# A Spatial Simultaneous Growth Equilibrium Modeling of Agricultural Land Development in the Northeast United States

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**Abstract:** This study aims to understand the relationship between regional growth in population, employment, and per capita income, and agricultural land values and development in the Northeast United States. A system of spatial simultaneous equations is estimated using three-stage-least squares on county level data. Results indicate that regional growth positively influences agricultural land values and negatively affects the stock of agricultural lands. Farm performance and some farmland protection policies were not effective in preserving farmland. The study recommends that agricultural land protection policies could be better coordinated at a regional level and more effective if integrated within state economic development programs.

**Key Words:** equilibrium model, spatial econometrics, land use, farmland, development, policy.

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The conversion of agricultural lands to urban and suburban development has initiated policy interest in many states concerned with land use management. The policy interest is particularly pronounced in states where agricultural land development has accelerated. At the center of many such policy debates, however, is the need to understand the forces that shape regional land use change and the possible ways the determining forces can be managed.

Development of suburban and rural lands may have a series of benefits as perceived by economic agents. Suburban places may offer a lifestyle t characterized as “high quality” (Brown et al. 1997). Besides, rural markets may provide relatively cheaper land for single family homes. Rural areas may also provide a quality environment and scenic vistas as well as outdoor recreation opportunities. Development may also bring increased opportunities to farmers in terms of off-farm employment and higher demand for local agricultural products along with higher tax income for local government. All these benefits are, of course, valuable to communities and add to welfare benefits associated with development.

Development, however, also brings its own set of negative externalities. One known impact of development of suburban and rural areas is the conversion of agricultural land to development uses. The direct effects of the loss of farmland can be measured in terms of output reduction and income losses. However, indirect impacts on the farming communities may include regulatory restrictions on farming practices, technical impacts, and speculative influences. When farmers become uncertain about the future viability of agriculture in their area, farmland production falls, as does farm income. Ultimately, the critical mass of farming needed to sustain the local farming economy may collapse (Daniels and Nelson 1986; Daniels 1986; Lapping and Fitzsimmon 1982; Lynch and Carpenter 2003).

Another challenge arises from positive externalities of agricultural land that may not be captured in the market value for land. Recently, attention has focused on preserving local benefits from farmland such as open space, environmental quality, and impediments to urban sprawl. Many of these benefits have public characteristics and, as a consequence, will tend to be undersupplied by private producers (Lopez, Shah and Altobello 1994; Plantinga and Miller 2001). In addition, there is value attached to open space, green surroundings, and the peace and serenity some associate with farmland (Bowker and Didychuk 1994; Kline and Wichelns 1996; Ready, Berger and Blomquist 1997; Rosenberger and Loomis 1999). The problem for surrounding communities is that the cash-driven marketplace often does not recognize these amenities (Gardner 1977). As a result, most states have initiated some type of land use policy tools to manage the loss of agricultural land and its associated private and public benefits (Nickerson and Hellerstein 2003).

Several studies have modeled the interaction between growth and changes in land use between urban and agricultural uses (Brueckner and Fansler 1983; Mieszkowski and Mills 1993). In general, urban “push factors” and rural and suburban “pull factors” determine the spatial patterns of development and hence agricultural land use change. The urban “push factors” are negative amenities associated with urban life that motivate suburban migration. Fiscal and social problems associated with central cities: high taxes, low quality public schools and other government services, crime, congestion and low environmental quality are expected to lead residents to migrate to suburban places (Mieszkowski and Mills 1993).

Following location equilibrium theory, rising per capita income is also associated with growth of communities if it leads to shifts in the demand for location-specific amenities. Since changes in consumption of location-specific amenities can only be possible through relocation (Knapp and Graves 1989), in the long-run, these changing demands may lead to migration to more desirable locations (Graves 1983). Reinforcing the urban flight (sprawl) process, the rural environment, including agricultural land, provides scenic views, recreational opportunities, and other non-market environmental benefits that attract new development (Irwin and Bockstael 2001; Bowker and Didychuk 1994; Kline and Wichelns 1996; Ready, Berger, and Blomquist 1997; Rosenberger and Loomis 1999; Dissart and Deller 2000). These rural qualities and endowments (pull factors) affect urban migration decisions, as households are drawn to areas with higher quality of life or amenity factors (Dissart and Deller 2000).

Deller et al. (2001) argue that in addition to local characteristics like taxes and income, a significant relationship between amenities, quality of life, and local economic performance exists. Similarly, Gottlieb (1994), English et al. (2000), Roback (1988), and Henry et al. (1999) indicate that the inclusion of amenity factors in explaining regional growth differences appears powerful.

The sources of suburban and rural growth that determine inter-temporal land use change are numerous and may well extend to factors other than the ones already discussed. Aldrich and Kusmin (1997), for instance, briefly discussed determinants of suburban and rural growth to include variables such as taxation, public spending, the unemployment rate, urbanization, minority population concentration, and local fire protection rates; Bell and Irwin (2002) mention spatial factors like proximity to employment and other activities, natural features, surrounding land use patterns, and land use policies that may affect the pattern of land use change.

For the purpose of regional agricultural land use change modeling, the major sources of development of suburban and rural agricultural land may be aggregated into forces of population growth, household formation, income growth (Heimlich and Anderson 2001), and employment growth. The overall objective of this study is to analyze the relationship between changes in regional growth and agricultural land development. The specific objectives are to develop a spatial simultaneous growth equilibrium model that captures the interactions among growth patterns, income changes, land price differentials, and changes in agricultural land density, and to determine the relationship between regional growth patterns, spatial income distribution, land price differentials, land use policies, and agricultural land development.

To achieve the objectives, this study uses county level data for the Northeastern U.S., made up of West Virginia, Maryland, Pennsylvania, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, Maine, and the District of Colombia.[1] This Northeast region contains 22 percent of the U.S. population, but it constitutes only 6.7 percent of the land area. It also contains the largest consolidated metropolitan areas, as well as some of the most rural states in the nation (Goetz 2002).

The northeastern region is used for a number of reasons. First, the Northeast has one of the highest land development rates and economic expansion rates in the U.S., while at the same time it has some very rural states. This variability in growth and land development provides heterogeneity in the data from this study area that should enable efficient identification of econometric relationships. Second, this study area also contains significant agricultural activity and agricultural land as a proportion of total county land. This enables testing of the relationship between rapidly growing regions and their agricultural land base. Third, the northeastern region

[1] This study uses the Northeastern U.S. states as listed by the Northeast Regional Center for Rural Development (see http://www.cas.nercrd.psu.edu/Toolbox/index.htm).

of the United States is made up of states with some of the earliest implemented agricultural land preservation policies (Maryland and New York) as well as states with limited or no statewide farmland preservation initiatives (West Virginia). This wide spectrum of farmland protection policies provides a policy rich environment under which the effect of these policies on development can be tested.

**Spatial Growth Equilibrium Model and Estimation**

To capture the impact of inter-temporal employment density, population density, income, and agricultural land value changes on farmland stocks, a growth equilibrium model is applied. Growth equilibrium models were initially developed to simultaneously explain growth in employment and population. These models have been used to examine relationships among population and employment changes, migration, and the demand for natural amenities.

The theoretical model is developed following a set of basic assumptions. It is assumed that mobile consumers maximize utility by consuming a vector of goods and services as well as location and non-market amenities. Households will migrate until marginal utilities are equalized across locations. Households are also assumed to be drawn to regions with high per capita income growth and employment opportunities. Producers are assumed to maximize profit from the production of goods and services. Firms select locations to capture locational cost and revenue advantages, minimize the cost of transportation, benefit from agglomeration and regional labor cost savings as well as labor quality. Firms enter and leave regions until competitive profits are equalized across regions.

