations for each of 591 non-urban counties. Counties identified as part of a major city based on the U.S. Census Bureau designation as a primary metropolitan statistical area are dropped from the sample. At the heart of this analysis is the issue of landscape changes. Therefore, it is sensible to consider only those non-urban areas where open space conversion is an issue. That being said, only those counties that are highly urbanized are excluded because as many counties with some urbanization may also face substantial changes in land use.

The theoretical model specifies population changes in each age group as a function of regional demographic characteristics, lagged population density, economic opportunities, and location-specific amenities. Therefore, independent variables that measure demographic features, economic opportunities, and amenities are selected. However, the specification may not cover all factors that influence population changes, and therefore there may be a number of relevant but unobserved factors specific to counties that are not explicitly included in the model. These unobserved factors are expected to be correlated with observed independent variables. As a result, a fixed effects framework is considered instead of a random effects framework in which unobserved heterogeneity is not correlated with explanatory variables. The estimation of parameters using pooled least squares is biased because unobserved, county-specific heterogeneity has the same effect as an omitted variable.

The basic fixed effects model is as follows:

$$y_{it} = x'_{it}\beta + \alpha_i + \varepsilon_{it} \tag{8}$$

where α_i is a county-specific constant term (Greene, 1997). By estimating a constant for each county, the fixed effects model eliminates any omitted-variable bias associated with unobserved, county-specific heterogeneity. Unobserved heterogeneity is captured in the constant. In addition, noteworthy is that the fixed effects model precludes the use of time-invariant explanatory variables. Fixed effects are employed to estimate different intercepts for each county, and therefore explanatory variables not varying over time for a given county are perfectly collinear with intercepts and cause singularity. Some explanatory variables for static natural endowments such as environmental amenities are time-invariant, and therefore a single observation is sufficient to populate the full sample. However, these time-invariant regressors cannot be included in a fixed effects model for reasons discussed earlier. Dropping these variables poses no problem because their effects are picked up by constants.

Panel data models require a fully populated data set. That is, they require that every variable have an observation for each cross-sectional unit and in every time period. In this study, county-level decadal observations for dependent variables range from 1960 to 2000 (Table 1), and therefore lagged exogenous variables require county-level decadal data from 1950 to 1990. As mentioned earlier, only a limited number of economic and demographic variables are available at the county level in time series. In this regard, the variables from this category considered are median family income (INC), the unemployment rate (UE), the occupancy rate of the housing stock (OCRATE), education (EDHS), the percentage of the population in the 18-25 category (PC18), the percentage of population in the 65+ category (PC 65), and population density (PD). In addition, exogenous variables include a state-level decadal variable, namely the rate of change in the population by state (STCH). Population changes represent the dependent variable expressed as the average rate of annual change in each decade by county and age group.

For the second step, coefficients (a_i) for regional averages in the estimation of the fixed effects model are used to explore relationships between population changes and county-specific variables. Constants from the fixed effects estimation represent systematic

