Regional Growth Impacts on Agricultural Land Development: A Spatial Model for Three States

Yohannes G. Hailu and Cheryl Brown

In this study we attempt to understand the relationship between regional growth in population, employment, and per capita income, and farmland development in Maryland, Pennsylvania, and West Virginia. A spatial simultaneous equations model is estimated using county-level data. Results indicate that while county income growth and agricultural land value increases in neighboring counties increase the rate of farmland loss, growth in county agricultural land values, increases in agricultural land density in neighboring counties, and increases in agricultural income per farm reduce farmland losses. Farmland protection policies were not significant in reducing agricultural land development. This approach, focused on regional growth, provides insight into linkages between growth and agricultural land development that can potentially enhance land use planning.

Key Words: farmland protection, regional growth, rural development, spatial growth equilibrium model

Understanding development of agricultural land requires understanding the economic forces that allocate land to different uses. Private sector land use decisions are typically determined by household utility maximization and profit maximization by businesses. Land development in suburban and rural communities impacts economic, fiscal, environmental, and social attributes of communities, with wide-ranging implications for income, employment, the tax base, public services, and non-market environmental goods that have a direct impact on quality of life (Heimlich and Anderson 2001). Studies have documented that the cost of providing public services is a function of the pattern of development (Burchell and Shad 1998). In addition, the development of agricultural land may impose long-term costs on society (Porter 1997).

Farmland is multifunctional in the sense that it not only acts as a factor of production in agriculture, for which competitive markets exist, but also provides scenic beauty and open space which are not necessarily accounted for in its market price (Batie 2003, Abler 2004). A number of studies have analyzed the non-market benefits of agricultural land and how the market may fail to internalize these externalities (Plantinga and Miller 2001, Irwin and Bockstael 2001, Bowker and Didychuk 1994, Kline and Wichelns 1996, Ready, Berger, and Blomquist 1997, Rosenberger and Loomis 1999, Rosenberger and Walsh 1997). When positive externalities from farmland are present, market allocation of farmland may not maximize social welfare, resulting in excessive conversion of agricultural land. In addition, development of agricultural land is for all practical purposes irreversible and results in a loss of option value, which may not be taken into account by land markets (Northeast Regional Center for Rural Development 2002). As a result, many states have initiated some type of land use policy to slow the loss of farmland and its benefits (Nickerson and Hellerstein 2003).

One popular farmland protection program that has been implemented in many states in the U.S., including the three states in this study, is the Pur-

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chase of Development Rights (PDR) program, also known as the Purchase of Agricultural Conservation Easements (PACE) program. This program was enacted in Maryland in 1980, in Pennsylvania in 1989 (AFT 2005), and in West Virginia in 2002. Under this program, a farmer sells the right to develop the land to a government agency or private organization, which places a permanent easement on the land restricting its future use to agriculture. Funds used to purchase these easements come from a variety of sources, including taxes on land transfers; federal funds for purchasing easements are available through the Farm and Ranch Land Protection Program authorized by the 2002 Farm Security and Rural Investment Act (Natural Resources Conservation Service 2004).

Farmland preservation programs are aimed at slowing the rate of farmland conversion and maintaining agriculture in counties with increasing development pressure from rising population and income (Klein and Reganold 1997, Daniels 1999). Specific programs, like PDR, are aimed at retaining a critical mass of farmland (Daniels 1991). Different studies have investigated the relationship between farmland protection programs and the rate of farmland loss (Lynch and Carpenter 2003, Feather and Barnard 2003, Daniels 1991, Brinkman, Miller, and Nickerson 2005, Lynch 2003). Results, however, are mixed. Lynch and Carpenter (2003), for instance, found that while preferential property tax programs decreased the rate of farmland loss, other programs had no significant impact on the rate of farmland development. However, consideration of other factors in their study indicated the effectiveness of farmland protection programs. Brinkman, Miller, and Nickerson (2005) found that PDR programs may have slowed down farmland conversion for the 1982–1987 time period in the Northeast of the United States; however, PDR programs did not reduce farmland conversion in a later time period (1988–1997). Feather and Barnard (2003) found that the existence of a PDR program significantly depends on the state of agricultural land density. Colyer (1998) indicated that despite all the programs to preserve farmland, substantial amounts of prime farmland continue to be converted, particularly in periods of robust economic development.

Several studies have modeled the interaction between economic growth and changes in rural and suburban agricultural land (Brueckner and Fansler 1983, Mieszkowski and Mills 1993). Other studies have focused on regional and local growth patterns determined by "rural renaissance" and "urban flight," a shifting economic base, and a change in employment opportunities (Dissart and Deller 2000, Power 1996, Lewis, Hunt, and Plantinga 2002). Despite the level of aggregation of these studies, many agree that urban "push factors" and rural and suburban "pull factors" determine patterns of development and hence agricultural land use change. Fiscal and social problems associated with central cities (high taxes, low quality public schools and other government services, crime, congestion, and low environmental quality) may also motivate residents to migrate to suburban places (Mieszkowski and Mills 1993).

Other factors that affect regional growth and land use change include public investment in transportation technologies and improved access to outlying areas. Studies show that investment in highways and transportation facilities increases local economic growth and productivity (Chandra and Thompson 2000, Keeler and Ying 1988, Garcia-Mila and McGuire 1992). Greater interstate highway density is also associated with higher levels of manufacturing and other sector employment (Carlino and Mills 1987). 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, Dissart and Deller 2000). Bell and Irwin (2002) found that spatial factors, such as proximity to employment and other activities, natural features, surrounding land use patterns, and land use policies affect the pattern of land use change. The major causes of development of suburban and rural land can be aggregated into forces of population growth, household formation, and income and employment growth (Heimlich and Anderson 2001), which in turn are affected by the abovementioned factors.