It is also assumed that firms and households adjust to disequilibrium over time. In a general equilibrium framework, population, employment, and income are affected not only by each other, but also by a variety of other variables. In principle, many such variables might be simultaneously determined along with population, employment, (Carlino and Mills 1987) and income. Agricultural land values and agricultural land stock changes are also assumed to adjust with lags.

Population, employment, income, land value, and agricultural land development may have significant spatial dependence. A limited number of studies have empirically estimated simultaneous spatial econometric models (Boarnet 1995; Rey and Boarnet 1998; Henry et al. 1999). The existence of spatial dependence in simultaneous econometric models can be examined by estimating a Moran's I statistic for the endogenous variables in the simultaneous system.

Following the stated assumptions, a simultaneous relationship between agricultural land development and employment growth, population growth, county per capita income, agricultural land values, the stock of agricultural land at a particular time, and the spatial lags of these variables can be specified as:

(1) $P^* = f_p(E^*, Y^*, P_L^*, WP^*, WE^*, WY^*, WP_L^* \mid \Omega^P)$,

(2) $E^* = f_e(P^*, Y^*, P_L^*, WE^*, WP^*, WY^*, WP_L^* \mid \Omega^E)$,

(3) $Y^* = f_y(P^*, E^*, P_L^*, WY^*, WP^*, WE^*, WP_L^* \mid \Omega^Y)$,

(4) $P_L^* = f_{p_l}(P^*, E^*, Y^*, AgL^*, WP_L^*, WP^*, WE^*, WY^*, WAgL^* \mid \Omega^{P_L})$,

(5) $AgL^* = f_{agl}(P^*, E^*, Y^*, P_L^*, WAgL^*, WP^*, WE^*, WY^*, WP_L^* \mid \Omega^{AgL})$,

where $P^*$, $E^*$, $Y^*$, $P_L^*$, and $AgL^*$ are the equilibrium levels of population, employment, per capita income, agricultural land value, and agricultural land stocks, respectively; and $\Omega^P$, $\Omega^E$, $\Omega^Y$, $\Omega^{P_L}$, $\Omega^{AgL}$ refer to vectors of other exogenous variables having a direct or indirect impact on the equilibrium levels. The spatially weighted equilibrium values, $WP^*$, $WE^*$, $WY^*$, $WP_L^*$, and $WAgL^*$, use a county-level contiguity-based spatial weights matrix, $W$. In this case, an element in the matrix will be 1 for a contiguous county and 0 if the county does not adjoin the given county.

Population and employment are likely to adjust to their equilibrium values with substantial lags (Mills and Price 1984). Similarly, regional income levels and agricultural land and its value are assumed to adjust to their lagged values. The rate and level of agricultural land conversion in the base year is likely to influence the behavior of agricultural land conversion in the current year; or conversely, equilibrium levels of agricultural land adjust to previous period conversion patterns. Thus, distributed lag adjustment equations can be introduced as:

(6) $P_t = P_{t-1} + \lambda_P (P^* - P_{t-1})$,

(7) $E_t = E_{t-1} + \lambda_E (E^* - E_{t-1})$,

(8) $Y_t = Y_{t-1} + \lambda_Y (Y^* - Y_{t-1})$,

(9) $P_{Lt} = P_{Lt-1} + \lambda_{PL} (P_L{}^* - P_{Lt-1})$,

(10) $AgL_t = AgL_{t-1} + \lambda_{AgL} (AgL^* - AgL_{t-1})$,

where $\lambda_P$, $\lambda_E$, $\lambda_Y$, $\lambda_{PL}$, and $\lambda_{AgL}$ are speed-of-adjustment coefficients between zero and one, and $t$-1 is a one period lag. Current employment, population, income, land prices, and agricultural land stocks are dependent on their one period lagged levels and on the change between equilibrium values and one period lagged values adjusted at their respective speed-of-adjustment values. Rearranging terms and using $\Delta$ to represent the change in the respective variables,

(11) $\Delta P = P_t - P_{t-1} = \lambda_P (P^* - P_{t-1})$,

(12) $\Delta E = E_t - E_{t-1} = \lambda_E (E^* - E_{t-1})$,

(13) $\Delta Y = Y_t - Y_{t-1} = \lambda_Y (Y^* - Y_{t-1})$,

(14) $\Delta P_L = P_{Lt} - P_{Lt-1} = \lambda_{PL}(P_L * - P_{Lt-1})$,

(15) $\Delta AgL = AgL_t - AgL_{t-1} = \lambda_{AgL}(AgL * - AgL_{t-1})$,

In equations (11) through (15), the right hand side equilibrium variables are not observable; however, they can be solved from equations (6) through (10) as follows:

(16) $P* = P_{t-1} + \frac{1}{\lambda_P}\left(P_t - P_{t-1}\right)$,

(17) $E* = E_{t-1} + \frac{1}{\lambda_E}\left(E_t - E_{t-1}\right)$

(18) $Y* = Y_{t-1} + \frac{1}{\lambda_Y}\left(Y_t - Y_{t-1}\right)$

(19) $P_L* = P_{Lt-1} + \frac{1}{\lambda_{PL}}\left(P_{Lt} - P_{Lt-1}\right)$

(20) $AgL* = AgL_{t-1} + \frac{1}{\lambda_{AgL}}\left(AgL_t - AgL_{t-1}\right)$.

The expression for the equilibrium values needs to be substituted in place of equilibrium values to develop a model with measurable variables. Hence, substituting relationships identified in equations (16) through (20) and relationships specified in equations (1) through (5) into the equilibrium right hand side endogenous variables in equations (11) through (15) yields:

(21)
$$\begin{aligned}\Delta P = \lambda_P . f_p(&E_{t-1} + \frac{1}{\lambda_E}\Delta E,\ Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y,\ P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P_L, \\ &W\left(E_{t-1} + \frac{1}{\lambda_E}\Delta E\right), W\left(Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y\right), W\left(P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P_L\right), \\ &W\left(P_{t-1} + \frac{1}{\lambda_P}\Delta P\right)) - \lambda_P P_{t-1} + \sum_i \delta_{iP}\Omega^P + \varepsilon_i\end{aligned}$$

$$\Delta E = \lambda_E (P_{t-1} + \frac{1}{\lambda_P}\Delta P,\ Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y,\ P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P_L,$$

(22) $$W\left(P_{t-1} + \frac{1}{\lambda_P}\Delta P\right), W\left(Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y\right), W\left(P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P_L\right),$$

$$W\left(E_{t-1} + \frac{1}{\lambda_E}\Delta E\right)) - \lambda_P E_{t-1} + \sum_i \delta_{iE}\Omega^E + \mu_i$$

$$\Delta Y = \lambda_Y (P_{t-1} + \frac{1}{\lambda_P}\Delta P,\ E_{t-1} + \frac{1}{\lambda_E}\Delta E,\ P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P_L,$$

(23) $$W\left(P_{t-1} + \frac{1}{\lambda_P}\Delta P\right), W\left(E_{t-1} + \frac{1}{\lambda_E}\Delta E\right), W\left(P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P_L\right),$$

$$W\left(Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y\right)) - \lambda_Y Y_{t-1} + \sum_i \delta_{iE}\Omega^E + \tau_i$$

$$\Delta P_L = \lambda_{PL}(P_{t-1} + \frac{1}{\lambda_P}\Delta P,\ E_{t-1} + \frac{1}{\lambda_E}\Delta E,\ Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y,\ AgL_{t-1} + \frac{1}{\lambda_{AgL}}\Delta AgL,$$

