The Joint Influence of Agricultural and Nonfarm Factors on Real Estate Values: An Application to the Mid-Atlantic Region

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County level farmland and residential housing values are estimated for the Mid-Atlantic region as a function of farm returns, developed land values, household incomes, population densities, and location. Results are based on the hypothesis that farmland owners anticipate land development and that nonfarm factors are important determinants of farmland prices. Response of farmland prices to change in farm returns is found to be inelastic and relatively uniform in rural and urban counties. Response to nonfarm factors is found to be more elastic and substantially greater in rural counties.

Key words: farmland values, land prices, Mid-Atlantic region, rural development, spatial econometric model.

Most studies of agricultural land values in the last thirty years have explained prices in terms of the discounted expected future returns from farming the land, with elaboration concerning expected interest rates, inflation, and speculative bubbles. For a brief review and assessment of such studies, see Just and Miranowski or Falk and Lee. The main observation that sparked these studies was the boom in land prices of the 1970s followed by the subsequent bust in the 1980s: macroeconomic factors were brought in to explain prices that could not be readily explained in terms of observed or reasonably expected returns to farming. An alternate approach to assessing agricultural land values that has received increasing attention in recent years focuses on potential nonfarm uses of agricultural land, particularly the value of a real estate parcel when converted to suburban residential or other nonfarm use. Shi, Phipps, and Colyer survey a number of studies that incorporate both agricultural returns and conversion to nonagricultural uses, and provide an application to West Virginia. The main observation that underlies this body of work is that land prices often exceed the reasonably expected future returns from farming, even in the absence of a speculative agricultural land boom.

The purpose of this paper is to explain farm real estate values in terms of both agricultural returns and potential nonfarm value. We extend the existing models in three ways. First, we introduce the geographical/locational element of real estate value more explicitly following models of urban growth pioneered by Alonso, Mills, and Muth. Second, since these models indicate that the market valuation of farmland and residential housing is jointly determined, we develop a simultaneous equation model of farm and house prices. Third, we use recent developments in spatial econometrics to test and correct for possible spatial autocorrelation between land values in neighboring counties. Our empirical model provides estimates of the effects of both farming and residential-use factors in determining the value of farm real estate, and provides information on which of these factors are most important in explaining farmland prices.

The Model

Urban economists (e.g., Anderson, Brueckner, Capozza and Helsley) model the value of farmland as the discounted present value of future rents from a combined stream of agriculture and nonfarm uses. Land is used in

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agriculture until a conversion date, t^*, after which the land is used for a nonfarm use. If the nonfarm use is residential, the value of agricultural land at location z at time t_0 is

$$(1)\quad P(t_0, z) = \int_{t_0}^{t^*} (A_t - G_t^a) e^{-r(t-t_0)}\, dt + \int_{t^*}^{\infty} (R_t - G_t^u) e^{-r(t-t_0)}\, dt - C_{t^*} e^{-r(t^*-t_0)},$$

where A_t is the rental value of parcel z when used in agriculture, R_t is the rental value of the parcel in residential use, C is the cost of converting land from agricultural to residential use, t is time, t_0 the time at which the valuation is made (the present), t^* is the time of conversion, r is the discount rate, and G^a and G^u are property taxes on agricultural and residential land, respectively. The conversion date t^* that maximizes $P(t_0, z)$ is the date when the residential rental value becomes equal to the sum of the agricultural rental value and the interest from the conversion cost:[1]

$$(2)\quad R_{t^*} - G_{t^*}^u = A_{t^*} - G_{t^*}^a + rC_{t^*}.$$

Note that if C is sufficiently high or R sufficiently low, t' will be far enough in the future that for practical purposes the value of land will be determined by its discounted future rental value in agriculture, as in the traditional farmland valuation model.

Equilibrium prices can be derived for farmland and for developed land in residential use by incorporating this type of land value capitalization into the monocentric open city model used to analyze urban growth.[2] The simplest formulation (Capozza and Helsley) yields

$$(3)\quad P^d(t_0, z) = C + \frac{1}{r}\Big(A + D(N, z) + \int_{t_0}^{\infty} R'(t, z) e^{-r(t-t_0)}\, dt\Big) \qquad z \leq z^b$$

as the equilibrium price of residential land and

$$(4)\quad P^a(t_0, z) = \frac{1}{r}\Big(A + \int_{t_0}^{\infty} R'(t, z) e^{-r(t-t_0)}\, dt\Big) \qquad z > z^b$$

as the equilibrium price of undeveloped farmland. In these equations, N represents population, $D(N, z)$ represents the value of accessibility of the urban center to residential households, $R'(= dR/dt)$ represents the marginal change in urban rents due to growth over time in population, and z^b represents the radial distance from the urban center to the rural–urban fringe. Location parameter z is the radial distance from the city center to whatever parcel is under consideration.

This model simplifies land development by placing all new housing construction at the rural–urban fringe, where land is being converted from rural to urban use. The value of accessibility, $D(N, z)$, declines with $(z^b - z)$ and becomes zero when $z = z^b$.[3] Note that equation (3) applies only to sites within the rural–urban boundary and equation (4) only to sites outside of it, but that when taken together, the two equations define a continuous price surface for all locations. This model feature depends on P^d and P^a being simultaneously determined. The marginal rent change R' occurs because population growth increases the distance of the new housing at the rural–urban fringe from the urban center. Faced with higher costs of commuting this greater distance, housing consumers become willing to pay more for a site that is closer to the urban center. Because the value of agricultural land depends on future urban rents (equation (1)), this marginal increase in location rent also increases the market price of agricultural land.