This study focuses on the relationship between regional growth and agricultural land development by systematically bringing the farmland conversion problem into a regional growth framework, using an extension of growth equilibrium models that have been applied to study regional economic changes. Departing from previous studies, this study applies regional equilibrium methods to agricultural land use change in a heterogeneous regional environment, including endogenous variables, such as income and land prices, along with land use policies, to better explain regional land use trends. In addition, the study takes into account the spillover effects that could occur from one county to another, or even across state boundaries for the states in this study, by adding a spatial component to the model.

Methodology

In a general equilibrium framework, population, employment, and income are affected not only by each other, but also by a variety of other variables that affect the number of jobs consistent with competitive profits, number of people consistent with utility levels that have been equalized over space, and an array of factors influencing income growth. In principle, many such variables are likely to be simultaneously determined, along with population and employment (Carlino and Mills 1987). Growth equilibrium models were developed to simultaneously explain employment and population changes for a region. In their early applications, these models were used to resolve the debate over whether people follow jobs or jobs follow people (Carlino and Mills 1987).

To capture the impact of intertemporal employment density, population density, and income changes on agricultural land development, a growth equilibrium model is introduced. It is assumed that firms and households adjust to disequilibrium over time to maximize profits and utility across space. Assuming a simultaneous relationship between growth factors, county per capita income, agricultural land prices, and the stock of agricultural land at a particular time, the model can be expressed as

$$P^* = f_P(E^*, Y^*, V^* | \Omega^P) \tag{1}$$

$$E^* = f_E(P^*, Y^*, V^* | \Omega^E) \tag{2}$$

$$Y^* = f_I(P^*, E^*, V^* | \Omega^Y) \tag{3}$$

$$V^* = f_V(P^*, E^*, Y^*, L^* | \Omega^V) \tag{4}$$

$$L^* = f_L(P^*, E^*, Y^*, V^* | \Omega^L)\ , \tag{5}$$

where P^*, E^*, Y^*, V^*, and L^* refer to equilibrium levels of population, employment, per capita income, value of agricultural land, and stock of agricultural land, respectively. Vectors of exogenous variables have direct or indirect impacts on population, Ω^P, employment, Ω^E, per capita income, Ω^Y, value of agricultural land, Ω^V, and stock of agricultural land, Ω^L.

Population and employment are likely to adjust to their equilibrium values with substantial lags (Mills and Price 1984). Similarly, regional income levels, amount of farmland, and farmland values are assumed to adjust over time to their equilibrium values. The initial rate and level of agricultural land conversion is likely to influence farmland conversion in the current year, t, or conversely, equilibrium levels of agricultural land adjust to previous period conversion patterns. Thus, a distributed lag adjustment equation is used:

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

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

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

$$V_t = V_{t-1} + \lambda_V(V^* - V_{t-1}) \tag{9}$$

$$L_t = L_{t-1} + \lambda_L(L^* - L_{t-1})\ , \tag{10}$$

where λ_P, λ_E, λ_Y, λ_V, and λ_L are speed-of-adjustment coefficients with values between zero and one (Carlino and Mills 1987), and $t-1$ is a one-period lag. Current population, employment, income, land prices, and the stock of agricultural land are dependent on their one-period lagged level and on the change between equilibrium values and one-period lagged values adjusted at their respective speed of adjustment values. Rearranging terms and letting Δ represent change between the two periods,

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

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

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

(14) $$\Delta V = V_t - V_{t-1} = \lambda_V (V^* - V_{t-1})$$

(15) $$\Delta L = L_t - L_{t-1} = \lambda_L (L^* - L_{t-1}) .$$

The equilibrium values in equations (11) through (15) are not observable; however, we can solve for these values using equations (6) through (10) and substitute the resulting expressions for the equilibrium values into equations (11) through (15). Including the impact of the exogenous variables from equations (1) through (5) and following Deller et al. (2001), who state that the speed-of-adjustment coefficients (λ's) are embedded in the linear coefficient parameters (α, β, and δ), the econometric equations can be specified linearly as

(16) $$\Delta P = \alpha_P + \beta_{P1} P_{t-1} + \beta_{P2} \Delta E + \beta_{P3} \Delta Y + \beta_{P4} \Delta V + \sum_i \delta_{iP} \Omega^P + \varepsilon$$

(17) $$\Delta E = \alpha_E + \beta_{E1} E_{t-1} + \beta_{E2} \Delta P + \beta_{E3} \Delta Y + \beta_{E4} \Delta V + \sum_i \delta_{iE} \Omega^E + \mu$$

(18) $$\Delta Y = \alpha_Y + \beta_{Y1} Y_{t-1} + \beta_{Y2} \Delta P + \beta_{Y3} \Delta E + \beta_{Y4} \Delta V + \sum_i \delta_{iY} \Omega^Y + \tau$$

(19) $$\Delta V = \alpha_V + \beta_{V1} V_{t-1} + \beta_{V2} \Delta P + \beta_{V3} \Delta E + \beta_{V4} \Delta Y + \beta_{V5} \Delta L + \sum_i \delta_{iV} \Omega^V + \eta$$

(20) $$\Delta L = \alpha_L + \beta_{L1} L_{t-1} + \beta_{L2} \Delta P + \beta_{L3} \Delta E + \beta_{L4} \Delta Y + \beta_{L5} \Delta V + \sum_i \delta_{iL} \Omega^L + \psi ,$$

where

$$\sum_i \delta_{ik} \Omega^k$$

refers to i exogenous variables, which can vary in number for each equation, and ε, μ, τ, η, and ψ are the error terms.