〈Table 1〉 Variable Definitions and Summary Statistics

Variables	Description	Time sets	Mean	Std. Err.
HC	Average annual rate of change in the housing stock by county	1990-2000	0.009848	0.000215
PCHtot	Average annual rate of change in the total adult population by county and decade	1950-2000	0.003304	0.000267
STCHtot	Average annual rate of change in the total adult population by state and decade	1950-2000	0.007256	0.000094
PCH18to25	Average annual rate of change in the population for the 18-25 age group by county and decade	1950-2000	0.001950	0.000596
STCH18to25	Average annual rate of change in the population for the 18-25 age group by state and decade	1950-2000	0.006766	0.000406
PCH25to65	Average annual rate of change in the population for the 25-65 age group by county and decade	1950-2000	0.004763	0.000266
STCH25to65	Average annual rate of change in the population for the 25-65 age group by state and decade	1950-2000	0.007871	0.000094
PCH65plus	Average annual rate of change in the population for the 65+ age group by county and decade	1950-2000	0.011122	0.000244
STCH65plus	Average annual rate of change in population for the 65+ age group by by state and decade	1950-2000	0.014153	0.000131
PD	Population density (per acre) for the total adult population by county and decade	1950-2000	0.088415	0.002007
POP18	Percentage of the population in the 18-25 age group by county and decade	1950-2000	0.3165	0.0010
POP65	Percentage of the population in the 65+ age group by county and decade	1950-2000	0.1382	0.0007
INC	Median family income in 1989 dollars by county and decade	1950-2000	23565.16	125.63
UE	Unemployment rate by county and decade	1950-2000	5.51	0.06
EDHS	Percentage of the population over 25 years of age with a high school degree by county and decade	1950-2000	51.08	0.58
OCRATE	Occupancy rate for the housing stock by county	1950-2000	0.864695	0.002243
WR	Rate of the water area by county	2000	0.144478	0.012221
FR	Rate of the forest area by county	1980s	0.232254	0.004400

〈Table 1〉 Variable Definitions and Summary Statistics (Continued)

Variables		Description	Time sets	Mean	Std. Err.
SPECIES	OakHickory	Rate of the forest area by county for Oak Hickory	1980s	0.084342	0.005275
	AspenBirch	Rate of the forest area by county for Aspen Birch		0.033440	0.003142
	WhiteRedJackPine	Rate of the forest area by county for White Red Jack Pine		0.011589	0.001415
	OakPine	Rate of the forest area by county for Oak Pine		0.002906	0.000456
	SpruceFir	Rate of the forest area by county for Spruce Fir		0.017729	0.002615
	ElmAshCottonwood	Rate of the forest area by county for Elm Ash Cottonwood		0.022016	0.001086
	MapleBeechBirch	Rate of the forest area by county for Maple Beech Birch		0.049774	0.003515
DS		Distance from a large city	2000	390643.02	3888.53

differences between counties that are not accounted for by explanatory variables and not attributable to random disturbances. A set of county-level variables is used to examine linkages between population growth and environmental amenities in a county. In the second step, these constants are regressed on final-period values for time-invariant, county-specified variables as follows:

$$\alpha_i = x'_i\beta + \varepsilon_i, \tag{9}$$

where county-specified variables include the proportion of the water area (WR) and the proportion of the forest area (FR) by species and the distance from a large city (DS) as proxies for the attractiveness of a county.

In this model, spatial autocorrelation may exist because neighboring counties can be influenced by the same omitted variables (Bockstael, 1996). To address the potential problem of spatial autocorrelation, residuals from OLS estimates are used to test whether spatial autocorrelation exists by utilizing Moran's *I*-statistic, $I = N(\hat{e}' W\hat{e})/M(\hat{e}'\hat{e})$, where N is the number of observations, $\hat{e}$ is the vector of estimated residuals, W is a spatial weight matrix indicating the spatial structure of data, and M is the standardization factor equal to the sum of elements of W. It is assumed that the error structure takes the form $\varepsilon = \rho W\varepsilon + v$, where ρ is a scalar and v is a vector of spherical disturbances with zero mean. Here the ArcGIS software package is used to construct a W matrix through Hawth's tools, which are used to construct a full distance matrix table between points (e.g., the center of each county). If spatial autocorrelation is identified, then residuals from OLS are used to estimate the spatial autoregressive parameter ρ for each equation. Then data are transformed using the matrix $\hat{P} = M - \hat{\rho} W$, where M is an N x N identity matrix. If spatial autocorrelation is not identified, then no data transformation is performed.