Although quite simplified, the urban growth model retains many key features observed in reality, notably that conversion of land from farming to residential use occurs mostly at a fringe zone that evolves outward from an urban center over time. These models also explain the discrete drop-off of land values that can be observed as one moves

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[1] Brueckner and Capozza and Helsley assume that A and C are constant over time. This assumption is stronger than needed. It is sufficient that changes over time in R, A, G^a, and G^u, together with the cost of back-conversion from housing to farming, never make it profitable to convert land from residential back to agricultural use.

[2] Equilibrium refers here to prices that ensure that all households are housed. These prices are conditional on population, income, transport cost, and, in this model, average lot size. Lot size has been made endogenous in more complex formulations of the monocentric open city model; see, for example, Fajita or Wheaton.

[3] $D(N, z)$ replaces the term $(T/rL)(z^b - z)$ in the Capozza–Helsley paper, where T is a constant per unit transport cost, and L is the average housing lot size. We use the model's equilibrium condition $\varphi z^b(t)^2 = LN(t)$ to substitute z^b out of this expression, so that the unobservable distance is replaced by population.

beyond the fringe area, and the rise in farm prices that occurs in anticipation of development. But agricultural rent A is assumed to be constant across space and over time in the Capozza–Helsley model, while in actuality, farmland parcels at different locations will have different agricultural rental values because of differences in soil productivity and suitability for crops that differ in market value. Agricultural land values also will vary across space when location creates differences in the costs of access to input supply and farm product markets. This key element is omitted from the urban growth models, but will be included in our empirical implementation by including variables that influence farmland prices at a given site, notably economic returns in cropping.

The empirical model also will relax the homogeneity of housing assumption of the Capozza–Helsley model by including variables that indicate the heterogeneity of existing housing. This extension will introduce the possibility that parcels differ in residential value because of soil characteristics (e.g., permeability), landscape features, infrastructure availability, and age of house. The introduction of variable farmland rents and housing heterogeneity puts us in a position to estimate the effects of both farming and residential-use factors in determining the value of farm real estate, and to provide information on which of these factors are most important in explaining farmland prices.

The Capozza–Helsey model implies that farmland and residential land prices are simultaneously determined. Our empirical implementation of this model is a simultaneous equation land price model with two equations:

$$(5) \qquad P^h(t,z) = F_d(P^a(t,z), D(N,z), \mathbf{X}_d)$$

and

$$(6) \qquad P^a(t,z) = F_a(P^h(t,z), \mathbf{X}_a).$$

Costs of development implicitly enter equation (5) because $P^h(t,z)$ is defined as a housing price instead of as a developed land price. Costs of buildings, streets, and other infrastructure associated with developing a parcel of land will be included in this price if the developed land market is in equilibrium and, at the rural–urban fringe, $P^a(t,z) = P^h(t,z) - C$. Following the open city equilibrium price model (Capozza and Helsley, p. 300, equation (18)), $D(N,z)$ is omitted from equation (6). But this accessibility value will enter implicitly through $P^h(t,z)$ because of the simultaneity hypothesis.

$\mathbf{X}_d$ and $\mathbf{X}_a$ are vectors of exogenous variables introduced to allow for our departures from the simplifying assumptions of the urban growth model. In addition to including agricultural rental variables and housing heterogeneity measures, we also include household income to relax the identical income assumption of the urban growth model. We replace its simple distance measure with a version of the gravity measure of accessibility developed by Shi, Phipps, and Colyer, and we introduce variables representing different climates and topographies. These changes convert the representative city model into a regional model with multiple metropolitan areas and also assist in econometric identification of the price equations. Conversion into a regional model is necessary because we use county data, with each county containing both residential and agricultural land.

Shi, Phipps, and Colyer carried out the empirical investigation that comes closest to implementing the ideas embodied in our econometric model. They consider counties in West Virginia, estimating a single equation model for farmland that includes locational as well as economic variables. Besides considering additional features of the real estate market, we generalize their approach in two main ways. First, we estimate the value of farmland as simultaneously determined with residential real estate values. Second, we utilize spatial econometric methods to correct for spatial autocorrelation in unexplained deviations of real estate values in counties that are adjacent to each other. Simultaneous estimation could be important in identifying the spatial economic forces that determine farmland values. The effect of residential real estate value on farmland value in a county is likely to be a locational effect in part, in that high real estate values indicate high values of farmland upon conversion, and real estate values will be higher in favorably located counties. But location also may matter for farm value over and above the conversion prospects, for reasons of marketing costs as spelled out in von Thunen models.