Accounting for Spatial Interdependence

Growth in population, employment, and per capita income in one county could have spillover effects on neighboring counties. Similarly, farmland values and development could be influenced by trends in neighboring counties. Thus, the existence of spatial interdependence (spatial autocorrelation) should be tested and modeled.

Results presented in Table 1 indicate spatial correlation of the endogenous variables in the simultaneous equation system as measured by Moran's I statistics. The diagonal elements of the table refer to spatial correlation for each variable with its spatial lag, and off-diagonal elements refer to cross-spatial correlation for different endogenous variables. If spatial dependence is present, non-spatial models give biased and inefficient coefficient estimates.

Some studies have considered extensions of growth equilibrium simultaneous equation models into a system of equations which accounts for spatial dependence using a spatial lag process (Boarnet 1995, Rey and Boarnet 1998, Henry et al. 1999, Hailu and Brown 2006). Gebremariam, Gebremedhin, and Schaeffer (2006) considered extensions to simultaneous growth equilibrium models incorporating spatial lag and spatial error components. Kelejian and Prucha (1998, 1999, 2004) provide a spatial two-stage least-squares (S2SLS) estimation procedure for models with spatial autoregressive disturbances that generates efficient estimates. Their methods have been adapted for use here with the previously presented system of simultaneous growth equations.

Each of the endogenous variables is included as before, but in addition, each spatially weighted endogenous variable is included in each equation

Table 1. Moran's I Statistics for Endogenous Variables

	$W\Delta P$	$W\Delta E$	$W\Delta Y$	$W\Delta V$	$W\Delta L$
ΔP	0.355	0.301	0.297	0.255	-0.321
ΔE	0.314	0.272	0.255	0.262	-0.253
ΔY	0.327	0.262	0.292	0.170	-0.253
ΔV	0.263	0.252	0.174	0.368	-0.220
ΔL	-0.326	-0.253	-0.232	-0.217	0.363

through use of a contiguity-based spatial weights matrix, W. Adjusting for spatial dependence in the model, equations (16) through (20) become

$$(21)\quad \Delta P = \alpha_P + \beta_{P1}P_{t-1} + \beta_{P2}W\Delta P + \beta_{P3j}(I+W)\Delta E + \beta_{P4j}(I+W)\Delta Y + \beta_{P5j}(I+W)\Delta V + \sum_i \delta_{iP}\Omega^P + \varepsilon$$

$$(22)\quad \Delta E = \alpha_E + \beta_{E1}E_{t-1} + \beta_{E2}W\Delta E + \beta_{E3j}(I+W)\Delta P + \beta_{E4j}(I+W)\Delta Y + \beta_{E5j}(I+W)\Delta V + \sum_i \delta_{iE}\Omega^E + \mu$$

$$(23)\quad \Delta Y = \alpha_Y + \beta_{Y1}Y_{t-1} + \beta_{Y2}W\Delta Y + \beta_{Y3j}(I+W)\Delta P + \beta_{Y4j}(I+W)\Delta E + \beta_{Y5j}(I+W)\Delta V + \sum_i \delta_{iY}\Omega^Y + \tau$$

$$(24)\quad \Delta V = \alpha_V + \beta_{V1}V_{t-1} + \beta_{V2}W\Delta V + \beta_{V3j}(I+W)\Delta P + \beta_{V4j}(I+W)\Delta E + \beta_{V5j}(I+W)\Delta Y + \beta_{V6j}(I+W)\Delta L + \sum_i \delta_{iV}\Omega^V + \eta$$

$$(25)\quad \Delta L = \alpha_L + \beta_{L1}L_{t-1} + \beta_{L2}W\Delta L + \beta_{L3j}(I+W)\Delta P + \beta_{L4j}(I+W)\Delta E + \beta_{L5j}(I+W)\Delta Y + \beta_{L6j}(I+W)\Delta V + \sum_i \delta_{iL}\Omega^L + \psi\ ,$$

where all variables remain as defined before, I is an identity matrix, and $j\in[1,2]$ such that, for example from equation (21),

$$\beta_{P3j}(I+W)\Delta E = \beta_{P31}\Delta E + \beta_{P32}W\Delta E\,.$$

The above specification captures the spatial lag and cross-spatial lag effects in each equation. However, the errors in each equation may or may not be spatially random. If spatial correlation exists in the errors, they need to be modeled as, for example, $\varepsilon = \gamma_1 + \lambda_1 W\varepsilon$, where λ_1 measures the degree of spatial correlation ($|\lambda| \le 1$). In this study, equation errors are generated to test for the existence of spatial correlation in the errors using a two-stage least-squares procedure. The endogenous variables in the model are estimated following Kelejian and Prucha (1999), using a set of instrumental variables (X, WX, W^2X, W^3X), where X is a matrix of the exogenous variables and W is the spatial weights matrix. Letting D represent any of the endogenous variables in the system, a matrix of instrumented variables, $\hat{Z}$, is created such that $\hat{Z} = [X, \widehat{\Delta D}, \widehat{W\Delta D}]$, where $\widehat{\Delta D}$ is an instrumented endogenous variable and $\widehat{W\Delta D}$ is an instrumented spatially weighted endogenous variable. Each dependent endogenous variable in the system, ΔD, is estimated following the S2SLS estimator $\widehat{\widehat{\Delta D}} = (\hat{Z}'\hat{Z})^{-1}\hat{Z}'\Delta D$. The error term for each equation, for example ε, is thus generated following $\varepsilon = \Delta D - \widehat{\widehat{\Delta D}}$, and tested using a Lagrange Multiplier (LM) test. The result, showing significant spatial autocorrelation in the errors of several of the equations of the model, is reported in Table 2.