Another econometric issue arises in the estimation of equation (7) because equations (4), (5), (6), and (7) are not independent. The dependent variable in (4), (5), and (6) appears on the right-hand side of (7) as an explanatory variable because the rate of population growth by age affects the rate of housing density change. In addition, it is first assumed that the exogenous variables in equation (7) can affect both population growth and housing density changes. Then the endogeneity problem must be addressed by using a consistent estimator. Here two-stage least squares (2SLS) and instrumental variable (IV) techniques are used to address this endogeneity issue and estimate model parameters. All exogenous variables are chosen as IVs, and the rate of population growth by age is instrumented. The population growth of each state (STCH), the percentage of the young population (POP18), the percentage of the old population (POP65), median family income (INC), the unemployment rate (UE), the percentage of the educated population over 25 years of age (EDHS), and population density (PD) are assumed to be uncorrelated with ε_{it} in equation (7) and used as IVs for the rate of population change by age (PC). However, if this system is recursive, then housing density changes are affected by population growth. In this case, ordinary least squares (OLS) can serve as a consistent and efficient estimator because there is no issue of endogeneity. To verify the endogeneity issue, parameters are estimated using these two estimators, namely OLS and 2SLS.

IV. Estimation Results

1. Econometric Estimates for Panel Models

Population growth equations (4), (5), and (6) are estimated using panel data (1950-2000) and fixed effects models described in the previous section (Table 2). The fixed effects model provides a consistent estimator by eliminating any omitted variable bias related to unobserved, county-specific heterogeneity captured in constants. A pooled regression model is estimated for comparison purposes. The results for the fixed effects model are significantly different from those for the pooled regression model. Coefficient estimates for some variables in the fixed effects model have different values or signs in comparison to those for the pooled regression model (Table 2). These results provide support for the

〈Table 2〉 Estimation Results for the Rate of Population Change by Age Group

Variables	Total age group		Young-age group	
	Pooled	FE	Pooled	FE
STCHtot	.5150601***	.320279***		
STCH18to25			1.166155***	1.077994***
STCH25to65				
STCH65plus				
INC	5.36e-07***	3.10e-07***	1.14e-06***	1.28e-06***
UE	−.000635***	-.0007376***	-.0004728***	-.0015089***
OCRATE	-.0436599***	-.0547288***	-.0380994***	-.0148534
EDHS	3.93e-06	-5.57e-06	-4.78e-06	-.0000292*
POP18	.000136	.018795***	.0048525	.0876693***
POP65	-.0470993***	.0882405***	.0498422***	.3330557***
PD	.0093899***	-.1027944***	.0089438**	-.1689517***
Cons	.0336107***	.0362945***	-.071665***	-.071665***
AdjR^2	0.15	0.25	0.56	0.60
F Value	65.90	2.71	468.88	8.50
Prob> F	0.00	0.00	0.00	0.00
# of obs.	2954	2954	2954	2954

〈Table 2〉 Estimation Results for the Rate of Population Change by Age Group (Continued)

Variables	Middle-age (working) group		Old-age (retirement) group	
	Pooled	FE	Pooled	FE
STCHtot				
STCH18to25				
STCH25to65	.721736***	.3708522***		
STCH65plus			.313007***	.341553***
INC	8.35e-07***	1.09e-06***	1.79e-07***	4.50e-07***
UE	-.000342***	-.0004084***	-.0004593***	-.0003593**
OCRATE	-.0410122***	-.0439854***	-.044222***	-.0478212***
EDHS	.0000269***	.0000183***	-1.76e-06	-3.25e-06
POP18	.0819461***	.1267834***	-.0017666	.0004237
POP65	.007205	.1465511***	-.1609492***	-.2082019***
PD	.0090693***	-.0746963***	.0026033	-.0239911**
Cons	-.012349***	-.0382928***	.0659111***	.0699473***
AdjR^2 F Value Prob> F # of obs.	0.41 258.72 0.00 2954	0.67 11.03 0.00 2954	0.36 211.28 0.00 2954	0.38 4.08 0.00 2954

Significance: *10%, **5%, ***1%.

assumption that the least squares estimators of coefficients are biased and inconsistent because the (unobserved) error term is correlated with independent variables. This problem is avoided by using the fixed effects model, which embodies all observable effects and specifies an estimable conditional mean. For all age group models, the F-test ($N_0 : u_i = 0$ for all i) rejects the null hypothesis, providing support for the use of the fixed effects model. Therefore, the fixed effects model is used to estimate coefficients of panel models.