(24) $$W\left(P_{t-1} + \frac{1}{\lambda_P}\Delta P\right), W\left(E_{t-1} + \frac{1}{\lambda_E}\Delta E\right), W\left(Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y\right),$$

$$W\left(AgL_{t-1} + \frac{1}{\lambda_{AgL}}\Delta AgL\right), \left(P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P_L\right)) - \lambda_{PL} P_{Lt-1} + \sum_i \delta_{iP_L}\Omega^{P_L} + \gamma_i$$

$$\Delta AgL = \lambda_{AgL}(P_{t-1} + \frac{1}{\lambda_P}\Delta P,\ E_{t-1} + \frac{1}{\lambda_E}\Delta E,\ Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y,\ P_{Lt-1} + \frac{1}{\lambda_{PL}}\Delta P,$$

(25) $$W\left(P_{t-1} + \frac{1}{\lambda_P}\Delta P\right), W\left(E_{t-1} + \frac{1}{\lambda_E}\Delta E\right), W\left(Y_{t-1} + \frac{1}{\lambda_Y}\Delta Y\right), W\left(P_{L_{t-1}} + \frac{1}{\lambda_{P_L}}\Delta P_L\right),$$

$$W\left(AgL_{t-1} + \frac{1}{\lambda_{AgL}}\Delta AgL\right)) - \lambda_{AgL} AgL_{t-1} + \sum_i \delta_{iAgL}\Omega^{AgL} + \psi_i$$

As before, the speed-of-adjustment coefficients ($\lambda_i$) can be embedded in the linear coefficient parameters (Deller et al. 2001) $\alpha$, $\beta$, and $\delta$. To simplify the equations and combine terms we can use the fact that $X + WX = (I + W)X$ , where $X$ is a data matrix, $W$ is the spatial weights matrix, and $I$ is an identity matrix. The final spatially explicit econometric relationships can be specified as:

$$\begin{aligned}\Delta P = {} & \alpha_{0P} + \beta_{1P}(I+W)P_{t-1} + \beta_{2P}(I+W)E_{t-1} + \beta_{3P}(I+W)Y_{t-1} + \beta_{4P}(I+W)P_{Lt-1} \\ & + \beta_{5P}(I+W)\Delta E + \beta_{6P}(I+W)\Delta Y + \beta_{7P}(I+W)\Delta P_L + \beta_{8P}W\Delta P + \sum_i \delta_{iP}\Omega^P + \varepsilon_i\end{aligned} \tag{26}$$

$$\begin{aligned}\Delta E = {} & \alpha_{0E} + \beta_{1E}(I+W)E_{t-1} + \beta_{2E}(I+W)P_{t-1} + \beta_{3E}(I+W)Y_{t-1} + \beta_{4E}(I+W)P_{Lt-1} \\ & + \beta_{5E}(I+W)\Delta P + \beta_{6E}(I+W)\Delta Y + \beta_{7E}(I+W)\Delta P_L + \beta_{8E}W\Delta E + \sum_i \delta_{iE}\Omega^E + \mu_i\end{aligned} \tag{27}$$

$$\begin{aligned}\Delta Y = {} & \alpha_{0Y} + \beta_{1Y}(I+W)Y_{t-1} + \beta_{2Y}(I+W)P_{t-1} + \beta_{3Y}(I+W)E_{t-1} + \beta_{4Y}(I+W)P_{Lt-1} \\ & + \beta_{5Y}(I+W)\Delta P + \beta_{6Y}(I+W)\Delta E + \beta_{7Y}(I+W)\Delta P_L + \beta_{8Y}W\Delta Y + \sum_i \delta_{iY}\Omega^Y + \tau_i\end{aligned} \tag{28}$$

$$\begin{aligned}\Delta P_L = {} & \alpha_{0P_L} + \beta_{1P_L}(I+W)P_{Lt-1} + \beta_{2P_L}(I+W)P_{t-1} + \beta_{3P_L}(I+W)E_{t-1} + \beta_{4P_L}(I+W)Y_{t-1} \\ & + \beta_{5P_L}(I+W)AgL_{t-1} + \beta_{6P_L}(I+W)\Delta P + \beta_{7P_L}(I+W)\Delta E + \beta_{8P_L}(I+W)\Delta Y \\ & + \beta_{9P_L}(I+W)\Delta AgL + \beta_{10P_L}W\Delta P_L + \sum_i \delta_{iP_L}\Omega^{P_L} + \gamma_i\end{aligned} \tag{29}$$

$$\begin{aligned}\Delta AgL = {} & \alpha_{0AgL} + \beta_{1AgL}(I+W)AgL_{t-1} + \beta_{2AgL}(I+W)P_{t-1} + \beta_{3AgL}(I+W)E_{t-1} + \beta_{4AgL}(I+W)Y_{t-1} \\ & + \beta_{5AgL}(I+W)P_{Lt-1} + \beta_{6AgL}(I+W)\Delta P + \beta_{7AgL}(I+W)\Delta E + \beta_{8AgL}(I+W)\Delta Y \\ & + \beta_{9AgL}(I+W)\Delta P_L + \beta_{10AgL}W\Delta AgL + \sum_i \delta_{iAgL}\Omega^{AgL} + \psi_i\end{aligned} \tag{30}$$

Estimating equations (26) through (30) should provide insight into the factors that affect regional agricultural land development. If spatial correlation is present, this model gives an unbiased and efficient estimate of coefficients by directly integrating spatial dependence into the model. The existence of spatial autocorrelation in the data for the northeastern U.S. is tested using Moran's I statistics, as they indicate the degree of correlation between endogenous variables and their spatial lags. The Moran's I statistics is reported in Table 1. For the population density change equation ($\Delta P$), some spatial autocorrelation is detected for spatial lags of population density change and employment density change, with Moran's I estimates of 0.358 and 0.381, respectively. For the employment density change equation ($\Delta E$), spatial autocorrelation measures of 0.373 and 0.351 show some spatial autocorrelation for spatial lags of the population density change and employment density change variables, respectively. For the per capita income change equation ($\Delta Y$), Moran's I statistics of 0.776 for the spatial lag in per capita income change and 0.514 for the value of land change indicate strong positive spatial autocorrelation. Measures of spatial autocorrelation between the change in land value ($\Delta P_L$) and its spatial lag and the spatial lag of income growth, at 0.542 and 0.467, respectively, indicate relatively strong positive spatial autocorrelation. Finally, in the agricultural land change equation ($\Delta AgL$), positive spatial autocorrelation is reported for its spatial lag variable, 0.411.

The estimation of the spatial model benefits from earlier works by Boarnet (1995), Henry et al. (1999), and Rey and Boarnet (1998) which used instrumental variable estimation in spatial systems of equations models. The existence of right-hand-side spatially weighted endogenous variables poses estimation problems in a spatial system of equations. One theoretical approach for solving this problem has been suggested by Anselin (1980) where right-hand-side spatially-weighted endogenous variables can be instrumented on exogenous variables in the system. Using this method, first, the right hand side endogenous variables are predicted using instrumental variables (initial condition variables and a set of exogenous variables). The resulting predicted endogenous variable values are post-multiplied by the appropriate weights matrix to generate predicted spatially weighted variables. Mathematically, this can be represented as: $W[X(X'X)^{-1}X'\Delta Y] = W(X\beta)$, where $W$ is the spatial weights matrix, $X$ represents a matrix of all exogenous variables, and $\Delta Y$ represents a vector for a right-hand side endogenous variable, and $\beta$ is a vector of coefficients being estimated. These estimated, spatially-weighted values for the right-hand-side endogenous variables are then substituted into the right-hand side of the original model for estimation using three-stage least squares. The three-stage least squares procedure provides consistent estimates of model parameters. It is also preferred to two-stage least squares because it is a full-information estimation procedure that estimates all parameters simultaneously. As a result, three-stage least squares provides asymptotically more efficient results than that of two-stage least squares (Ma and Yasuo 2003).