A spatial three-stage least-squares (S3SLS) estimator should be used if the variance-covariance matrix of contemporaneous cross-equation errors is not diagonal. The existence of contemporaneous cross-equation error correlation can affect the efficiency of model estimates. The LM test suggested by Breusch and Pagan (1980) was used to test for diagonality of the covariance matrix. The calculated LM statistic (53.712) is less than the critical value at a 5 percent significance level; thus, the null hypothesis that the variance-covariance matrix is diagonal cannot be rejected.

Table 2. Lagrange Multiplier Tests for Spatial Error Correlation

Variable	Value	Marginal Probability
ΔP	0.63	0.43
ΔE	0.12	0.73
ΔY	22.99	0.00
ΔV	2.68	0.10
ΔL	12.72	0.00

As a result, an S2SLS estimator can be used to estimate the system of equations.

Given the existence of spatial correlation both in the endogenous variables and in model errors, estimation follows Kelejian and Prucha's (1999) generalized method of moments (GMM) estimation procedure. A GMM approach provides efficient and unbiased estimation of spatial lag models with autoregressive errors. The approach generates a spatial autoregressive coefficient (λ mentioned above) for each equation that filters out the error spatial correlation from the data. The data in the original model is transformed such that any endogenous variable in the system, ΔD, becomes $\Delta D^* = \Delta D - \lambda W \Delta D$, any spatially weighted endogenous variable, $W\Delta D$, becomes $W\Delta D^* = W\Delta D - \lambda W^2 \Delta D$, and the exogenous variables, X, become $X^* = X - \lambda WX$. The transformed data is then estimated with MATLAB using the S2SLS estimator

$$\widehat{\widehat{\Delta D}}^* = (\hat{Z}^{*\prime}\hat{Z}^*)^{-1}\hat{Z}^{*\prime}\Delta D^*,$$

$$\text{where } \hat{Z}^* = [X^*, \widehat{\Delta D}^*, \widehat{W\Delta D}^*].$$

Data

County-level data for Maryland, Pennsylvania, and West Virginia are used to estimate the econometric model. Table 3 gives definitions for the endogenous and initial condition variables, with Table 4 showing exogenous variable definitions. Population, employment, and per capita income data are from the Regional Economic Information Service (REIS) (U.S. Census 2001). Population and employment density are calculated as persons and jobs per square mile, respectively. Agricultural land density is number of farmland acres per square mile. Data on per acre farmland values, farmland acreage, average federal government payments to farmers, proportion of total land in farms, and agricultural income per farm (net of government payments) are generated from the U.S. Agricultural Census (National Agricultural Statistics Service 2004). Government payments and farm income are included as measures of agricultural performance in the county; percentage of county land in farms is included due to the probable influence of farmland concentration on farmland values and farmland changes. County-level data on average payment per acre for purchase of agricultural conservation easements and acres of farmland preserved as a percentage of farmland in the county are used to represent the possible impact of farmland protection programs on agricultural land values and acreage.

Per capita taxes, property taxes, government expenditures per capita, median housing values, education levels, and percentage of the population below the poverty line are from the County and City Data Book (1994) and reflect county characteristics that may impact growth, land values, and/or farmland development. Contributions of different sectors of the economy to regional growth are measured by number of persons employed in construction, farming, manufacturing, mining, and

Table 3. Endogenous and Initial Condition Variable Definitions

Variable	Definition
ENDOGENOUS VARIABLES	
ΔP	Change in population density from 1987 to 1999
ΔE	Change in employment density from 1987 to 1999
ΔY	Change in per capita income from 1987 to 1999
ΔV	Change in per acre value of farmland from 1987 to 2002
ΔL	Change in agricultural land density from 1987 to 2002
SPATIALLY WEIGHTED ENDOGENOUS VARIABLES	
$W\Delta P$	Spatial weights matrix times change in population density
$W\Delta E$	Spatial weights matrix times change in employment density
$W\Delta Y$	Spatial weights matrix times change in per capita income
$W\Delta V$	Spatial weights matrix times change in per acre value of farmland
$W\Delta L$	Spatial weights matrix times change in agricultural land density
INITIAL CONDITION VARIABLES	
P_{t-1}	Population density in 1987
E_{t-1}	Employment density in 1987
Y_{t-1}	Per capita income in 1987
V_{t-1}	Per acre value of farmland in 1987
L_{t-1}	Agricultural land density in 1987

Table 4. Exogenous Variable Definitions

Variable	Definition
$PerCapTax_{t-1}$	Per capita taxes (1987)
$PropTaxPct_{t-1}$	Property taxes as a percentage of total taxes (1987)
$GovtExpPC_{t-1}$	Local government expenditures per capita (1987)
$ConstEmp_{t-1}$	Number of persons employed in construction (1987)
$FarmEmp_{t-1}$	Number of persons employed in farming (1987)
$ManufEmp_{t-1}$	Number of persons employed in manufacturing (1987)
$MineEmp_{t-1}$	Number of persons employed in mining (1987)
$ServEmp_{t-1}$	Number of persons employed in the service sector (1987)
$AgIncPFarm_{t-1}$	Agricultural income per farm (1987)
$GovtPmt_{t-1}$	Average federal government payment per farm (1987)
$\%FrmLnd_{t-1}$	Percentage of total land in farming (1987)
$EasPayPAcr_{t-1}$	Farmland protection easement payment per acre (1992)
$\%PrsvFmlnd_{t-1}$	Acres preserved farmland as percentage of county farmland (1992)
$MedHsVal_{t-1}$	Median owner-occupied housing value (1990)
$\%BDPlus_{t-1}$	Percentage of population with bachelor's degree or higher (1990)
$\%BelowPov_{t-1}$	Percentage of population with income below poverty line (1989)
$StatHwyDen_{t-1}$	Miles of state highway per square mile (2000)

services; data are from the REIS. State highway density (miles of state highway per square mile) was computed by the Natural Resource Analysis Center at West Virginia University using Geographic Information System (GIS) data (Natural Resource Analysis Center 2005). The initial time period of 1987 is based on data available from the U.S. Agricultural Census; however, data for non-agricultural variables were not always available for 1987, so the closest year was used instead. Data on farmland protection programs were available only for 1992. Data for the "current" time period were based on the most recent 2002 U.S. Agricultural Census and the 2000 Census of the U.S. population (1999 values). Tables 5 and 6 provide descriptive statistics for all of the variables.