Equation (1) assumes perfect foresight of future rental values, taxes, and conversion costs. This assumption is of course false. Our empirical implementation uses current values of economic variables, which implicitly assumes naïve expectations of agricultural rental values, that is, that current values are used in agents' valuation of farmland. As the analysis in Just and Miranowski indicates, this assumption makes the model quite unpromising for explaining variations in land prices over time. It does not allow for rational dynamic adjustments in expectations or for speculative price bubbles as analyzed, for example, in Feldstein, Featherstone and Baker, or Falk and Lee. Thus we will not attempt to explain changes in land prices over time.[4]

Data and Econometric Analysis

The data used for both agricultural and residential real estate values are for 230 counties in six Mid-Atlantic states: Delaware, Maryland, New Jersey, Pennsylvania, Virginia, and West Virginia. Specific land parcels would provide a larger and more varied database, but we lack data for key variables for such parcels, notably farm return data and the value of land in alternative residential use. We have three cross-sections of observations, for 1982, 1987, and 1992. These are pooled in the econometric analysis, with a dummy variable giving a different intercept for each year (fixed-effects approach). This allows land price to change between these years, without specifying whether differences between years are due to commodity prices, general inflation, interest rates, or other variables that had common changes between years across all our observations.

The data are from the Census of Agriculture, the National Resource Inventory, and the Census of Population and Housing. Census data for counties has often been used in the empirical literature explaining land use and real estate values (see Miller and Plantinga and references therein). Following equations (5) and (6), our econometric model consists of two equations that simultaneously explain residential and farm real estate prices.

The equation for the residential real estate price is

$$
\begin{aligned}
(7)\qquad P_h(i,t) = {} & a_0 + a_1 P_a(i,t) + a_2 Y(i,t) \\
& + a_3 Z(i,t) + a_4 (Y \bullet Z)^{1/2} \\
& + a_5 \mathrm{DS}(i,t) + a_6 A(i,t) \\
& + a_7 \mathrm{SD}(i,t) + \mathbf{a}_8 \mathbf{DD}(\mathbf{i},\mathbf{t}) \\
& + e_h(i,t),
\end{aligned}
$$

where $P_h(i,t)$ is the median value of single family housing in county i in year t (in thousand dollar units), $P_a(i,t)$ is the mean value of farmland and buildings (in thousand dollars per acre), Y is median household income (in thousand dollars), Z is population density (persons per square mile), DS is the index of accessibility of the county to relevant urban centers, A is an index of the average age of houses in the county, and SD is an approximate measure of the standard deviation of house values within the county. Both A and SD are introduced to allow for heterogeneity in housing quality. **DD** is a vector of dummy variables, a_0 to $\mathbf{a}_8$ are parameters to be estimated, and e_h is a random error term that follows a spatial autoregressive process while being correlated with e_a, the error in equation (8).

Since residential land rents are conditional on income and population, household income and population density are included as primary housing demand factors in the econometric model. Income per household is expected to increase the demand for housing and hence real estate values for a given land area. Population in a given area also increases demand and is expressed as population per square mile in order to adjust for differences in the size of counties in our sample. Note that population density indicates more people per acre of residential land, i.e., smaller lots, so that density may increase the value of real estate per acre while nonetheless decreasing the value of the median house.[5]

Indicators of housing quality are included because the characteristics of the existing housing stock are likely to be important and

[4] In their review of evidence and prior studies finding inconsistency between the time series nature of U.S. average rental value of farmland and farm real estate prices, Clark, Fulton, and Scott note that the results suggest that land markets in different regions of the country may be quite different. They state: "A cross-sectional comparison of land markets might be useful in shedding light on which of the factors discussed above are important in generating differences in the time series of land prices and land rents within a particular market." (p. 154). This is a further justification for our analysis.

[5] We tried to account for the variation in lot size by adding a measure of the acreage of urban land per person, but found that it added nothing to the explanation of the variation in the median residential house price across counties. We do not know whether this happens because of offsetting effects, a poor measure of lot size, or correlation between the population density and the lot size proxy variable.

may vary substantially across our sample of counties. We do not have data on measures of square footage or number of rooms on a consistent basis for our sample, but we do have data on the age and value distributions of houses in each county. Housing age is used as an indicator of quality on the assumption that newer houses will have depreciated less. The Censuses of Population and Housing in 1980 and 1990 asked whether the residence was less than one year old, less than three years old, less than ten years old, and other age increments up to forty. We estimated a mean age for each county's housing stock by using midpoints of each age range, and an age of seventy-five for the open-ended class of houses over forty years old. Linear interpolation and extrapolation was used to project the 1980 and 1990 mean ages to 1982, 1987, and 1992.

A similar procedure was used to approximate the standard deviation of housing value in each county. The 1980 and 1990 housing censuses estimated the number of houses worth less than $20,000, the number in $10,000 intervals between $20,000 and $49,999, and the number in $50,000 intervals between $50,000 and $199,999. We used a midpoint of $350,000 for the open-ended interval of $200,000 and over, and computed an approximate standard deviation of this frequency distribution of housing values for each county.

The distance measure, DS, is the sum of two components. We use the formula $\mathrm{DS}_i = N_0/z_0^2 + N_j/z_j^2$ to calculate the population-weighted distance measure, with the subscript 0 indicating population (N_0) and distance (z_0) from the county i to New York City and j indicating the nearest central city to the ith county. The predominance of New York City is observable in our data. Simple correlation coefficients indicate significantly declining real estate values throughout the Mid-Atlantic area for both house and farm as distance from New York City increases. The whole structure of real estate prices is lower in counties further west or south of New York City, irrespective of local price gradients associated with Pittsburgh, Philadelphia, Washington DC, Norfolk, or other city centers.