**Data and Statistical Summary**

Estimation of the spatial growth equilibrium model requires a variety of county-level data ranging from population and employment growth to an assortment of agricultural information. The endogenous variables, initial condition variables, and their spatial lag variables are reported in Table 2. County-level data for changes in population density, employment density (total employment per square mile), and per capita income were computed from the Regional Economic Information System (REIS) (U.S. Census 2001) and the County and City Data Book (C&CDB) and represent changes from 1987 to 1999. County-level changes in the per acre value of farmland and agricultural land density (farmland per square mile) were calculated from the U.S. Census of Agriculture (USDA 1992; USDA 2002) and the County and City Data Book showing changes from 1987 to 2002. Initial conditions for these variables, for 1987, are from the same data sources.

Table 3 presents the independent variables used in the model. Several variables measure agricultural performance and its impact on farmland development, agricultural income per farm, and average government payment per farm. All are computed from the U.S. Census of Agriculture (1992) for 1987. The percentage of county land in farms (U.S. Census of Agriculture) is included to test whether concentration of farming activity influences the value of land per acre and the extent of farmland development. Variables for a variety of farmland protection policies examine their impacts on farmland development. The farmland protection policies included in this study are agricultural districts, farmland protection zoning, transfer of development rights, and tax incentives for donation of farmland preservation easements. County level data was not available for these farmland protection policies, thus a dummy variable is used which indicates the presence or absence of these policies at the state level. All policy data are from the Northeast Sustainable Agriculture Working Group (NSAWG) for 2002.

Employment classification variables, government tax and expenditure variables, per capita local government taxes (total taxes paid in a county divided by county population), property taxes as a percentage of total taxes, and per capita local government expenditures (at the county level), are also used in the model. Per capita local government expenditures were computed from the REIS and C&CDB. A series of county-level characteristics are used to analyze the impact of local conditions on farmland development. The urban influence code, developed by the USDA Economic Research Service (ERS) (2003), measures the extent of development pressure from urbanized places and ranges from 1 to 9. A code of 1 indicates a county that is in a metro area with at least 1 million residents or more and code 9 represents a non-core county which is adjacent to a micro area and which contains a town of 2,500 to 9,999 residents. The median value of owner-occupied housing, unemployment rate, and number of hospital beds per 100,000 people represent county characteristics which reflect the attractiveness of moving to a county or staying there based on access to affordable housing, economic opportunities and healthcare services. These variables help measure the indirect impact of these local characteristics on farmland development.

The percentage of a county's population (age 25 and above) with a bachelor's degree and higher, along with the percentage of persons in a county below the federal poverty line reflect county characteristics regarding the degree of human capital formation and distribution of poverty. These variables may have significant bearing on county income and employment growth, which consequently may affect the extent of farmland development. State and interstate road density, calculated as miles per square mile, reflect the degree of infrastructure development, which could have a significant influence on county economic growth, demographic change, and consequent farmland development. These variables were calculated by the West Virginia University (WVU) Natural Resources Analysis Center (NRAC) using 2003 data.

The descriptive statistics of all the variables in the model are reported in Tables 4 and 5. There are 299 counties in the northeastern states; however, the descriptive statistics are based on 290 counties. One of the excluded counties is Baltimore, Maryland, which was excluded because it is not included in the Census of Agriculture (1992 and 2002). The other 8 counties excluded from this study are: Suffolk, Massachusetts; Hudson, New Jersey; Bronx, New York; Kings, New York; New York, New York; Queens, New York; Richmond, New York; and Philadelphia, Pennsylvania. Each of these counties, except Philadelphia, reported zero agricultural employment for the study period. Seven of the counties had less than 26 acres in agricultural land, and by 2002, Philadelphia had only 31 acres of farmland. Although these counties are fast growth centers, attempting to measure the impact of their growth on the negligible amount of farmland in these counties will be misleading as there will be almost no change. However, the impact of other fast growing counties on agricultural land in neighboring counties is important and will maintain some of this information from the excluded counties. In addition, the urban influence code for each of the included counties is used to capture part of the missing information due to the excluded counties.

**Estimation Results**

The coefficient estimates for all variables in the model are provided in Tables 6 and 7. Population density change ($\Delta P$) is significantly and positively associated with employment density change ($\Delta E$). This result reinforces similar conclusions in other studies that regions with employment growth attract population. The relationship with per capita income change ($\Delta Y$) is negative and significant. Even though it can be expected *a priori* that counties with income growth will experience higher population growth, this result for the Northeast indicates that population density is growing in counties with declining per capita income. This result may be picking up an increase in population in suburban and rural locations where income is not growing very quickly. The last endogenous variable in the population density change equation is change in per acre value of land ($\Delta P_L$). It was expected that higher land prices would lead to a decline in population density; however, the result was statistically insignificant.

The spatially lagged endogenous variables of change in population density, employment density change, per capita income change, and change in the per acre value of agricultural land are introduced to test for cross county growth interdependence. The significant and negative coefficient associated with spatially-weighted change in population density ($W\Delta\hat{P}$) indicates that population growth in neighboring counties decreases population density in the county in question. It was expected that population growth in a neighboring county would spillover and result in increasing population due to commuting residents. However, it may be the case that better economic opportunities in fast growing areas are attracting residents away from a rural county, resulting in decreasing population there, or that decreasing population density due to flight from urban areas is reflected in increasing population density in a neighboring rural county. Per capita income change in neighboring counties ($W\Delta\hat{Y}$) has a positive and significant relationship with population density change. Interestingly, once income is made it has no spatial fixity; people can maximize their utility across locations given their income. Hence, a county surrounded by counties with increasing income may attract some commuters to move there, raising overall population density. For example, counties surrounding cities with high income growth may see increases in population as demand increases for characteristics provided by the surrounding counties. Population density is negatively and significantly related with the spatial lag of the change in farmland value ($W\Delta\hat{P}_L$). It was expected that higher land values in neighboring counties would drive some residents to locate in the county of interest. One possible explanation for this counterintuitive result may be that counties with increasing land values also have high economic growth and the economic opportunity in these locations outweighs the disincentive associated with higher land prices.

Lagged population density ($P_{t\text{-}1}$) is significant and negative, indicating counties with higher initial population density have less population growth in the following time period. The spatial lag of initial population ($WP_{t\text{-}1}$) is positively related with population density change, however, this result is not statistically significant, indicating that earlier population density in neighboring areas does not have an impact on the change in population density in the county of interest.

Local characteristics such as taxes, local government spending, owner-occupied housing values, the unemployment rate, and accessibility are also included in the change in population density equation. The results indicate that per capita taxes and property taxes are significantly associated with decreasing population density, as expected. The value of owner-occupied housing is positive and significant. Counties with high housing values are associated with population growth.

The dependent change in employment density variable ($\Delta E$) is significantly and positively related with population density change ($\Delta P$). An increase of one person per square mile increases jobs per square mile by 0.443. A \$1 per acre increase in the value of agricultural land ($\Delta P_L$) would result in a decrease in employment density of 0.003. Although population growth encourages employment growth, higher land values do not.

The spatial lag of population density change ($W\Delta\hat{P}$) is positively and significantly related with county employment growth, suggesting that population growth in neighboring counties can increase job growth in own county. However, employment growth in a neighboring county ($W\Delta\hat{E}$) is negatively related with employment growth in the county of interest. Counties experiencing high employment growth may attract opportunities from a neighboring county causing employment to decline in that county.