Discussion of Results [1]

Econometric estimation results for all of the equations are presented in Tables 7, 8, and 9. The results for each equation will be discussed separately in the sections that follow. Table 10 shows the estimation results for the spatial error coefficients as well as the adjusted R^2 measure for each equation. The variables in the population density, employment density, and agricultural land density equations generally do a good job of explaining changes in these dependent variables. The lower R^2 values for the income and agricultural land value equations indicate less explanatory power for the variables in these equations.

Change in Population Density Equation

Change in population is one factor that could affect the rate of farmland loss. The change in population itself is affected by a series of endogenous and exogenous variables. Estimates for the population density change (ΔP) equation indicate that population growth is positively and significantly impacted by change in county employment density (ΔE). A one percent increase in employment growth encourages population growth by 1.45 percent. The negative and significant relationship between per capita income change (ΔY) and change in population indicates that population density is increasing in counties with declining per capita income. A one percent decrease in the change in per capita income is expected to increase growth in population density by 1.19 percent. This result may be picking up an increase in population at suburban and rural locations where income is not growing very quickly. The initial level of population (P_{t-1}) is inversely related to population density change. Counties with high initial population density lost population, while those with low population density gained. A one percent higher population density in the initial time period would lead to a 1.66 percent

[1] The total effects of the explanatory variables, which would reflect the global connectivity among all counties in the analysis, are not reported here; only direct effects are presented.

Table 5. Descriptive Statistics for Endogenous and Initial Condition Variables

Variable	Mean	Std. Dev.	Minimum	Maximum
ENDOGENOUS VARIABLES				
ΔP	15.76	51.94	-134.59	326.32
ΔE	23.03	42.13	-27.24	265.28
ΔY	4699.18	1465.90	2027.00	10014.00
ΔV	1473.03	1738.43	-492.00	16360.00
ΔL	-2.35	26.65	-65.31	115.14
SPATIALLY WEIGHTED ENDOGENOUS VARIABLES				
$W\Delta P$	15.78	37.95	-37.51	197.53
$W\Delta E$	22.55	27.62	-4.48	133.97
$W\Delta Y$	4710.00	978.04	3139.00	7965.00
$W\Delta V$	1486.00	1187.00	25.20	6472.00
$W\Delta L$	-2.22	19.28	-48.61	56.16
INITIAL CONDITION VARIABLES				
P_{t-1}	221.64	374.55	9.85	2987.08
E_{t-1}	110.29	205.53	4.69	1349.09
Y_{t-1}	13296.54	3378.80	7311.00	27203.00
V_{t-1}	1372.89	964.32	385.00	6492.00
L_{t-1}	179.32	101.42	0.69	478.84

Table 6. Descriptive Statistics for Exogenous Variables

Variable	Mean	Std. Dev.	Minimum	Maximum
$PerCapTax_{t-1}$	415.26	176.50	90.00	1245.00
$PropTaxPct_{t-1}$	77.64	13.01	50.10	99.10
$GovtExpPC_{t-1}$	1.09	0.32	0.42	3.26
$ConstEmp_{t-1}$	3440.00	6726.00	48.00	40272.00
$FarmEmp_{t-1}$	972.00	1075.00	0.00	8337.00
$ManufEmp_{t-1}$	8558.00	15079.00	46.00	92806.00
$MineEmp_{t-1}$	601.00	944.00	9.00	5479.00
$ServEmp_{t-1}$	14815.00	33010.00	197.00	267673.00
$AgIncPFarm_{t-1}$	38427.15	37828.47	1695.00	199243.00
$GovtPmt_{t-1}$	5090.07	4557.95	0.00	24741.00
$\%FrmLnd_{t-1}$	26.16	15.05	0.00	73.40
$EasmtPayPAcr_{t-1}$	198.64	765.17	0.00	6103.00
$\%PrsvFmlnd_{t-1}$	1.00	5.00	0.00	35.00
$MedHsVal_{t-1}$	62590.97	31713.23	15800.00	200800.00
$\%BDPlus_{t-1}$	13.28	7.04	4.60	49.90
$\%BelowPov_{t-1}$	14.85	7.49	3.10	39.20
$StatHwyDen_{t-1}$	0.36	0.15	0.04	0.80

Table 7. Econometric Estimation Results for Endogenous and Initial Condition Variables

	ΔP Equation		ΔE Equation		ΔY Equation		ΔV Equation		ΔL Equation	
Variable	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
ENDOGENOUS VARIABLES										
ΔP	-	-	**0.310**	0.000	**7.614**	0.053	**9.257**	0.031	0.103	0.121
ΔE	**1.038**	0.000	-	-	-2.614	0.688	-7.814	0.248	-0.112	0.333
ΔY	**-0.004**	0.053	**0.003**	0.043	-	-	0.001	0.988	**-0.002**	0.097
ΔV	0.003	0.192	0.001	0.436	-0.028	0.796	-	-	**0.004**	0.025
ΔL	-	-	-	-	-	-	3.966	0.383	-	-
INITIAL CONDITION VARIABLES										
P_{t-1}	**-0.118**	0.000	-	-	-	-	-	-	-	-
E_{t-1}	-	-	**0.127**	0.000	-	-	-	-	-	-
Y_{t-1}	-	-	-	-	**-0.221**	0.027	-	-	-	-
V_{t-1}	-	-	-	-	-	-	**0.947**	0.000	-	-
L_{t-1}	-	-	-	-	-	-	-	-	**-0.269**	0.016

Note: Bold indicates a statistically significant parameter estimate at the 0.10 level or better.