The estimated equations explain approximately 25% of the variation in the total population and 60%, 67%, and 38% of the variation in the young-, middle-, and old-age groups, respectively (i.e., *adj.* $R^2 = 0.25(A)$, $0.60(B)$, $0.67(C)$, and $0.38(D)$, respectively)

(Table 2). State population changes explain 17% of the variation in the total population and 49%, 27%, and 31% of the county-level variation (i.e., *adj.* $R^2 = 0.17(A')$, $0.49(B')$, $0.27(C')$, and $0.31(D')$, respectively) in the young-, middle-, and old-age groups, respectively.[2] The rest of the county-level variation is explained by other variables indicating to what extent the county-level population growth rate deviates from the state-level population growth rate (i.e., $0.07(A- A')$, $0.11(B- B')$, $0.40(C- C')$, and $0.07(D- D')$, respectively). Coefficients for state population changes in all age groups are positive and significant at the 5% confidence level, suggesting that increases in the state population have positive effects on the county population over time. The gap in explanatory power between the full and state models indicates that state population changes are not the major factor explaining county-level variations in the population growth of the middle-age group. By contrast, state population changes for independent variables have the greatest explanatory power for county-level variations in the population growth of the young- and old-age groups. These results imply that variations in the population growth of the middle-age group can be better explained by economic and demographic factors than those of the young- and old-age groups.

Coefficients of economic variables such as median family income and the unemployment rate are significant at the 5% confidence level in all age groups. As expected, the estimated coefficient of median family income is positive, suggesting that an increase in income attracts people to live in the county by providing an opportunity to find a better job. On the other hand, the estimated coefficient of the unemployment rate is negative. This expected result suggests that an increase in the unemployment rate induces some people to migrate to other locations. As expected, the estimated coefficient for the occupancy rate of the housing stock is negative and significant at the 5% confidence level for all age groups except for the young-age group. Because the occupancy rate can

2) To estimate the extent to which changes in the state population explain variations in county population growth, the average annual rate of change in the county population by age group (PCH**) is regressed on the average annual rate of change in the state population by age group (STCH**) and constant to determine adj. R^2 values.

be a proxy for house prices, an increase in these prices reduces the attractiveness of living in the county because of high living expenses. However, the estimated coefficient for the occupancy rate of the housing stock for the young-age group is not significantly different from zero, suggesting that house prices do not really affect location decisions of young individuals because they are less likely to purchase a house as a place of permanent residence.

Theory provides no expectation of the sign of any demographic variables because these conceivably can have positive or negative effects on population changes. The estimated coefficient for the percentage of the population in the young age group (18-25) is positive and significant at the 5% confidence level except in the model for the old-age group, suggesting that younger people are more likely to be drawn to residential locations with a large proportion of other young people. Although the estimated coefficient for the percentage of the population in the old-age group (66+) is negative and significant at the 5% confidence level, the equivalent estimated coefficient in the young- and middle-age groups is positive and significant at the 5% confidence level, which implies that young and middle-aged people are less likely to be attracted to places where middle-aged families are likely to live.

The estimated coefficient for the percentage of the population with a high level of education is negative and nonsignificant at the 5% confidence level for the young- and old-age groups but positive and significant at the 5% confidence level for the middle-age group (25-65). This suggests that an increase in the percentage of the population with a high level of education attracts people in the middle-age group with children. The estimated coefficient for population density is negative and significantly different from zero at the 5% confidence level, suggesting that an increase in population density reduces the population growth rate in all age groups. Although people want to live in a county area with a high population density, the migration rate may be limited by space.