The initial employment density situation ($E_{t-1}$) is negatively and significantly related with employment density change. This result suggests that counties with high initial employment density saw a decline in employment expansion compared to counties with low initial employment density. This may indicate a rural renaissance (Deller et al. 2003). The spatial lag of initial employment density ($WE_{t-1}$) was not significant.

There is a significant and positive relationship between employment density change and state and interstate road densities. Other things remaining constant, a 1 mile of road per square mile increase would cause employment to increase by approximately 68 jobs and 41 jobs per square mile for state and interstate roads, respectively. Employment is analyzed by sectors to see whether employment growth is significantly associated with job creation in specific industries. Both service sector and mining sector employment are positively and significantly related with overall employment growth, however, construction employment is negative (and significant). Counties with higher construction jobs experienced slower overall employment creation. This may indicate construction and development activities in rural counties where overall job growth may have been slower.

Change in per capita income ($\Delta Y$) as a dependent variable is significantly and negatively related with population density change ($\Delta P$), and positively and significantly related with change in employment density ($\Delta E$). A one person per square mile increase in population is expected (on average) to reduce per capita income by $8.38, a similar 1 job per square mile increase in employment would increase per capita income by $8.25. The relationship with change in the value of land ($\Delta P_L$) is positive and significant. This result is contrary to prior expectations that high per acre land values drive jobs to lower land value counties and reduce per capita income. The result suggests that counties with significant increases in land values experienced increases in per capita income. There is a two directional effect here, the impact of land values on income and the impact of income on land values. Perhaps this result may be picking up the fact that counties with income growth also experience land value increases.

The initial per capita income condition ($Y_{t-1}$) is not significant in explaining income changes, however, spatially-weighted initial per capita income ($WY_{t-1}$) is negative and significant. This suggests that a county with high initial per capita income in neighboring counties experienced less income growth.

The cross county effects of all of the endogenous variables, except per capita income ($W\Delta\hat{Y}$), are not significant, thus, income growth in a county is not determined by population, employment and land value changes in neighboring counties. However, income growth in neighboring counties has a significant effect on own-county income changes. A $100 increase in per capita income in neighboring counties is expected to result in a $43 increase in income in the county of interest, *ceteris paribus*. This result suggests that county income growth is significantly affected by regional income growth patterns.

Local factors related to taxes, human capital development, poverty distribution, and accessibility are also included in the per capita income change equation. The results indicate that the per capita tax burden is not associated with per capita income change. A positive and significant relationship is found between income growth and property taxes. This result is unexpected but suggests that counties with a high proportion of tax income from property taxes experienced per capita income growth. The proportion of the county's population with a bachelor's degree or higher is positively and significantly related with changes in per capita income. A 1% increase in this percentage should increase per capita income by $225.73, *ceteris paribus*. But, the proportion of a county's population below the poverty line has a greater negative impact such that a 1% increase in the percentage in poverty leads to a $429.53 decrease in per capita income. Thus, while human capital development increases income growth, increasing poverty may hinder it. The county interstate density variable is significant. A 1 mile per square mile increase in interstate is expected to increase per capita income by $2,850.07.

A change in per capita income ($\Delta Y$) has a positive relationship in the change in per acre value of land ($\Delta P_L$) equation; change in employment density ($\Delta E$) has a negative relationship. Counties with high income growth are expected to see increases in land values. The marginal impact of income growth on land values means a $1 increase in per capita income results in a $0.74 increase in the value of agricultural land per acre. This suggests that regional income growth pushes land values up through its impact on development of farmland. The negative coefficient estimate for employment density change is contrary to prior expectations that employment growth exerts pressure on existing land uses and results in higher land values. The agricultural land change ($\Delta AgL$) coefficient has a positive and significant effect. This indicates that counties with positive agricultural land density changes or with more agricultural land stock have higher land values per acre. One possible explanation for this is that farmland in counties with an expanding agricultural land area is more productive, leading to higher per acre values for farmland.

Increases in population density in neighboring counties ($W\Delta\hat{P}$) are positively associated with land value increases in the relevant county. A 1 person per square mile increase in a neighboring county's population is expected to increase agricultural land values by $56.11 per acre. This result is consistent with prior expectations that increasing population in neighboring counties puts pressure on agricultural land use, increasing the value of farmland. Employment density growth ($W\Delta\hat{E}$) in one county is also expected to increase land values in its neighbor; however, this variable was not statistically significant. Spatially weighted per capita income change ($W\Delta\hat{Y}$) is significant and negatively related with land values. This is unexpected as income growth in neighboring counties is thought to result in high land values nearby. This result may be capturing the effect that population and businesses tend to be attracted to high income regions, which would reduce pressure on land values in neighboring counties. The estimated impact is very small, with a $1 increase in per capita income in a neighboring county reducing land values by $0.74 per acre. The spatial lag of land values ($W\Delta\hat{P}_L$) in neighboring counties is positive but not significant. Agricultural land density change in neighboring counties ($W\Delta\widehat{AgL}$) was significant in predicting own county agricultural land value per acre. A rise in agricultural land density in neighboring counties is associated with an increase in the value of land per acre in the relevant county.

Counties surrounded by high land value counties experience increases in land value as indicated by the estimated coefficient on the spatial lag of initial land value ($WP_{Lt\text{-}1}$) which is positive and significant. Similarly, counties with high initial own county agricultural land values

($P_{Lt\text{-}1}$) experience upward movement in land prices with the estimated coefficient positive and significant.

Road density variables have positive relationships with land value; however, state road density is not significant. For interstate road density, a 1 mile per square mile increase results in an increase in farmland values of $10,339.18 per acre. This may be due to the effect of interstate development on regional population, employment, and income growth which directly and indirectly impose pressure on existing land at local levels, in addition to decreasing the supply of land. Development of road infrastructure itself claims some land, including from agriculture.

Agricultural income and government payments per farm test the effect of farm income and government support programs on agricultural land values. The positive coefficients confirm prior expectations that farm income and government support payments increase farmland values, although the government payments variable is not significant. All other variables remaining fixed, a $100 increase in agricultural income per farm is expected to raise the value of agricultural land by $2.60 per acre. The proportion of county land devoted to farming is significant and negatively related with county agricultural land value per acre. For every 1% increase in the amount of county land used for agriculture, the per acre value of agricultural land is expected to decrease by $92.51. This coefficient simply captures the relationship between county farmland supply and its price, indicating that a higher proportion of land in agriculture reduces its scarcity, hence lowering its value.

A set of farmland protection policies is introduced to study their effects on agricultural land value. Dummy variables capture differences in land use policies across states in the Northeast. The coefficient estimates for these policy variables indicate that states which have these policies have significantly higher land values compared to states that have not implemented these policies. Aside from agricultural zoning, which was insignificant, all of the other policy instruments have positive and significant coefficient estimates. States that have implemented tax easements, agricultural districts, and transfer of development rights (TDR) have higher agricultural land values with per acre marginal impacts of these policies of $16,019.16, $7,491.82, and $9,756.59, respectively. These impacts could mean that states which have implemented these policies were already experiencing significant increases in land values. Hence, this result suggests that farmland protection policies have been in response to high growth and rapid farmland conversion rather than being implemented as preventive measures.