Table 8. Econometric Estimation Results for Spatial Endogenous and Exogenous County Characteristic Variables

	ΔP Equation		ΔE Equation		ΔY Equation		ΔV Equation		ΔL Equation	
Variable	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
SPATIALLY WEIGHTED ENDOGENOUS VARIABLES										
$W\Delta P$	**0.398**	0.004	-0.121	0.121	**-21.438**	0.002	-7.279	0.171	0.100	0.181
$W\Delta E$	**0.639**	0.002	**0.483**	0.000	16.451	0.129	**20.696**	0.016	-0.078	0.586
$W\Delta Y$	-0.003	0.338	-0.001	0.495	**0.992**	0.000	-0.026	0.847	0.002	0.262
$W\Delta V$	**-0.011**	0.002	**-0.006**	0.013	-0.092	0.588	**0.622**	0.000	**-0.005**	0.035
$W\Delta L$	-	-	-	-	-	-	-1.729	0.795	**0.481**	0.000
COUNTY CHARACTERISTICS										
$PerCapTax_{t-1}$	0.003	0.894	-0.010	0.388	-0.072	0.949	-	-	-	-
$PropTaxPct_{t-1}$	**0.479**	0.003	**-0.217**	0.047	16.457	0.116	-	-	-	-
$GovtExpPC_{t-1}$	2.438	0.759	1.718	0.697	-250.02	0.527	-	-	-	-
$MedHsVal_{t-1}$	**5×10^{-4}**	0.001	-	-	-	-	-	-	-	-
$\%BDPlus_{t-1}$	-	-	**1.091**	0.001	**119.344**	0.000	-	-	-	-
$\%BelowPov_{t-1}$	-	-	0.231	0.290	**-76.869**	0.001	-	-	-	-

Note: Bold indicates a statistically significant parameter estimate at the 0.10 level or better.

decline in the change in population density in the current period. This result suggests decentralization of population over time as people move from urban areas to rural and suburban locations.

Spillover effects from neighboring counties are found for population ($W\Delta P$), employment ($W\Delta E$), and farmland values ($W\Delta V$). Population and employment growth in neighboring counties encourage population growth in the county of interest, with elasticities of 0.40 and 0.91, respectively. Contrary to expectations that higher land values would drive residents to neighboring counties,

Table 9. Econometric Estimation Results for Exogenous Employment, Agricultural, and Accessibility Variables

	ΔP Equation		ΔE Equation		ΔY Equation		ΔV Equation		ΔL Equation	
Variable	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
$ConstEmp_{t-1}$	-	-	**-0.003**	0.000	-	-	-	-	-	-
$FarmEmp_{t-1}$	-	-	-0.001	0.433	-	-	-	-	2×10^{-4}	0.786
$ManufEmp_{t-1}$	-	-	**5×10^{-4}**	0.001	-	-	-	-	-	-
$MineEmp_{t-1}$	-	-	9×10^{-4}	0.430	-	-	-	-	-	-
$ServEmp_{t-1}$	-	-	**3×10^{-4}**	0.027	-	-	-	-	-	-
$AgIncPFarm_{t-1}$	-	-	-	-	-	-	-0.005	0.120	**1×10^{-4}**	0.000
$GovtPmt_{t-1}$	-	-	-	-	-	-	**0.059**	0.049	-2×10^{-4}	0.552
$\%FrmLnd_{t-1}$	-	-	-	-	-	-	8.141	0.154	**1.706**	0.002
$EasPayPAcr_{t-1}$	-	-	-	-	-	-	0.142	0.247	0.002	0.221
$\%PrsvFmlnd_{t-1}$	-	-	-	-	-	-	**-8067.485**	0.004	**-111.623**	0.030
$StatHwyDen_{t-1}$	24.721	0.108	-21.501	0.181	271.518	0.733	-736.174	0.319	-1.414	0.797
Constant	**-45.978**	0.030	8.468	0.618	1585.009	0.356	463.720	0.567	**9.8931**	0.056

Note: Bold indicates a statistically significant parameter estimate at the 0.10 level or better.

Table 10. Econometric Results for Spatial Error Coefficient and Goodness of Fit

	ΔP Equation	ΔE Equation	ΔY Equation	ΔV Equation	ΔL Equation
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Spatial error (λ)	-0.1305	-0.4092	-0.0360	-0.1175	-0.6554
Adjusted R^2	0.85	0.86	0.49	0.59	0.78

increasing land values in neighboring counties result in a decline in own-county population growth. A one percent increase in the change in farmland values in a neighboring county leads to a 1.04 percent decrease in own-county change in population density. One explanation 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.

Only one fiscal factor has an impact on population growth. An increase in property taxes as a percentage of total taxes ($PropTaxPct_{t-1}$) increases population growth. Population growth would increase by 2.36 percent if the percentage of total taxes from property taxes increased by one percent. High property taxes might indicate better schools, amenities (such as parks), and services, thus attracting people. Counties with high median housing values ($MedHsVal_{t-1}$) are associated with population growth, indicating that higher quality housing attracts residents (elasticity = 0.20).