2. Effects of County-Specific Environmental Amenity Factors on Population Changes

The estimation results for effects of county-specific environmental amenity factors on the fixed effects (equation 9) are shown in Table 3. These results are based on a cross-sectional model that analyzes the effects of forest cover by species and other county-level variables on differences in population changes between counties for the last time period (1990-2000). Given the use of coefficients from the previous estimation and county-specific data, the spatial autocorrelation of residuals is tested. Because the effects of county-specific environmental amenity factors such as the proportion of the water area, the proportion of the forest area, and the distance from a large city are modeled, a potential source of spatial autocorrelation is the cross-county effect of these environmental factors on population growth in each county. Here Moran's I statistic is used to test the

〈Table 3〉 Estimation Results for the Spatial Error Model (SEM) for Fixed Coefficients by Age Group with Time-invariant Variables

Variables		Total age group	Young-age group	Middle-age group	Old-age group
		SEM	SEM	SEM	SEM
WR		.0036051***	.0041119**	.0030665***	.0022426***
FOREST	Oak Hickory	.006197	.0141802	.0241397***	.0171441***
	Aspen Birch	.031564**	.029969	.0255593**	.0335482***
	White Red Jack Pine	.0282998	.0270945	.0358843*	.0570368***
	Oak Pine	.0388002	.052024	.0479318	.0417758
	Spruce Fir	-.036026**	-.0391884*	-.0293047**	-.0220055***
	Elm Ash Cottonwood	.0383759	.0670576	.0233078	-.024477**
	Maple Beech Birch	-.0163732*	-.0101116	-.0075404	-.0047068
DS		-3.37e-08***	-4.27e-08***	-2.45e-08***	1.46e-09
Cons		-.0054826***	-.073166***	-.0762832***	.0214924***
Lambda (λ)		.3990405	.1297506	-.1329701	.0915158
Adj. R^2		.18	.14	.22	.33
# of obs.		591	591	591	591

Significance: *10%, **5%, ***1%.

presence of spatial autocorrelation. Then any spatial autocorrelation is detected and adjusted for each equation. The null hypothesis of no spatial autocorrelation is rejected at the 1% level in each equation. The spatial autocorrelation parameter λ is estimated to be 0.40, 0.13, -0.13, and 0.09 for equations by age (Table 3), which indicates the presence of some positive spatial autocorrelation in all groups except in the middle-age group.

The estimated coefficient for the proportion of the water area in the county is positive and significantly different from zero at the 5% confidence level, suggesting that a high proportion of the water area increases the population growth rate of a county. This may be because water is typically viewed as a desirable environmental amenity by most people. The estimated coefficient for the proportion of the forest area has a different sign according to the species. More specifically, Oak Hickory, Aspen Birch, White Red Jack Pine, and Oak Pine have positive signs, whereas Spruce Fir, Elm Ash Cottonwood, and Maple Beech Birch have negative signs. These variables are not significant at the 5% confidence level for the young-age group, but some are significant at the 5% confidence level for the middle- and old-age groups (Oak Hickory (+), Aspen Birch (+), White Red Jack Pine (+), Spruce Fir (−), and Elm Ash Cottonwood (−)). These results suggest that the proportion of the forest area by species has varying effects on county population growth across age groups. These differences may depend on existing conditions or factors associated with particular forest types. For example, Spruce Fir is highly susceptible to infection by insect pests (e.g., spruce budworm [*Choristoneuraoccidentialis* Freeman][3]) in large portions of the study area. People who enjoy living near healthy forests may be disinclined to live near insect-infested forests. Signs of coefficients by species are stable across all age groups, which implies that people do show common preferences for tree species in forests around their residential areas. The estimated coefficient for the distance from a large city is negative and significant at the 1% level for all age groups except for the old age group. The distance from a large city may be an important consideration when

3) This is referenced from the Area Changes for Forest Cover Types in the United States, 1952 to 1997, with a projection to 2050 (General Technical Report PNW-GTR-613).

deciding on where to live for young- and middle-aged individuals such that the farther the location from the city, the less likely it is to attract young adults. This preference for proximity seems to coincide with the shorter commute time to potential employment opportunities as well as greater access to desired economic (e.g., shopping) and cultural (e.g., museums) amenities. However, the effect of city proximity diminishes after retirement. Younger groups desire a functional location more than retirement groups because the former are more likely to prioritize good infrastructure systems and access to large cities.