In the agricultural land density change ($\Delta AgL$) equation, change in population density ($\Delta P$) is not significant in determining regional changes agricultural land stocks, but change in per capita income ($\Delta Y$) is significant and negative. In line with theoretical expectations, increases in income result in agricultural land conversation to satisfy the demand for growth. Holding other factors constant, a $1,000 increase in per capita income would lead to conversion of 4 acres of farmland per square mile. The positive marginal effect of employment growth ($\Delta E$) on agricultural land conversion was not as anticipated. Employment growth may have two effects, market creation and an increase in the demand for land. The net impact will determine the overall change in agricultural land use. In this case, an increase in employment density increases agricultural land density, however, an increase in per capita income decreases it. A significant and positive relationship is observed between change in agricultural land value ($\Delta P_L$) and agricultural land density change. This positive impact suggests that counties with increasing agricultural land values have less agricultural land conversion. This result confirms that development is more likely in low land value counties compared to counties with high prices for farmland.

The initial condition variable ($AgL_{t-1}$), agricultural land density in 1987, was not significant. The spatially lagged initial condition variable ($WAgL_{t-1}$), however, was significant and positive, indicating that agricultural land density is expected to be high in counties bordering those with high initial agricultural land density.

Estimates of the spatially lagged endogenous variables indicate that population growth in neighboring counties ($W\Delta\hat{P}$) has a significant and negative effect on agricultural land. Similarly, increasing agricultural land values in neighboring counties ($W\Delta\hat{P}_L$) lead to a greater loss of farmland in the county of interest. Increasing land values may encourage local farmers to develop their land if the gain from selling is greater than the discounted benefits of using the land in agriculture. Both the spatial lag of income ($W\Delta\hat{Y}$) and of employment ($W\Delta\hat{E}$) are positive and significant. This result, in conjunction with own-county effects, generally suggests that while own-county income growth increases pressure on existing agricultural land, the increase of these variables in neighboring counties has the opposite impact. Income and employment growth in neighboring counties may create market outlets for farmers in a nearby county while decreasing development pressure in their own county. This conclusion is supported by the negative and significant coefficient for the farm income variable, which indicates that less farmland is developed in counties where farm income is higher.

The marginal effect of state road density is negative and significant. This supports the idea that better access increases the susceptibility of agricultural land to development. An increase of 1 mile of state road per square mile results in a loss of 32.7 farmland acres per square mile. A variable that measures the influence which urban areas exert on farmland development (ranging from 1 for urbanized areas to 9 for rural areas) is positive and significant, meaning that counties close to highly urbanized areas are likely to experience greater farmland losses than counties which are rural.

Results from four land use policy instruments show that states which have implemented tax easements and TDR programs experience higher levels of agricultural land development compared to states that have not implemented these policies. States using these programs have higher agricultural land conversion at the margin of 198 and 176 acres per square mile, respectively. However, states with agricultural districts and zoning did not see a significant difference in farmland development compared with states that did not have these policies. This raises questions regarding the effectiveness of these farmland protection policies and whether land use policies are introduced as a response to already existing development pressure or as a preventive land management tool.

**Conclusions**

Based on the empirical results in this study, the following general conclusion can be made. Regions with increasing employment experience more population growth. While increases in per capita taxes, property taxes, and the unemployment rate reduce county population density, increases in road access, per capita local government spending, and jobs increase population density. Income growth in neighboring counties increases population, and an increase in per acre value of farmland in neighboring counties reduces population density change.

While growth in county population and per capita income positively influence employment density, growth in agricultural land values reduces employment growth. The results also show that higher taxes and a higher county unemployment rate reduce employment density change, and higher interstate and state road densities increase employment expansion.

Per capita income change is negatively influenced by population density change, but positively related with employment density and agricultural land values. Increases in per capita taxes and the percentage of the county population below the poverty line tend to slow income growth, whereas state and interstate road density and the percentage of the county population with a bachelor's degree or higher have a positive impact on income growth. Moreover, income growth is positively affected when income growth occurs in neighboring counties, showing economic interdependence among counties.

Counties with population and income growth are likely to experience significant increases in the per acre value of agricultural land. Interstate and state road densities have a positive influence on per acre value of farmland. The more accessible farmland is the higher its value. Similarly, agricultural income per farm has a positive relationship with land values. States that implemented farmland protection policies have significantly higher land values, possibly because land use policies were introduced in areas where farmland was already increasing in value due to development pressure. Agricultural land values are also influenced by neighboring county population (positively), income growth (negatively), and farmland density (positively).

Counties with significant increases in per capita income and population density are likely to experience farmland losses. Proximity to a metropolitan area and higher state road density encourage development of farmland. A negative relationship was found between tax breaks for farmland preservation easements and a TDR farmland protection program, indicating that states that implemented these policies have significantly more agricultural land loss per square mile compared to states that do not have these policies. Population growth in neighboring counties encourages own-county farmland development, however, income and employment growth in neighboring counties have positive impacts on changes in agricultural land density.

Findings in this study on agricultural land development indicate that land use change is not only affected by growth within a county, but also by growth patterns in neighboring counties. This cross-county interdependence may indicate the need for coordinated regional farmland protection policies and programs for effective land use management. To achieve this goal, open cooperation across states is important. In addition, consideration should be given to the impact of economic development on agriculture, and agriculture should be taken into account when making economic development decisions. Some states already have in place agricultural impact statutes that require consideration of the impact of economic development on the agricultural sector. Similar policy approaches may help harmonize growth and farmland protection.

Raising money for farmland protection can be challenging, and resource scarcity may hinder county-level land protection initiatives. It may be more effective to focus federal and state farmland protection resources on counties with high susceptibility to development based on accessibility, adjacency to major urban centers, current population and income growth, and agricultural land development trends. Farmland will be developed at a faster pace to accommodate development encouraged through improved transportation access. Though transportation infrastructure development is an important social investment, analysis of the impact of road development on agricultural lands may help minimize the social cost of building roads in terms of lost farmland.

The usefulness of this study comes from its ability to improve understanding of the relationship between regional growth patterns and agricultural land development. It expanded on earlier works by bringing agricultural land use questions into a regional framework and by introducing a system of equations model that integrates cross-county spatial interactions. However, there are limitations in this study that could be improved upon in future work. A number of theoretically relevant variables were not included in the models. For example, amenity indicators could explain differences in population growth, and land quality differences may explain changes in land values. Degree of implementation of farmland protection policies at the county level might better explain differences in farmland conversion. Additional research extending this study from a regional to a national level could bring in more variation within the data and yield results with more general application. A national study would eliminate biases that result from the unique characteristics of the Northeast and allow for regional variations in economic, demographic and agricultural sector variables. A national study is the logical next step for expansion of this regional model.

