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**International Agricultural Trade and Policy Center**

**URBAN SPRAWL AND FARMLAND PRICES**

**By**

**Grigorios Livanis, Charles B. Moss, Vincent E. Breneman, & Richard F. Nehring**

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# Urban Sprawl and Farmland Prices

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*Abstract*

## **Urban Sprawl and Farmland Prices**

A theoretical model of farmland valuation is developed that allows urban sprawl to affect farmland values through the conversion of farmland to urban uses, shifts in production to higher-valued crops, and the speculative effect of urban pressure on farmland values. This model is estimated using county level data in the continental United States. Evidence is found for all three effects of urban sprawl on farmland values, with a significant contribution of urban pressure on net agricultural returns around major urban centers. Ancillary evidence supports that the latter effect is attributable to shifts to high-valued crops.

**Keywords:** hedonic determinants, land prices, spatial productivity, urban sprawl.

**JEL Classification:** R14, Q15, D24, C33.

## **Urban Sprawl and Farmland Prices**

Urban sprawl and land use has become a major policy issue since the 1980s. The expansion of urban areas has led to a reduction in the amount of farmland around many major metropolitan areas along with a reduction in prime farmland, and rangeland (Imhoff et al.; Greene and Stager). This increased farmland demand for urban uses has led to higher farmland values over time, particularly in areas of rapid urban growth (Shi, Phipps and Colyer). This paper investigates whether urban sprawl has also affected the productivity of farmland close to urban centers by increasing the share of high-valued crops resulting in higher farmland prices.

The effect of urban sprawl (e.g., population, income) on farmland prices have been investigated by several studies (i.e., Chicoine; Shonkwiler and Reynolds; Mendelsohn, Nordhaus and Shaw; Shi, Phipps and Colyer). Recently, several studies have used the urban growth model of Capozza and Helsley (1989) to examine the effect of urbanization on farmland values at the parcel (Cavailhes and Wavresky) and county level (Plantinga and Miller; Hardie, Narayan, and Gardner; Plantinga, Lubowski, and Stavins). Hardie, Narayan, and Gardner applied the model at the county level to six Mid-Atlantic States. Their results indicate that the response of farmland values to changes in development is more elastic and greater in rural counties, while response to changes in farm returns is inelastic and relatively uniform for rural and urban counties. Plantinga, Lubowski, and Stavins use the stochastic version of the model (Capozza and Helsley 1990) to decompose farmland values into rents from agricultural production and future land development at the county level of the United States. Their results suggest that option value associated with irreversible and uncertain land development is capitalized into current farmland values.

The idea behind the urban growth model of Capozza and Helsley (1989) as well as other models of urban sprawl (i.e., Arnott and Lewis; Wheaton; Brueckner) is that current farmland

values represent the present value of future agricultural and potential development rents. This formulation assumes that the return to agricultural production initially exceeds the return to urbanization for a period of time until the value of urban use increases enough to trigger conversion. As a result, land far enough from a city sells for its discounted rents from agriculture, while farmland close to the urban-rural boundary sells for a premium that is equal to the present value of anticipated increases in rent after the land is converted to urban use.

Proximity of farmland to urban centers may not only affect the development component of farmland values but may also increase the productivity of farmland by reallocating production from commodity-oriented agriculture to higher-valued alternatives. That is, urban-growth could increase the share of area-specific, high-valued crops, such as fruits, vegetables, and horticultural crops, and reduce land in commodities such as corn, wheat, and soybeans. This phenomenon is apparent in Table 1, which presents the share of high-valued crops for groups of counties ranked by their 1997 accessibility index. The accessibility index is a measure of urban pressure that increases as the population weighted distance to urban centers decreases.<sup>1</sup> From this table it is apparent that counties that are more accessible have a larger share of high-valued crops.

The shift to high-valued crops increases the profitability of agriculture, which in turn accentuates the increase in farmland values from urban pressure. Thus, urban pressure also affects the anticipated rents from agricultural production. Differences between the two effects have implications for the farm sector. Increased farmland values that result from increased opportunity for conversion implicitly increase the opportunity cost of farmland. This increased opportunity cost could then result in reduced competitiveness and productivity for agriculture adjacent to urban areas. However, increased farmland values resulting from changes in the crop portfolio towards higher-valued crops represent increased productivity for farms close to urban

areas. The novelty of this paper is the examination of the effect of urban sprawl on agricultural returns and, in turn, the isolation of this effect in determining farmland values.