Equation (7) is linear in variables except for the cross-product term $(Y * Z)^{1/2}$. This term is introduced with the expectation that the positive effect of population density on the price of housing will be larger when income is higher (and that increased density could even reduce the value of housing if income is low). The square root of the cross product (the geometric mean) is used as a simple (generalized Leontief) extension of the linear model.

The vector of dummy variables is a set of instruments for variables that are expected to influence real estate values but for which we do not have quantified measures. Omitting them would risk correlation between included variables and the error term. The vector **DD** includes year dummies to allow a different intercept for 1982, 1987, and 1992 (as discussed earlier), and state dummies to reflect differences between states in infrastructure or policies (tax rates, land-use restrictions) that may affect property values. It also includes dummies for fifteen "major land resource areas" as delineated by the USDA Soil Conservation Service.[6] These areas differ in ways that may affect construction costs or amenities that influence the value of residential real estate.

The second equation of our econometric model explains the mean value of farm real estate in the sample counties. This equation is

$$(8) \quad P_a(i,t) = b_0 + b_1 V(i,t) + b_2 W(i,t) + b_3 K(i,t) + b_4 P_h(i,t) + b_5 Z(i,t) + b_6 \mathrm{DS}(i,t) + \mathbf{b_7 DD(i,t)} + e_a(i,t),$$

where P_a is the estimated value of farm land and buildings in county i and year t, V is the per-acre market value of agricultural products, W is farm production expenses per acre,[7] K is the per-acre value of machinery reported in the Census of Agriculture (a measure of non-land capital), P_h is the median price of residential real estate in the county, and DS and **DD** are the same distance index and dummy variables used in equation (7).

[6] The land resource areas are primarily agriculturally based. Our data includes the following areas, with their NRI identifying numbers: Erie fruit and truck area (100), Cumberland Plateau and Mountains (125), Central Allegheny Plateau (126), Eastern Allegheny Plateau and Mountains (127), Southern Appalachian Ridges and Valleys (128), Blue Ridge (130), Southern Coastal Plain (133A), Southern Piedmont (136), Glaciated Allegheny Plateau and Catskill Mountains (140), New England and Eastern New York Upland (144A), Northern Appalachian Ridges and Valleys (147), Northern Piedmont (148), Northern Coastal Plain (149A), Atlantic Coast Flatlands (153A), Tidewater (153B), and Mid-Atlantic Coastal Plain (153C).

[7] Different sets of expenditure items were reported in the Censuses of 1982, 1987, and 1992. We use expenditures from the list of 1982 items, which are reported in all three Censuses.

V, W, and K are the main economic variables in equation (8). $V - W$ provides an estimate of net cash value of farm output per acre. Our reason for disaggregating is that the two components, in the cross-sectional data we have, may incorporate different kinds of information. For example, the market value of output is likely to have a larger transitory component than does input expenditures, because random variation in output prices is greater than in input prices.[8] Therefore a \$1 increase in V in a particular year will have a smaller effect on farmland price than a \$1 increase in W, because V is a less reliable source of information about persistent economic changes that influence asset prices. The econometric result would be $b_1 < b_2$ in absolute value.

A theoretical justification for a (capitalized) farmland rent model, based on maximizing quasi-rents to a fixed land factor, can be found in Palmquist. In our model K is included along with V and W because the returns to land given by $V - W$ incorporate returns to all fixed factors, not just land. The availability of more capital per acre will increase V by the marginal product of capital, but that effect should already be measured in V. For a given level of V and W, meaning a given level of measured current net cash flow per acre, more capital per acre may be an indicator of larger permanent net returns per acre, and hence increased farmland value per acre.

The theoretical model justifies inclusion of the value of residential housing. A full analysis also should incorporate the value of land in alternative commercial uses, for example, retail businesses or manufacturing facilities. We lack data on county-level real estate values of land for these purposes. Our assumption is that equilibrium in the nonagricultural land market roughly equates the marginal value of land in all urban uses, so that those counties that have a high value of residential housing also have similar values of commercial real estate. But if there are important exogenous variables that influence the value of commercial real estate and that are not captured by our population, income, and locational variables, then their influence will be omitted.

[8] For the 1910–1997 period, the standard deviation of annual changes in the log of USDA's index of prices received by farmers is 0.128, while the analogous standard deviation in the prices paid index is 0.082.

Spatial autocorrelation is an econometric issue that has received attention in recent statistical analysis of geographical cross-sectional data. Measurement errors can arise if spatial effects on land prices do not correspond to counties as units of observation. For example the flue-cured tobacco belt of Virginia extends across a set of contiguous counties. If the tobacco program affects land values in those counties over and above effects of the cost and return variables because of the role of the tobacco quota, and we have no variable to measure this effect, we would expect correlated errors in this set of counties. Of course, if we have data on such a variable, it should be included. But there are many reasons why neighboring counties may be similar, in respects for which no data are available, and there is a real possibility that any model using county data may have correlated errors among geographically adjacent observations. Depending on whether the correlation is positive or negative, the estimated variances of the uncorrected model would be too small or too large.