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**Table 1. Moran's I Statistics for spatial autocorrelation**

| Moran's I Statistic | $\Delta P$ Equation | $\Delta E$ Equation | $\Delta Y$ Equation | $\Delta P_L$ Equation | $\Delta AgL$ Equation |
|---|---|---|---|---|---|
| $W\Delta\hat{P}$ | 0.358 | 0.373 | 0.211 | 0.166 | -0.230 |
| $W\Delta\hat{E}$ | 0.381 | 0.351 | 0.166 | 0.167 | -0.187 |
| $W\Delta\hat{Y}$ | 0.182 | 0.185 | 0.776 | 0.467 | -0.191 |
| $W\Delta\hat{P}_L$ | 0.162 | 0.240 | 0.514 | 0.542 | -0.065 |
| $W\Delta\hat{AgL}$ | - | - | - | -0.056 | 0.411 |

**Table 2. Definition and Data Source for Endogenous and Initial ConditionVariables**

| Variable | Definition | Source of Data |
|---|---|---|
| *Endogenous Variables* | | |
| $\Delta P$ | Change in population density from 1987 to 1999 | REIS and C&CDB |
| $\Delta E$ | Change in employment density from 1987 to 1999 | REIS and C&CDB |
| $\Delta Y$ | Change in per capita income from 1987 to 1999 | REIS and C&CDB |
| $\Delta P_L$ | Change in per acre value of farmland from 1987 to 2002 | U.S. Census of Ag. and C&CDB |
| $\Delta AgL$ | Change in agricultural land density from 1987 to 2002 | U.S. Census of Ag. and C&CDB |
| *Initial Conditions* | | |
| $P_{t\text{-}1}$ | Population density in 1987 | REIS and C&CDB |
| $E_{t\text{-}1}$ | Employment density in 1987 | REIS and C&CDB |
| $Y_{t\text{-}1}$ | Per capita income in 1987 | REIS and C&CDB |
| $P_{Lt\text{-}1}$ | Per acre value of land in 1987 | U.S. Census of Agriculture |
| $AgL_{t\text{-}1}$ | Agricultural land density in 1987 | U.S. Census of Agriculture |

**Table 3. Definition and Data Source for Independent Variables**

| Variable | Definition | Source of Data |
|---|---|---|
| *Agricultural Performance and Land Variables* | | |
| $AgIncPF_{t-1}$ | Agricultural income per farm in 1987 (thousands of dollars) | U.S. Census of Ag. |
| $GvPayPF_{t-1}$ | Average government payment per farm in 1987 (dollars) | U.S. Census of Ag. |
| $\%CLFarm_{t-1}$ | Percentage of county land in farms in 1987 | U.S. Census of Ag. |
| *Farmland Protection Policies* | | |
| TaxEasemt | Tax incentive for donation of farmland preservation easement | NSAWG |
| AgDistrc | Agricultural district | NSAWG |
| AgPZone | Agricultural land protection zoning | NSAWG |
| TDR | Transfer of development rights | NSAWG |
| *Employment Classifications* | | |
| $FarmEmp_{t-1}$ | Number of persons in farm employment in 1987 | REIS |
| $ServEmp_{t-1}$ | Number of persons in service employment in1987 | REIS |
| $MinEmp_{t-1}$ | Number of persons in mining employment in 1987 | REIS |
| $ConstEmp_{t-1}$ | Number of persons in construction employment in 1987 | REIS |
| *Local Government Taxes and Expenditures* | | |
| $PCTax_{t-1}$ | Per capita taxes in 1987 | C&CDB |
| $Prop\%Tax_{t-1}$ | Property tax as percentage of total taxes in 1987 | C&CDB |
| $PCGovExp_{t-1}$ | Per capita local government expenditures in 1987 | C&CDB and REIS |
| *Local County Characteristics* | | |
| UInfCode | Urban influence code (1 to 9) | ERS USDA |
| $MVOwnOcc_{t-1}$ | Median value of owner-occupied housing in 1990 | C&CDB |
| $UnempRate_{t-1}$ | Unemployment rate in 1991 | C&CDB |
| $HospB100k_{t-1}$ | Number of hospital beds per 100,000 population in 1991 | C&CDB |
| $\%Degree_{t-1}$ | Percentage of county population with bachelor's degree or higher in 1990 | C&CDB |
| $\%BlPov_{t-1}$ | Percent of persons in a county below poverty level in 1989 | C&CDB |
| StateRD | State road density (miles of state road per square mile) | NRAC, WVU |
| InterstD | Interstate road density (miles of interstate per square mile) | NRAC, WVU |

**Table 4. Descriptive Statistics – Endogenous and Initial Condition Variables**

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| *Endogenous Variables* | | | | |
| $\Delta P$ | 16.87 | 55.28 | -494.91 | 326.32 |
| $\Delta E$ | 22.55 | 44.67 | -240.37 | 265.28 |
| $\Delta Y$ | 8,015.08 | 4,465.55 | 2,027.00 | 29,382.00 |
| $\Delta P_L$ | 2,904.74 | 6,328.51 | -492.00 | 74,107.00 |
| $\Delta AgL$ | -7.69 | 24.49 | -143.92 | 115.14 |
| *Initial Conditions* | | | | |
| $P_{t-1}$ | 361.14 | 711.11 | 2.89 | 6,426.30 |
| $E_{t-1}$ | 194.75 | 414.46 | 1.34 | 3,656.26 |
| $Y_{t-1}$ | 14,847.90 | 3,879.12 | 7,311.00 | 27,680.00 |
| $P_{Lt-1}$ | 2,131.66 | 2,740.89 | 385.00 | 29,697.00 |
| $AgL_{t-1}$ | 157.64 | 105.84 | 0.67 | 478.84 |
| *Endogenous Variables (Spatially Weighted)* | | | | |
| $W\Delta P$ | 17.57 | 28.41 | -66.00 | 124.75 |
| $W\Delta E$ | 22.55 | 22.79 | -30.75 | 120.00 |
| $W\Delta Y$ | 8,059.06 | 3,750.00 | 2,937.50 | 19,245.75 |
| $W\Delta PL$ | 3,026.56 | 4,690.82 | -800.50 | 31,159.50 |
| $W\Delta AgL$ | -7.92 | 12.35 | -41.75 | 21.75 |
| *Initial Conditions (Spatially Weighted)* | | | | |
| $WP_{t-1}$ | 371.66 | 542.55 | 21.50 | 3,827.25 |
| $WE_{t-1}$ | 201.88 | 316.66 | 9.25 | 2,165.00 |
| $WY_{t-1}$ | 14,892.84 | 3,448.73 | 8,593.00 | 25,786.25 |
| $WP_{Lt-1}$ | 2,213.10 | 2,400.39 | 451.25 | 15,380.25 |
| $WAgL_{t-1}$ | 158.47 | 83.31 | 5.50 | 421.00 |

**Table 5. Descriptive Statistics of Independent Variables**

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| *Agricultural Performance and Land Variables* | | | | |
| $AgIncPF_{t-1}$ | 50,475.71 | 39,302.73 | 1,695.00 | 260,507.00 |
| $GvPayPF_{t-1}$ | 5,492.16 | 4,498.59 | 0.00 | 24,741.00 |
| $\%CLFarm_{t-1}$ | 24.06 | 15.92 | 0.40 | 75.00 |
| *Farmland Protection Policies* | | | | |
| TaxEasemt | 0.33 | 0.47 | 0.00 | 1.00 |
| AgDistrc | 0.63 | 0.48 | 0.00 | 1.00 |
| AgPZone | 0.32 | 0.47 | 0.00 | 1.00 |
| TDR | 0.67 | 0.47 | 0.00 | 1.00 |
| *Employment Classifications* | | | | |
| $FarmEmp_{t-1}$ | 1,008.19 | 927.60 | 0.00 | 8,337.00 |
| $ServEmp_{t-1}$ | 22,594.19 | 41,970.38 | 53.00 | 326,659.00 |
| $MinEmp_{t-1}$ | 376.32 | 717.65 | 0.00 | 5,479.00 |
| $ConstEmp_{t-1}$ | 5,083.02 | 7,893.12 | 48.00 | 48,511.00 |
| *Local Government Taxes and Expenditures* | | | | |
| $PCTax_{t-1}$ | 602.16 | 318.44 | 90.00 | 2,503.00 |
| $Prop\%Tax_{t-1}$ | 83.94 | 13.67 | 50.10 | 99.90 |
| $PCGovExp_{t-1}$ | 1.38 | 0.49 | 0.65 | 3.54 |
| *Local County Characteristics* | | | | |
| UInfCode | 4.10 | 2.73 | 1.00 | 9.00 |
| $MVOwnOcc_{t-1}$ | 86,228.28 | 49,036.48 | 15,800.00 | 299,400.00 |
| $UnempRate_{t-1}$ | 7.89 | 2.93 | 2.90 | 22.00 |
| $HospB100k_{t-1}$ | 335.91 | 270.70 | 0.00 | 3,224.00 |
| $\%Degree_{t-1}$ | 17.01 | 7.94 | 4.60 | 49.90 |
| $\%BlPov_{t-1}$ | 12.14 | 6.39 | 2.60 | 39.20 |
| StateRD | 0.36 | 0.16 | 0.00 | 0.91 |
| InterstD | 0.08 | 0.10 | 0.00 | 0.63 |