This paper investigates the effect of urban sprawl on farmland values in the United States, explicitly accounting for the effect of urbanization on farmland productivity and the rents from future farmland development. In the next section we develop a theoretical approach for this decomposition. We assume that at each point of time, farmland may be converted into urban use or remain in agriculture. Each event is modeled as a Poisson probability that depends on population and on the distance from the urban center. Following the insights of von Thunen we develop a theoretical formulation showing that higher farmland values close to urban centers may be related to shifts in production to higher-valued crops. We then rely on Brueckner to model the effect of urbanization on the development component of farmland. Unlike the formulations of previous studies, our formulation includes three relationships: one for farmland pricing, one for returns to agriculture, and one for development rents. This specification isolates the relative contribution of urban pressure to returns to agriculture and the contribution of urban pressures through the conversion of farmland to urban uses. We then apply our model to county data of the contiguous United States. The results are presented in the following two sections. Finally, we discuss the results and implications of our estimates.

### **Modeling Conversion of Farmland and Productivity**

Let  $T$  be a stochastic variable that denotes the moment of farmland conversion to residential land. In all moments after  $T$  land remains in residential use. Following the formulation in urban growth models (Capozza and Helsley 1989), farmland value at time  $t$  and location  $\delta$  reflects both the discounted economic rents from farming plus the discounted rents from urbanized farmland if urbanization occurs:



$$V_A(t, \delta) = E_t \left[ \int_t^T e^{-rs} R_{AG}(s, \delta) ds + \int_T^\infty e^{-rs} R_U(s, \delta) ds \right] \quad (1)$$

where  $R_{AG}(s, \delta)$  is the net return to farmland in period  $s$  at location  $\delta$ ,  $\delta$  is a vector of spatial coordinates,  $R_U(s, \delta)$  is the net return to urbanization in period  $s$  at location  $\delta$  (including the cost of conversion),  $r$  is the discount rate, and  $E_t[\cdot]$  is the expectation operator conditional on information available at time  $t$ .

Suppose that farmland will be converted with probability  $\lambda ds$  in the interval  $ds$ . If  $\lambda = 0$  conversion will never occur, while if  $\lambda \rightarrow \infty$  conversion occurs instantly ( $\lambda$  can take any non-negative value). Using the Poisson distribution the probability of farmland remaining in agriculture at a given moment  $s$  (i.e., implying that the conversion did not happen until that moment) is  $e^{-\lambda s}$ . The probability that farmland converts into residential uses in moment  $s$ , is given by  $\lambda e^{-\lambda s}$ . Since we are interested in cross-sectional changes in farmland values (as in Plantinga, Lubowski, and Stavins) we assume for the moment that net agricultural rents are constant over time ( $R_{AG}(s, \delta) = R_{AG}(\delta)$  for all  $s$ ). We also assume that returns to urbanization are constant over time ( $R_U(\delta)$ ).<sup>2</sup> Solving for the value function of the second term in Equation 1 the farmland value at time  $t$  and location  $\delta$  can be written as

$$V_A(t, \delta) = \int_t^\infty e^{-rs} R_{AG}(\delta) e^{-\lambda s} ds + \int_t^\infty \frac{e^{-rs}}{r} R_U(\delta) \lambda e^{-\lambda s} ds \quad (2)$$

Next, we assume that the arrival rate  $\lambda$  of the Poisson process depends on a parameter  $\theta$  related to agglomeration (i.e., population) and on the distance  $\delta$  of the parcel of farmland to the central business district (CBD) of the urban place ( $\lambda = \lambda(\theta, \delta)$ ). An increase in population is expected to have a positive effect on the probability of urbanization, while an increase in the distance to the CBD is expected to have a negative effect on the probability of urbanization.<sup>3</sup>

Since rents per unit of land decline at a decreasing rate with distance  $\delta$  from the CBD of the urban place (Muth), we assume that a similar specification holds for the probability of urbanization per unit of time. O’Kelly and Horner use a similar specification to measure accessibility or the relative potential of a given location. Hence, we adopt the following specification for the arrival rate

$$\lambda(\theta, \delta) = \frac{\theta}{\delta} \quad (3)$$

The expected value of the Poisson process is given by  $(1/\lambda)$  and defines the expected time of urbanization for a specific parcel of land. The expected time to urbanization decreases as distance to the CBD decreases or as population increases. Taking into account the above specification for the arrival rate, Equation 2 becomes

$$V_A(t, \delta) = \frac{e^{-t(r+\lambda(\theta, \delta))}}{r + \lambda(\theta, \delta)} R_{AG}(\delta) + \frac{\lambda(\theta, \delta) \cdot e^{-t(r+\lambda(\theta, \delta))}}{r(r + \lambda(\theta, \delta))} R_U(\delta) \quad (4)$$