Anselin spells out different methods to deal with spatial autocorrelation, and the econometric literature shows that a maximum likelihood estimator can achieve the desirable properties of unbiased parameter estimates, consistency, asymptotic efficiency, and asymptotic normality (Andrews). Following Benirschka and Binkley, we assume that the errors for each equation in our simultaneous system follow a first order Markov process: $e_j = \lambda_j \mathbf{W} e_j + u_j, j = a, h$, where, since our model is a panel for three years, the spatial weight matrix $\mathbf{W}$ is defined as

$$(9) \quad \mathbf{W} = \begin{bmatrix} \mathbf{W}_1 & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{W}_2 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{W}_3 \end{bmatrix}$$

The contiguity matrix for each year, $\mathbf{W}_t$, can differ across years in the number of observed counties. These matrices summarize all of the information about spatial dependence in the model. $\mathbf{W}$ is constructed so that the (i, k) element of $\mathbf{W}_t$ is 1 if a county is contiguous and zero if it is not. The lambdas are the spatial autoregressive coefficients that measure the correlation between county i error and composites of the errors of its contiguous counties.

GLS estimates are obtained by transforming the stacked data:

$$(10) \quad [\mathbf{I} - (\lambda \otimes \mathbf{W})]\mathbf{Y} = [\mathbf{I} - (\lambda \otimes \mathbf{W})]\mathbf{X}\mathbf{b} + \mathbf{u},$$

where $\mathbf{u} \sim \mathbf{N}(\mathbf{0}, \sigma^2\mathbf{I})$, $\mathbf{Y}$ contains the price variables $P_a(i,t)$ and $P_h(i,t)$, $\mathbf{X}$ contains the explanatory variables in equations (7) and (8), $\mathbf{b}$ contains the stacked parameters of the two equations, and λ is a 2 by 2 diagonal matrix containing λ_j. Parameter estimates for, $\lambda\mathbf{b}$, and σ^2 are obtained for the system by maximizing the corresponding likelihood function.

Estimation Results

Table 1 gives the coefficients and standard errors of the equation used to predict farmland prices after correction for spatial autocorrelation (equation (8)). The spatial autocorrelation coefficient λ_a is 0.353, significantly different from zero at the 5% level. This indicates that neighboring counties have farmland values that are positively correlated for reasons that are not captured by the set of explanatory variables used in the model. In the unadjusted equation, however, 93% of the variation in farmland price is explained. This is large compared to most results with cross-sectional data, and suggests that omitted variables cannot add a lot to the explanation of county farmland prices in the Mid-Atlantic region. As is the case with autocorrelation in time series analysis, we do not expect correction to change the magnitude of coefficients by correcting for bias, but rather we hope to find improvements in efficiency.

In fact, using either a 1% or 5% two-tailed significance test, only one variable (an area dummy) that was insignificant in the uncorrected model became significant as a result of the spatial autocorrelation correction, and no variable that was significant in the uncorrected model became insignificant after correction. Coefficients were observed to change only slightly. Thus, although we do find spatial clustering of the residuals from the fitted equation (8), correcting for this turns out to have no important consequences for statistical inference about the determinants of farmland prices.[9]

Table 1 shows the economic variables to be significant and to have the expected signs. The unit of measurement for farmland price is thousands of dollars per acre while value of production is measured as dollars per acre. Thus, the coefficient of 0.00295 for V means that a \$1 increase in output value per acre generates a \$2.95 increase in the price of farmland, other things equal. The coefficient for W similarly implies a \$4.82 decline in the price of farmland for every \$1 increase in production expenses. An increase in receipts or reduction in costs of \$1 per acre would be expected to generate a higher multiple of asset value if they were expected to be permanent. But in our county cross-sectional data for single years, the differences between counties may have a substantial transitory component and/or measurement error, which would bias the coefficients of both V and W toward zero.[10] Note that the absolute value of the expense coefficient is larger than the receipt coefficient, as hypothesized earlier. The coefficient of the non-land capital variable, K, also is significant, and means a \$2.95 land price increase for a \$1 increase in machinery value per acre.[11]

A principal motivation for our study is to investigate the effects of non-land opportunities for farmland in determining the market value of land that remains in farming. The variable that most directly measures this effect is P_h, the median price of residential houses in the county. The coefficient of P_h is significantly positive, and has a higher t statistic than any of the farm economic variables. The coefficient of 0.0272 means that a \$1,000 increase in the value of the median house increases the value of farmland by \$27.20 per acre.

The distance variable DS is a variation of the Shi–Phipps–Colyer population-weighted measure, the calculation of which was described earlier. Ideally, the effects of location on capitalized income from agriculture would be captured by our cost and return measures. But transportation and market access costs are not included in the

[9] This is qualitatively similar to the findings of Benirschka and Binkley. The effects might have been stronger in magnitude if we were using individual farm data instead of county level aggregates, as it is possible that contiguous farms would be more strongly spatially correlated.

[10] As noted earlier, we included only expenses in the categories that were common to all three Census years in the variable W. Thus this measure of expenditure data is incomplete. Another measurement problem is that the receipts include livestock sales, which are less directly related to land returns in many farming operations. Both errors-in-variables problems will tend to bias the coefficients toward zero.

[11] One of the reviewers of the paper states that "I think you could go further in your discussion of the impact of more capital per acre. More capital per acre probably increases net returns per acre because it reduces the amount of labor input required per acre. Labor cost per acre is not included in W, yet it is certainly an important determinant of net returns per acre." This is plausible, since only the cost of hired labor is included in W.