Employment Density Change Equation

Employment density change (ΔE) is positively related to population density change (ΔP) and change in per capita income (ΔY), with elasticities of 0.21 and 0.61, respectively. Employment growth following population growth is supported in previous studies. A growing population provides the markets and labor pool that might attract new businesses and hence employment. Similarly, higher incomes mean more demand for goods and services, leading to job creation. Initial employment density (E_{t-1}) is positively related to changes in employment density. A one percent increase in the initial level of employment density would increase the change in employment density by 0.61 percent. Businesses may be more likely to move to counties with higher initial employment in order to take advantage of labor pool agglomeration effects and to locate in areas experiencing economic growth.

The effects of employment growth in one county apparently spill over to its neighbor, as shown by the positive and significant coefficient on spatially weighted change in employment density ($W\Delta E$). A one percent increase in employment growth in neighboring counties increases own-county employment growth by 0.47 percent. Low agricultural land values in neighboring counties ($W\Delta V$) encourage growth in own-county employment density, possibly reflecting less than desirable land characteristics for farming or for development in the next county, leading to own-county job creation from development of industrial and office parks or shopping centers (elasticity = -0.39). No impacts were significant for neighboring population or per capita income changes.

Property taxes appear to have the opposite impact on employment growth as compared to population growth: an increase in the percentage of taxes from property taxes leads to a decrease in employment density. Increasing the percentage of taxes from property taxes by one percent would decrease growth in employment density by 0.73 percent. The impact of these taxes on the cost of doing business apparently discourages businesses from locating or expanding in these areas.

Human capital development helps explain differences in county employment creation. As the proportion of a county's population with a bachelor's degree or higher ($\%BDPlus_{t-1}$) increases, county job growth goes up; counties with a higher proportion of human capital formation gained employment density (elasticity = 0.63). Employment classification variables are introduced to determine the marginal contribution of different sectors to overall county employment growth. Counties with a high proportion of jobs in construction ($ConstEmp_{t-1}$) experienced overall declines in employment density, whereas counties with a high proportion of jobs in manufacturing ($ManufEmp_{t-1}$) and the service sector ($ServEmp_{t-1}$) saw a gain in employment density (although the impacts were quite small). A one percent increase in jobs in construction would decrease the change in employment density by 0.48 percent, whereas a one percent increase in jobs in manufacturing or the service sector increases growth in employment density by 0.02 percent in both cases.

Per Capita Income Change Equation

Changes in population (ΔP) have a positive impact on changes in per capita income (ΔY), indicating that counties with increasing population density were also experiencing growth in income, although the impact is inelastic (0.03). This could reflect the impact of high-income households moving into rural and suburban areas with desirable natural or environmental amenities. Initial per capita income (Y_{t-1}) is negatively related to county per capita income changes; thus, counties with lower initial income levels saw greater growth in per capita income. If initial per capita income was higher by one percent, change in per capita income would be lower by 0.63 percent.

Population growth in a neighboring county ($W\Delta P$) leads to declining income growth in the county of interest, as seen by the negative coefficient and elasticity of 0.07. This could be the result of high income individuals moving to neighboring counties. Income growth increases in counties that share a border with counties experiencing growth in per capita income ($W\Delta Y$). This reflects the spillover effects of income growth due to regional rather than county-specific economic growth. A one percent increase in income growth in one county spills over for approximately a one percent own-county increase in income growth. Employment growth and agricultural land values in neighboring counties do not have a significant effect on own-county income growth.

The percentage of a county's population with a bachelor's degree or higher ($\%BDPlus_{t-1}$) is positively related to per capita income growth. As expected, more education results in higher incomes (elasticity = 0.34). The percentage of a county's population with income below the poverty line ($\%BelowPov_{t-1}$) has the expected negative impact on income growth, with an elasticity of -0.24.

Per Acre Agricultural Land Value Change Equation

As expected, change in farmland value per acre (ΔV) is significantly and positively explained by county population change (ΔP). A one percent increase in the change in county population density increases the change in per acre agricultural land values by 0.02 percent. Initial county farmland values (V_{t-1}) are positively related to current changes in agricultural land values, indicating that there is an increase in farmland values over time. If agricultural land values in the initial period were one percent greater, the change in current farmland values would be higher by 0.88 percent.

Changes in employment density ($W\Delta E$) and farmland values ($W\Delta V$) in neighboring counties have a positive impact on own-county agricultural land values. Job creation in a neighboring county may decrease the supply of farmland in that county, increasing the value of farmland nearby, although this price increase is inelastic (elasticity = 0.32). Spillover effects in land values indicate the regional nature of land markets that are not confined to within-county borders. However, the increase does not spill over on a one-to-one basis; if the change in agricultural land values in a neighboring county increases by one percent, the change in own-county land values will rise by only 0.63 percent.

Agricultural sector characteristics, such as agricultural income per farm ($AgIncPFarm_{t-1}$), government payments per farm ($GovtPmt_{t-1}$), and the proportion of county land in farms ($\%FrmLnd_{t-1}$), are expected to explain differences in agricultural land values; however, only government payments per farm is significant. Increases in government payments to the farm will increase the per acre value of agricultural land; a one percent increase in government payments is expected to increase farmland values by 0.2 percent.

Two county-level farmland preservation policies are included to determine their impact on agricultural land values—average conservation easement payments per acre ($EasPayPAcr_{t-1}$) and preserved farmland as a proportion of total county farmland ($\%PrsvFmlnd_{t-1}$). Average easement payment per acre is not significant. Counties with active farmland preservation programs reflected in a higher percentage of preserved farmland have significantly lower agricultural land values per acre; that is, farmland preservation activities lower the price of farmland. If preserved farmland as a proportion of total county farmland were to increase by one percent, the change in value of agricultural land in the county would fall by 5.48 percent. This could occur if the best agricultural land is preserved first, such that the remaining farmland is of low value. This is possible, as one criterion used to rate a farm for priority enrollment in a farmland protection program is often the value of the land for agriculture.