3. Differences Between Population and Housing Density Changes

Equation (8) is estimated using ordinary least squares (OLS) and two-stage least squares (2SLS) by defining a set of instrumental variables (Table 4). First, the OLS model is used to estimate parameters based on the assumption of no endogeneity between dependent and independent variables. Second, the 2SLS model is used to identify parameters of structural models of endogenously determined dependent variables and provide consistent estimates of structural parameters. Hausman's (1978) specification test is used to test for the endogeneity of each regressor based on the remaining set of variables as instruments.[4] However, population and housing density changes do not affect each other simultaneously but recursive. The population growth of a county affects housing density changes by increasing the demand for residential housing. The housing market in turn influences core economic variables, including income and the employment rate, which in turn influence regional population growth. Therefore, OLS provides a consistent and efficient estimator for coefficients for models of housing density changes.

4) The results fail to reject the null hypothesis that the least squares and instrumental variable estimates are the same, indicating the regressors to be exogenous.

〈Table 4〉 Estimation Results for Housing Changes in the Last Decade (1990 - 2000) based on OLS and 2SLS

Variables		Model 1		Model 2	
		OLS	2SLS	OLS	2SLS
PCHTOT		.8023771***	1.016239***		
PCH18TO25				-.0271983**	-.0153184
PCH25To65				.5685978***	.6321466***
PCH65plus				.2949667***	.2510215***
OCRATE		.0265237***	.0307121***	.0253498***	.026741***
WR		.0000791	-.000283	-.0002009	-.0001878
FOREST	Oak Hickory	.0078197***	.0042908***	.0068912***	.0060445***
	Aspen Birch	.0136575***	.0118739***	.0057223**	.0064132**
	White Red Jack Pine	.0071905	.0044977	-.0029412	-.0008827
	Oak Pine	.0300151**	.0230994	.0252994*	.0246438*
	Spruce Fir	-.0041003	-.0000473	.0007126	.0003937
	Elm Ash Cottonwood	-.0028969	-.0053827	-.0168478***	-.0159205***
	Maple Beech Birch	.0063126***	.0062418***	.0024724	.0022524
DS		-8.09e-10	-8.77e-10	-2.42e-10	-2.98e-10
Cons		-.02099***	-.0254565***	-.0209394***	-.0226433***
AdjR^2		0.82	0.77	0.85	0.84
F Value		238.31	109.69	256.48	137.14
Prob > F		0.00	0.00	0.00	0.00
# of obs.		590	590	590	590

Significance: *10%, **5%, ***1%.

The estimated equations explain 82% (in Model 1) and 85% (in Model 2) of the variation in changes in the housing stock (Table 4). Population changes explain 70% and 71% of the variation in changes in the housing stock.[5] The rest of the county-level housing variation is explained by other variables indicating the extent to which the county-level housing stock growth rate deviates from the county-level population

5) To estimate the extent to which changes in the state population explain variations in county population growth, the average annual rate of change in the county population by age group (PCH**) is regressed on the average annual rate of change in the state population by age group (STCH**) and constant to determine adj. R^2 values.

growth rate.