Table 1. Parameter Estimates for the Farmland Price Equation—Dependent Variable: Value of Farmland and Buildings ($1,000/Acre)

Variable	Parameter Estimate	t-Statistic	Variable Description
	−1.308	−5.86	Intercept
DD1	0.388	3.60	Dummy for 1982
DD2	−0.0018	−0.01	Dummy for 1992
V	0.00295	4.39	Market value of farm production ($/acre)
W	−0.00482	−3.65	Farm production expenditures, 1982 items ($/acre)
K	0.00294	4.51	Farmer-owned farm machinery ($/acre)
P_h	0.0272	21.57	County median house price (1,000 $)
DS	0.0264	12.27	Distance index (see text)
DD3	−0.090	−0.321	Dummy for Delaware
DD4	0.919	4.16	Dummy for New Jersey
DD5	0.386	2.00	Dummy for Virginia
DD6	0.031	0.17	Dummy for Pennsylvania
DD7	0.394	2.06	Dummy for West Virginia
λ_a	0.353	5.85	Spatial autoregressive coefficient

farm cost data collected in the Census of Agriculture. The estimated coefficient is significantly positive, indicating that greater nearness (which gives larger values of DS since distances appear in the denominators) is associated with higher farmland values. An increase in the index of 10% of its mean value (5.45) is estimated to increase the value of farmland by $14 per acre.

The coefficients of the fifteen land resource area dummies included in the equation are not shown in table 1. Using an F test on exclusion of the whole set of land resource dummies, we cannot reject the hypothesis at the 90% confidence level that all of these coefficients are zero. Coefficients on the state dummies, which are jointly significant, indicate that it is worth $910 an acre to be in the state of New Jersey, $368 an acre to be in Virginia, and $394 to be in West Virginia, as compared to Maryland, Pennsylvania, and Delaware, which are all insignificantly different from one another. The year dummies indicate a significantly higher price of farmland in 1982 than in 1992 or 1987 (the intercept), with prices all measured in 1987 dollars using the Consumer Price Index as deflator. This result is not unexpected as national farmland prices fell more than in proportion to net farm income in the early 1980s.

The estimated coefficients for the equation explaining the median house price (equation (7)) are shown in table 2. The spatial autocorrelation coefficient, λ_h, is 0.146, significantly different from zero, but it is small in magnitude and the parameter values are even less affected by correcting for spatial autocorrelation than was the case for the farmland price equation.

The main economic variables in the house value equation are median household income, population density, and the interaction between them. As discussed earlier, the reason for including the interaction term is to allow population density to have different effects in high-income and low-income areas. Using the notation of equation (7), the partial derivative of P_h with respect to income, Y, is

$$(11) \quad \frac{\partial P_h}{\partial Z} = a_2 + \frac{0.5 a_4 Z^{0.5}}{Y^{0.5}}$$

and the partial derivative of P_h with respect to population density, Z, is

$$(12) \quad \frac{\partial P_h}{\partial Z} = a_3 + \frac{0.5 a_4 Y^{0.5}}{Z^{0.5}}.$$

Using the coefficients of table 2 and mean values of Y and Z, the partial effect of Y on P_h is 0.626, meaning that a $1,000 increase in median household income increases the median value of the county's houses by $626. The partial effect of Z on P_h is 0.0277, meaning that an increase of 100 people per square mile would increase the median house value by $2,770. The cross-product term (coefficient of $(Y * Z)^{1/2}$) being positive while that for Z is negative means that lower county income levels, as expected, decrease the positive effect of population density on housing prices. The partial effect of 0.0277 is calculated at the mean sample income value of

Table 2. Parameter Estimates for the House Price Equation—Dependent Variable: Median House Value ($1,000)

Variable	Parameter Estimate	t-Statistic	Variable Description
	−8.174	−1.73	Intercept
DD1	3.092	2.77	Dummy for 1982
DD2	−6.29	−5.44	Dummy for 1992
Y	2.054	17.04	County median income (1,000 $)
Z	−0.0164	−4.86	Population per square mile
$(YZ)^{1/2}$	0.1508	6.16	Square root of income times population density
A	−0.672	−3.99	Average age of houses
STD	0.542	16.18	Standard deviation of house values
DS	0.0133	0.34	Distance index (see text)
P_a	1.069	0.94	Value of farmland and buildings ($1,000/acre)
DD3	−3.21	−1.01	Dummy for Delaware
DD4	7.14	2.70	Dummy for New Jersey
DD5	−1.82	−0.98	Dummy for Virginia
DD6	−4.17	−2.23	Dummy for Pennsylvania
DD7	3.13	1.60	Dummy for West Virginia
λ_a	0.146	2.46	Spatial autoregressive coefficient

$27,150. At the income level of the county with the lowest median income in our sample, $10,200, the partial effect of density is reduced to 0.0164. Thus, even when quality of housing is held constant, the positive demand effect of increasing population density on house values is attenuated when median income is lower.[12]

Our indicator of housing quality, the average age of houses as reported in the 1990 Census of Population and Housing, has a significantly negative effect on residential real estate values. The coefficient indicates that each additional year of average age of houses reduces the average value by $672. We also included in the house value equation an indicator of the heterogeneity of housing value, the standard deviation of house values as explained earlier. This variable is highly significant in explaining the house values, its positive sign meaning that greater variation in housing values in a county is associated with higher average values. However, neither farmland value nor closeness to urban centers, as indicated by our distance index, has a significant effect on house values given the county's housing quality, income, and population density.