## Table 6. Spatial Growth Equilibrium Model Econometric Results

| Variable | $\Delta P$ Equation | | $\Delta E$ Equation | | $\Delta Y$ Equation | | $\Delta P_L$ Equation | | $\Delta AgL$ Equation | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | p-value | Coeff. | p-value | Coeff. | p-value | Coeff. | p-value | Coeff. | p-value |
| Constant | **127.768** | **0.005** | 7.303 | 0.474 | 15.41 | 0.996 | **-18336.91** | **0.000** | **90.701** | **0.094** |
| *Endogenous Variables* | | | | | | | | | | |
| $\Delta P$ | - | - | **0.443** | **0.000** | **-8.38** | **0.009** | 9.74 | 0.219 | -0.041 | 0.605 |
| $\Delta E$ | **0.679** | **0.000** | - | - | **8.25** | **0.076** | **-74.84** | **0.000** | **0.424** | **0.002** |
| $\Delta Y$ | **-0.005** | **0.039** | 0.001 | 0.390 | - | - | **0.74** | **0.000** | **-0.004** | **0.005** |
| $\Delta P_L$ | 0.001 | 0.384 | **-0.003** | **0.000** | **0.09** | **0.005** | - | - | **0.006** | **0.000** |
| $\Delta AgL$ | - | - | - | - | - | - | **58.31** | **0.000** | - | - |
| *Spatially-weighted Endogenous Variables* | | | | | | | | | | |
| $W\Delta\hat{P}$ | **-1.289** | **0.030** | **0.597** | **0.002** | -13.65 | 0.189 | **56.11** | **0.078** | **-1.256** | **0.000** |
| $W\Delta\hat{E}$ | 0.032 | 0.950 | **-0.534** | **0.059** | -9.28 | 0.589 | 27.52 | 0.439 | **0.667** | **0.083** |
| $W\Delta\hat{Y}$ | **0.008** | **0.070** | -0.001 | 0.527 | **0.43** | **0.001** | **-0.74** | **0.072** | **0.009** | **0.060** |
| $W\Delta\hat{P}_L$ | **-0.008** | **0.068** | 0.001 | 0.676 | 0.06 | 0.506 | 0.04 | 0.892 | **-0.005** | **0.009** |
| $W\Delta\widehat{AgL}$ | - | - | - | - | | | **144.07** | **0.025** | -0.794 | 0.274 |
| *Initial Conditions* | | | | | | | | | | |
| $P_{t-1}$ | **-0.043** | **0.000** | - | - | - | - | - | - | - | - |
| $E_{t-1}$ | - | - | **-0.038** | **0.042** | - | - | - | - | - | - |
| $Y_{t-1}$ | - | - | - | - | 0.15 | 0.206 | - | - | - | - |
| $P_{Lt-1}$ | - | - | - | - | - | - | **0.80** | **0.000** | - | - |
| $AgL_{t-1}$ | - | - | - | - | - | - | - | - | 0.024 | 0.721 |
| *Spatially-weighted Initial Conditions* | | | | | | | | | | |
| $WP_{t-1}$ | 0.031 | 0.319 | - | - | - | - | - | - | - | - |
| $WE_{t-1}$ | - | - | 0.034 | 0.282 | - | - | - | - | - | - |
| $WY_{t-1}$ | - | - | - | - | **-0.38** | **0.054** | - | - | - | - |
| $WP_{Lt-1}$ | - | - | - | - | - | - | **0.93** | **0.029** | - | - |
| $WAgL_{t-1}$ | - | - | - | - | - | - | - | - | **0.228** | **0.011** |

**Bold** indicates significance for variable at p-value ≤10%.

**Table 7. Spatial Growth Equilibrium Model Econometric Results (continued).**

| Variable | $\Delta P$ Equation | | $\Delta E$ Equation | | $\Delta Y$ Equation | | $\Delta P_L$ Equation | | $\Delta AgL$ Equation | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | p-value | Coeff. | p-value | Coeff. | p-value | Coeff. | p-value | Coeff. | p-value |
| *Local Government Taxes and Expenditures* | | | | | | | | | | |
| $PCTax_{t-1}$ | **-0.054** | **0.098** | - | - | -1.08 | 0.202 | - | - | - | - |
| $Prop\%Tax_{t-1}$ | **-1.594** | **0.004** | - | - | **53.14** | **0.000** | - | - | - | - |
| $PCGovExp_{t-1}$ | 20.662 | 0.225 | - | - | - | - | - | - | - | - |
| *Local County Characteristics* | | | | | | | | | | |
| $MVOwnOcc_{t-1}$ | **0.001** | **0.013** | - | - | - | - | - | - | - | - |
| $UnempRate_{t-1}$ | -0.940 | 0.591 | -1.389 | 0.107 | - | - | - | - | - | - |
| $\%Degree_{t-1}$ | - | - | - | - | **225.73** | **0.000** | - | - | - | - |
| $\%BlPov_{t-1}$ | - | - | - | - | **-429.53** | **0.000** | - | - | - | - |
| StateRD | 54.694 | 0.414 | **67.618** | **0.024** | 205.25 | 0.919 | 1660.98 | 0.671 | **-32.696** | **0.048** |
| InterstD | 23.703 | 0.664 | **41.214** | **0.083** | **2850.07** | **0.054** | **10339.18** | **0.005** | -37.048 | 0.233 |
| UInfCode | - | - | - | - | - | - | - | - | **11.057** | **0.001** |
| *Agricultural Performance and Land Variables* | | | | | | | | | | |
| $AgIncPF_{t-1}$ | - | - | - | - | - | - | **0.026** | **0.015** | **-0.0002** | **0.043** |
| $GvPayPF_{t-1}$ | - | - | - | - | - | - | 0.405 | 0.229 | -0.0004 | 0.915 |
| $\%CLFarm_{t-1}$ | - | - | - | - | - | - | **-92.510** | **0.016** | - | - |
| *Farmland Protection Policies* | | | | | | | | | | |
| TaxEasemt | - | - | - | - | - | - | **16019.16** | **0.000** | **-197.99** | **0.000** |
| AgDistrc | - | - | - | - | - | - | **7491.819** | **0.019** | -45.767 | 0.183 |
| AgPZone | - | - | - | - | - | - | 296.215 | 0.887 | -7.156 | 0.738 |
| TDR | - | - | - | - | - | - | **9756.587** | **0.003** | **-176.00** | **0.000** |
| *Employment Classifications* | | | | | | | | | | |
| $FarmEmp_{t-1}$ | - | - | - | - | - | - | - | - | 0.005 | 0.202 |
| $ServEmp_{t-1}$ | - | - | **0.001** | **0.000** | - | - | - | - | - | - |
| $MinEmp_{t-1}$ | - | - | **0.015** | **0.069** | - | - | - | - | - | - |
| $ConstEmp_{t-1}$ | - | - | **-0.431** | **0.022** | - | - | - | - | - | - |

**Bold** indicates significance for variable at p-value ≤10%.