Agricultural Land Density Change Equation

It was expected *a priori* that regional growth will negatively affect the stock of agricultural land. This is true for changes in employment (ΔE) and income (ΔY), which have negative coefficients, although employment is not significant. The elasticity for change in income implies that a one percent increase in per capita income growth would lead to a decline of about 4 percent in agricultural land density change in the county. The per acre farmland value parameter is positive and significant, indicating that higher farmland values result in greater stocks of agricultural land. If the change in per acre agricultural land values increases by one percent, the change in farmland density in the county would increase by 2.5 percent. One might expect that higher value farmland is better able to remain in agriculture. The initial level of agricultural land density (L_{t-1}) is negative and significant, indicating that those counties with more farmland in the earlier period experienced greater loss of farmland over time. Counties with a one percent higher level of agricultural land density in the initial time period would see a 20.5 percent decrease in the change in farmland density by the current time period.

Regional growth in neighboring counties as reflected in changes in population, employment, and income does not have a significant impact on the stock of own-county farmland. Neighboring land values ($W\Delta V$), however, have a significant negative impact on stocks of agricultural land in the county of interest. High farmland values in a neighboring county likely sends developers next door to purchase agricultural land for development, thus decreasing the stock of farmland there, although the impact is small. A county would see a decrease in its change in farmland density of 0.03 percent if the change in value of agricultural land in a neighboring county increased by one percent. Loss of farmland in a neighboring county leads to in-county losses as regional development of farmland sprawls across borders. If the change in agricultural land density in a neighboring county ($W\Delta L$) fell by one percent, a county would see a drop of 0.45 percent in its own farmland density change.

The importance of agriculture to a county's economy may determine development trends. Farm employment as a proportion of total county employment ($FarmEmp_{t-1}$) and the percentage of county land used for farming ($\%FrmLnd_{t-1}$) are used to measure this importance. Although farm employment was not significant, in counties where a greater proportion of land is devoted to farming agricultural land density increases. If the proportion of county land used for farming increases by one percent, the increase in agricultural land density change would be approximately 19 percent. This reinforces the idea that a critical mass of agriculture may be effective in reducing agricultural land development. A concentration of agricultural activity may provide agglomeration benefits to farmers that could potentially reduce incentives to develop farmland. Local agricultural performance factors could also influence the nature of agricultural land density changes. As expected, agricultural income per farm ($AgIncPFarm_{t-1}$) is positively related to agricultural land density change. Farmland density can more easily be maintained when farm income is high. A one percent increase in farm income would lead to an increase in the change in agricultural land density of 0.16 percent. Government payments per farm ($GovtPmt_{t-1}$) were not significant in explaining agricultural land density changes.

Farmland preservation programs attempt to reduce farmland losses; however, this study found a negative impact on agricultural land density from higher levels of preserved farmland as a proportion of county farmland ($\%PrsvFmlnd_{t-1}$). This most likely reflects attempts to preserve farmland in areas with strong development pressure. Even if the proportion of county farmland preserved were to increase by one percent, the county would see a decrease in agricultural land density change of 47.5 percent. Even though a high percentage of farmland is protected, overall agricultural land density in the county is declining. Average easement payment ($EasPayPAcr_{t-1}$) is not significant in explaining agricultural land density change.

Summary and Conclusions

This study examines the relationship between regional growth, land use policy, and agricultural land development using a spatial system of equations model and county-level data for Maryland, Pennsylvania, and West Virginia. Regional growth (in income), importance of agriculture to the local economy (in terms of land devoted to farming), farm income, initial stock of farmland, and farmland prices, along with farmland preservation efforts (percentage of farmland preserved), are factors that impact agricultural land density change. Both land prices and stock of farmland in neighboring counties also have an effect.

The importance of agriculture to the local economy, as measured by percentage of county land used for agriculture, positively impacts the level of agricultural land density. Where agriculture is more important to the local economy, there is an expected gain in farmland density. This reinforces the idea that a critical mass in agriculture could potentially reduce farmland losses. Counties with high agricultural income per farm are associated with gains in agricultural land density; however, counties with a higher initial stock of farmland experienced losses.

Local land use policies could potentially impact agricultural land development; however, easement payment levels and proportion of farmland preserved were not associated with maintaining agricultural land density. These policies were most likely introduced in response to existing development pressure, which has continued to result in loss of farmland. Similar to findings in other studies, there is no evidence in this study that farmland protection policies are effective for decreasing farmland development. However, an examination of these policies using time-series data could determine whether they have slowed the loss of farmland in any particular county over time.

Spillover effects from neighboring counties show that changes in agricultural land prices and stocks are influenced by what is happening in the overall region and not just within a particular county. Higher land prices in bordering counties drive up prices and decrease the amount of farmland next door. Development also tends to spill over, as farmland losses in one county cause losses in neighboring counties, or as maintaining a critical mass of agricultural land in one county encourages retention of farmland in a neighboring county as well. This should encourage farmland protection policy proponents to work across borders when considering programs to direct development to particular areas or to preserve contiguous farmland acres.

This study establishes agricultural land development within a regional growth framework. Such a regional outlook helps connect agricultural land development to regional economic trends and provides insight for regional land use planning and agricultural land preservation. The fact that regional growth factors significantly affect agricultural land density means that factors that determine regional growth also indirectly determine agricultural land density change and need to be considered by planners, developers, and policymakers. Explicitly incorporating impacts on agriculture when considering regional land use initiatives should be part of the planning process, including having farmers as members of planning and zoning boards. This research framework also provides detailed linkages that can enhance the quality and effectiveness of agricultural land protection programs.

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