In contrast with the farmland value equation, an F test indicates that exclusion of the group of land resource area dummies has a significant effect on the house value equation. Again, to conserve space, their coefficients are not shown in table 2. House values are significantly lower, holding other variables constant, in areas 126, 133a, 136, 144a, 149a, and 153b (see footnote 6 for locations). The state and year dummy coefficients are shown. New Jersey median house values are $7,140 higher and Pennsylvania $4,170 lower compared to Maryland (the state in the intercept), holding other variables constant. With respect to the year dummies, 1992 is $6,290 lower than the intercept year (1987), and 1982 is $3,090 higher. This indicates a declining trend in real (1987 dollars) housing prices since 1982, reflecting the general decline in housing prices that occurred in the Eastern U.S. during this period.

How Urbanization Affects Farmland Prices

Table 3 presents some results from an analysis of how farmland prices respond to changes in land value determinants in counties with different population densities.[13] Values in this table are computed by sorting the

[12] It could be argued that population density is properly an endogenous variable, because low housing values attract more people. If true, the mis-specification in our model would mean our estimated positive effect of density is biased toward zero (because it is contaminated by the negative causality running from housing value to density). Therefore our estimated positive effect should be viewed as a lower bound on the true effect.

[13] The results in table 3 are for 1992. We also computed these values for 1987 and 1982. Results are similar for the three years and our interpretations apply to all three time periods. Numerical results are presented only for 1992 to simplify explanation and to save space.

Table 3. Relationships between Farmland Value and Selected Land Value Determinants, by County Population Density Quintile Grouping, 1992

Item	Population Density Quintile Grouping				
	1st	2nd	3rd	4th	5th
Population per square mile	25.7	52.3	85.2	199.3	1537.4
Farmland value ($/acre)	1,173	1,473	1,952	2,719	7,892
Farm revenues ($/acre)	182.79	217.83	399.86	373.06	1,234.19
Mean revenue elasticity	0.460	0.437	0.605	0.405	0.462
Median house value ($)	59,461	68,273	83,156	101,351	149,668
Median house value elasticity	1.381	1.262	1.161	1.016	0.517
Median household income ($)	28,211	30,449	34,286	40,277	49,827
Mean income elasticity	1.396	1.217	1.405	0.902	0.432
Mean population elasticity	0.042	0.045	0.043	0.043	−0.004

county observations by population density, finding quintile values, and then calculating mean values for farmland prices, farm revenues, house prices, household incomes, and population densities for the counties within each quintile grouping. Partial elasticities then are computed using estimated coefficients from tables 1 and 2 and the means for each quintile grouping. These elasticities show the percentage response in estimated farmland prices to small percentage changes in farm revenues per acre, county median house prices, median household incomes, and population,[14] other land value determinants held constant. They can be compared across quintile groups to see the potential effect of urbanization on the response of farmland prices to changes in other economic factors.

The comparison indicates that policies or events that affect revenues, house prices, incomes, and population size can affect farmland prices differently in rural and urban counties. For some policies, these effects will vary substantially, and a uniformly applied policy will create quite different farmland price responses. For others, population density will not matter and responses will be relatively uniform across counties.

Gardner and Heimlich and Barnard have noted that the character of farming changes as areas become more urban and farming practices alter to reflect more expensive land and greater access to markets. While commercial farmers seek to increase net revenues per acre, farms also are increasingly purchased for purposes other than income generation. Table 3 shows that average revenue per acre increases substantially with population density across the quintile groupings. Despite this increase in absolute value, farmland prices respond similarly to changes in farm revenue in rural and urban counties. As a rule of thumb, the table indicates that each permanent 1% change in farm revenue translates into an approximate change in farmland price of 0.4 to 0.6%. Although not shown in the table, a similar pattern can be observed for farm expenditures. Each permanent 1% change in farm expenditure translates into an inverse 0.2–0.5% change in farmland values, with the largest response of −0.5 occurring in the counties in the third quintile grouping and the smallest response of −0.2 occurring in the urban counties in the fifth quintile grouping.

More distinct differences between rural and urban counties are observed in farmland prices when median house values and non-farm household incomes are considered. Farm prices tend to increase systematically relative to house values as counties become more populous, and the elasticity of response of farmland price to house price diminishes as a result. The elastic response of farmland prices to changes in house values observed in rural counties becomes an inelastic response when urban counties are considered. From a policy perspective, a change in inflation, taxes, or other factors that uniformly change house values will alter the structure of farmland prices across counties.

Why farmland prices rise more rapidly than house prices as counties become more urban

[14] Since total county land area drops out of the elasticity computation, these partial elasticity estimates may be interpreted as the response to a change in either total county population or in the number of people per square mile within the county.