Evaluating this expression at  $t = 0$  yields

$$V_A(0, \delta) = \frac{1}{r + \lambda(\theta, \delta)} R_{AG}(\delta) + \frac{\lambda(\theta, \delta)}{r(r + \lambda(\theta, \delta))} R_U(\delta) \quad (5)$$

The intuition behind Equation 5 is consistent with economic theory. The first part of the equation represents the discounted value of net agricultural returns. As in the standard farmland pricing formula, the value of farmland is an increasing function of the net return to agriculture and a decreasing function of the discount rate. The second term in the right-hand side of Equation 5 is the discounted expected returns to development, which have a positive effect on the farmland value. Moreover, both terms depend on the speculative component of farmland values as captured by the probability of conversion  $\lambda(\theta, \delta)$ . Comparative statics on Equation 5 lead to the following proposition:

**Proposition 1.** *If  $\delta^b$  defines the distance from the CBD to the boundary of urban place, then farmland values in equilibrium are characterized by the following properties:*

(a) *If  $\theta \rightarrow 0^+$  or  $\delta \rightarrow +\infty$  then  $\lambda \rightarrow 0^+$ , which implies that  $\lim_{\lambda \rightarrow 0^+} V_A(0, \delta) = R_{AG}(\delta)/r$ ,  $\forall \delta \geq \delta^b$ .*

(b) *If  $\theta \rightarrow +\infty$  or  $\delta \rightarrow 0^+$  then  $\lambda \rightarrow +\infty$ , which implies that  $\lim_{\lambda \rightarrow +\infty} V_A(0, \delta) = R_U(\delta)/r$ ,  $\forall \delta < \delta^b$ .*

(c) *Ceteris paribus, an increase in the instantaneous probability of conversion results in a smaller percent of farmland value contributed by net returns to agriculture and to a larger percent contributed by the net returns to urbanization, since  $\forall \delta \geq \delta^b$  we have that*

$$\frac{\partial V_A(0, \delta)}{\partial \lambda} = \frac{(R_U(\delta) - R_{AG}(\delta))}{(r + \lambda)^2} \begin{matrix} > \\ < \end{matrix} 0.$$

The proof of the proposition is straightforward with the exception of Proposition 1.b where we have applied L' Hospital's rule and in Proposition 1.c where we assume that net returns to urbanization are always positive, for every  $\delta$ . Proposition 1.a indicates that in locations with low population density or that are far from the CBD, the probability of conversion is zero and so the value of farmland should only be reflected by the discounted net returns to agriculture. If the land is located within the CBD ( $\delta < \delta^b$ ) then it has been converted into urban uses and its value is reflected by the discounted net returns to urbanization (1.b). Given that the probability of conversion  $\lambda$  has also been defined as the accessibility of a given location to the CBD, then from Proposition 1.c we have that the effect of accessibility to the value of farmland depends on the relationship between net returns to agriculture and urbanization. Specifically, if net returns to agriculture are negative or if the net returns to urbanization are greater than the net returns to agriculture, then an increase in the accessibility ( $\delta \downarrow$  or  $\theta \uparrow$ ) of farmland will lead to an increase in its value. However, for farmland at a given location  $\delta > \delta^b$ , where the net returns to agriculture are greater than net returns to urbanization, an increase in accessibility will result in lower farmland values.<sup>4</sup>

Equation 5 allows for a cross-sectional decomposition of the current farmland value into agricultural and development components. Following the insights of von Thunen and Ricardo, farmland at different locations will have different net returns to agriculture because of differences in soil characteristics, suitability for crops with different market values, and proximity to urban centers. The latter implies that net returns to agriculture are endogenously determined in Equation 5.

### *Effect of Urban Pressure on the Return to Farmland*

To model the effect of urban pressure on the agricultural component of farmland values, we construct a profit function formulation consistent with the von Thunen effect of distance from a central place that explicitly accounts for heterogeneity in soil characteristics of different parcels of land and climate. Under the von Thunen formulation, higher-valued crops with relatively high transportation costs are grown in proximity to urban areas. As the distance to the central place increases agriculture becomes increasingly commodity focused.

Profit at the farm level, accounting for the spatial variation in farmland prices and differences in soil quality, is given by

$$\begin{aligned} \max_{y,x,A,K,D} \quad & (p - \tau(\delta))' y - w' x - rD - e^{-r} R_U \\ \text{st} \quad & f(y, x, A, K, S) = 0 \\ & (K - K_0) + (A - A_0) V_A = D - D_0 \end{aligned} \tag{6}$$

where  $p$  is a vector of output prices,  $y$  is a vector of outputs,  $w$  is a vector of input prices,  $x$  is a vector of inputs,  $r$  is the interest rate on farm debt,  $D$  is the level of farm debt,  $f(\cdot)$  is a multiproduct production function,  $A$  is the acres of farmland,  $K$  is the level of intermediate assets,  $S$  denotes soil characteristics,  $V_A$  is the value of farmland,  $\tau(\delta)$  is the transportation cost associated with each commodity,  $\delta$  is the distance from the parcel of farmland to the CBD and

the subscript zeros denote initial levels. As the multiproduct production function is written in an implicit form, we assume that  $f_x < 0$ ,  $f_A < 0$ ,  $f_K < 0$ ,  $f_S < 0$  and  $f_Y > 0$ , where the subscripts denote partial derivatives.