The estimated coefficients of variables for population changes (PCHTOT, PCH18TO25, PCH25TO65, and PCH65plus) are significantly different from zero at the 5% confidence level and indicate the dependence of changes in the housing stock on population growth (Table 4). The estimated coefficients for Model 1 indicate that every 1% increase in the rate of change in the total adult population produces an increase slightly less than 1% in the rate of change in the housing stock. This suggests that the population elasticity of the housing stock is inelastic (i.e., less than 1) on average in sample counties. In addition, the estimated coefficients for Model 2 also show that every 1% increase in the rate of change in the population in the 18-25, 25-65, and 65+ age groups produces -0.02%, 0.9%, and 0.1% increases, respectively, in the rate of change in the housing stock (Table 4). The estimated coefficient for population changes in the young-age group is negative, suggesting that an increase in the population in this age group contributes to a decrease in the housing stock. Conceivably, an increase in the population of the young-age group may reduce net housing density[6] if young adults in the 18-25 age group find existing houses to rent instead of buying new ones. They may also be more likely to share housing with housemates than older individuals. These results are consistent with the theoretical assumption about the effect of the age cohort on changes in housing density.

The occupancy rate of the housing stock can be a proxy for average house prices in a county. The coefficient estimates for Models 1 and 2 are significantly different from zero at the 5% confidence level and imply that home builders supply more houses in a county if prices are high. The estimated coefficient for the proportion of the forest area has signs varying according to the species. Oak Hickory and Aspen Birch are the most abundant forest types on private timberlands in the study area, and their estimated coefficients are positive and significant at the 5% confidence level. This suggests that the housing stock tends to increase near these forest types. By contrast, the estimated coefficient for Elm

6) Net housing density change = New housing stock−Old housing stock (to be destroyed).

Ash Cottonwood is negative and significant at the 5% confidence level, suggesting that housing is less likely to be located near this forest type. These results suggest that the proportion of the forest area by species has differential effects on changes in housing density in a county. Other variables such as water resources and the distance from a large city are not significant, implying little effect of these variables on changes in the housing stock. This suggests that either these variables do not factor into the growth of new housing or perhaps county-level housing density data are not finely scaled enough to capture prevalent effects.

V. Conclusions

This study presents a modeling framework for examining population and housing density changes because these are influenced by the behavior of individuals in three age groups. The proposed approach employs three estimation approaches, namely a fixed effects model, a spatial error model, and an OLS model. These empirical models are used to identify factors associated with population changes by age group and housing density changes in counties.

The study offers insights into effects of socioeconomic factors, forest resources, and environmental amenity factors on population growth by age group and rural housing development. The results indicate that the age of immigrants is an important factor in the choice of residential locations and specifically that the effect of environmental amenity factors on population growth varies according to age. Although socioeconomic factors such as median family income and the unemployment rate have considerable influence on the net population growth rate in all age groups, environmental amenity factors including water resources and forest type also play a role but have a greater impact on the older-age group than on the younger-age group. In addition, proximity to a large city has a positive effect on the housing choice of the young-age group but does not influence that of the old-age group. Because age influences an individual’s interests and preferences such as those concerning residential locations and house size, population growth by age group is a critical factor that can explain changes in the housing density of a region.

The analysis provides empirical estimates of effects of key economic variables on population growth by county. For example, the results verify that several important economic factors such as income and the unemployment rate influence human migration, which in turn influences changes in housing density. The occupancy rate as a proxy for the price of housing in the local housing market influences the population growth of a county. For example, people may prefer living in places with inexpensive, not expensive, housing. However, home builders may prefer to construct houses in regions with high house prices.

In addition, the analysis provides empirical estimates of effects of forest cover by species on housing density. Average immigrants tend to move into counties with more oak hickory and aspen birch and may avoid counties with spruce fir and elm ash cottonwood. Although the results imply distinct preferences of residents for neighboring forests by species, there are some limitations. These species cannot represent the general attitude of all residents in the study area. Instead, the results provide important insights into a general environment. Future research should focus on examining how environmental amenity factors and specifically forest types influence human migration and residential development in the perspective of a long transition period. This study’s main contribution is to develop theoretical and empirical models that can explain locations and magnitudes of changes in county-level housing density since 1950 in the north central region of the U.S.

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