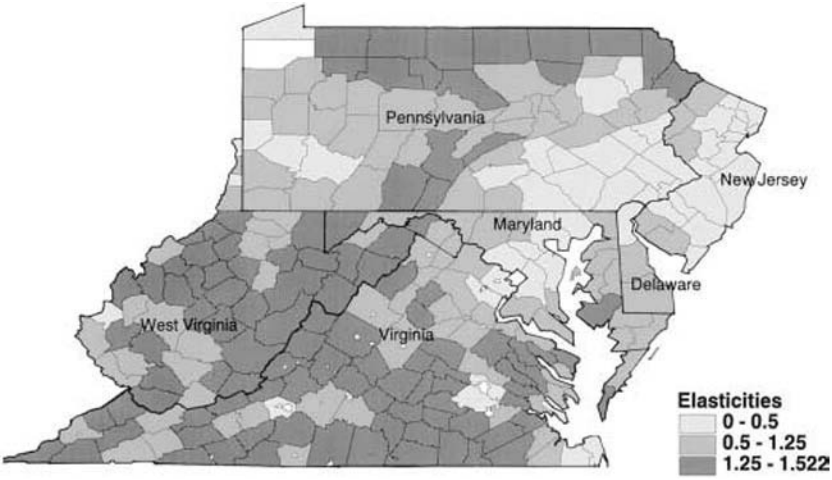

Figure 1. Elasticity of farmland prices with respect to median household income, 1992

remains an open question. One reviewer of this paper points to changes in the ratio of value of the structure to the lot: bigger houses on smaller lots and more houses per acre increase the value of an acre of developable land in urban areas relative to rural areas. But other factors also may come into play. "Gentlemen farmers"seeking country estates may, for example, demand more farmland in urban counties where access to urban centers is high. It is interesting to note that capitalization of farm revenues into land values does not seem to change with urbanization, since there is no systematic pattern in the ratio of farmland values to farm revenues across the quintile groupings.

Elasticities for household income show a similar pattern to those for house prices, in part because the effect of income on farmland price occurs through change in house prices in the model. This response consequently involves both price equations. The numbers in the table indicate that a uniform change in household income, such as might occur from changing a standard income tax exemption, will act through house values to alter the structure of farmland prices across counties. Prices in rural counties will increase significantly more than prices in urban counties if income increases. But if income decreases, prices in rural counties will decrease significantly more than prices in urban counties.[15]

Figure 1 shows how these different responses are distributed throughout the Mid-Atlantic region. Counties represented by the lightest shade in the figure have inelastic price responses. Rural counties represented by the darkest shade have elasticities that are greater than 1.25. As the figure shows, inelastic responses are mostly restricted to areas around major urban centers.

Computation of the elasticity of farmland price to change in county populations also involves both equations of the model, as population is postulated to be a fundamental determinant of both farmland and housing prices. Interestingly, the response of farmland prices to change in population density turns out to be very stable across all but the fifth quintile grouping of counties. Farmland prices increase about 0.04 to 0.05% for every 1% increase in population. In the fifth quintile grouping, the elasticity turns negative due to a negative relationship between median house value and population density. Although signs change when counties become urban in nature, all of the elasticities of farmland price with respect to population are close to zero. Thus farmland prices are found to respond to changes in income, house prices, farm revenues, and expenditures, but to be very inelastic with respect to population change when these other effects are held constant. Most of the effect of population change on farmland prices appears to operate through the markets for products obtained from land, rather than directly on farm real estate values.

[15] This result is possibly related to the distance-to-market explanation of farmland price volatility investigated by Benirschka and Binkley.

Conclusions

As noted at the outset, the analysis in this paper was carried out primarily to learn more about how non-farm factors might affect farmland prices. The model requires that farm owners be aware of land development opportunities. It depends on the hypothesis that the effect of these opportunities can be captured in an equilibrium farmland price model by including residential real estate house prices and factors such as population density as explanatory variables. Urban growth theory indicates, in turn, that developed land values depend on farmland values. Thus we estimate a model that simultaneously determines housing and farmland prices.

Results indicate that farm earnings and non-farm factors both play significant roles in determining farmland prices. When non-farm factors are controlled, An increase of \$1.00 per acre in farm revenues is estimated to change the value of farmland by \$2.95. A change of \$1.00 per acre in farm expenditures is estimated to change farmland value in the opposite direction by \$4.82. The larger magnitude of the expenditure effect is explained as a consequence of permanent and temporary value change; change in farm expenditures, as observed in any given year, has a smaller transitory component than change in farm revenues.

Farmland values are found to be more responsive to non-farm factors than to farm returns. Mean elasticities computed for county quintile groupings indicate that a 1% change in house prices always evokes a larger response in farmland prices than a 1% change in agricultural revenues. The difference is especially great in very rural counties, where the elasticities of farm price with respect to farm revenues are estimated to be less than 0.5 and the elasticity of farm price with respect to house prices is estimated to be greater than 1.2. A similar finding occurs for household income: farm prices respond more to change in household income than to change in farm revenues in all but the most urban counties, and the change is roughly equivalent in those counties.

These results have implications for the effects of policy interventions or other exogenous changes that may occur. From a wealth perspective, they indicate that farmers in the Mid-Atlantic region will be affected more by events that change non-farm income and house prices than by policies that specifically change farm returns. Furthermore, these effects, whether for better or worse, will be greater in rural counties where population density is lower and development is less. As an example, an income tax policy change that affects all residents of a rural county would have a greater effect on farmland prices than a policy that directly changes farm product prices or costs. Incidence of these effects also will be different, with small differences between rural and urban counties in the case of farm income policies and substantial differences in the case of nonfarm income changes.

These conclusions are specific to the Mid-Atlantic region and we do not know if they extend to the rest of the nation. They do suggest, however, that policies developed for broader purposes may have as much or more effect on farmland prices as policies targeted directly at improving agricultural returns. Also, our findings suggest that events that change the potential gains from developing farmland may play a greater role in explaining the volatility of farmland prices than has been recognized in previous studies.

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