From this formulation, we develop the marginal value of each unit of output given the transportation cost and the marginal value of farmland. The marginal value of each output is

$$\frac{\partial L}{\partial y_i} = (p_i - \tau_i(\delta)) - \mu_1 \frac{\partial f(y, x, A, K, S)}{\partial y_i} = 0 \quad (7)$$

where  $\mu_1$  is the shadow value on the production constraint (the Lagrange multiplier for the first constraint in Equation 6). Equation 7 yields the standard relationship that the marginal rate of transformation between two products equals the inverse of their price ratios. Note that increases in the transportation cost for each commodity implies a relative reduction in the output of that commodity. Equating the shadow value of production across all outputs yields

$$\mu_1 = \frac{(p_1 - \tau_1(\delta))}{\frac{\partial f(y, x, A, K, S)}{\partial y_1}} = \dots = \frac{(p_n - \tau_n(\delta))}{\frac{\partial f(y, x, A, K, S)}{\partial y_n}} \quad (8)$$

Differentiating the shadow value with respect to distance then yields

$$\frac{\partial \mu_1}{\partial \delta} = - \frac{\frac{\partial \tau_i(\delta)}{\partial \delta}}{\frac{\partial f(y, x, A, K, S)}{\partial y_i}} \leq 0 \quad (9)$$

as long as the transportation cost is an increasing function of distance.

Turning to the value of farmland, the first-order condition with respect to debt implies that  $\mu_2 = r$  (where  $\mu_2$  is the Lagrange multiplier for the second constraint in Equation 6). Substituting this result into the first-order condition with respect to land values yields the standard Ricardian equation for farmland values

$$V_A = \frac{-\mu_1 \frac{\partial f(y, x, A, K, S)}{\partial A}}{r} \quad (10)$$

Since the partial of the multiproduct production function with respect to land is negative, Equation 10 is the same value as found in Equation 5, if conversion to urban use never occurs. In particular, we are interested in specifying the net return to agricultural activities in Equation 1 as

$$R_{AG}(\delta) = -\mu_1 \frac{\partial f(y, x, A, K, S)}{\partial A} \quad (11)$$

Merging the results of Equations 8 and 11, we have

$$R_{AG}(\delta) = - \frac{(p_i - \tau_i(\delta))}{\frac{\partial f(y, x, A, K, S)}{\partial y_i}} \frac{\partial f(y, x, A, K, S)}{\partial A} = (p_i - \tau_i(\delta)) \frac{dy_i}{dA} \quad (12)$$

where the last derivative is evaluated at the optimal point of production.

Given the results from Equation 9 we conclude that the net return to farmland is a decreasing function of the transportation cost and distance to the market. In addition, the value of farmland is an increasing function of the relative productivity of farmland. Specifically,

$$\frac{dy_i}{dA} = - \frac{\frac{\partial f(y, x, A, K, S)}{\partial A}}{\frac{\partial f(y, x, A, K, S)}{\partial y_i}} \quad (13)$$

The solution in Equation 13 assumes that all agricultural products are produced continuously throughout the region. The formulation in Equation 6 could be changed to guarantee that only non-negative quantities of crops could be chosen. This would transform the problem into a Kuhn-Tucker optimization problem. The point is that not all crops would meet the marginal value condition in Equation 8. Hence, low-valued crops would not be grown close to urban places. This an important finding since it implies that higher values of farmland close to urban places are not entirely explained by agglomeration but instead may also be related to increased productivity as farmers shift their production to high-valued crops suitable for the specific area.

While the intuition of the von Thunen formulation appears sound, our formulation explicitly recognizes two caveats. High-valued crops are assumed to have the highest transportation costs. Undoubtedly this assumption would be justified by the value of freshness in delivering produce. However, improvements in transportation technology and infrastructure have flattened the von Thunen plane. In addition, differences in soil quality, climate, or economies of scale may be sufficient to offset transportation cost advantages.

#### *Determinants of the Development Component of Farmland Values and Aggregate Model*

We impose additional structure on the farmland valuation model by specifying the determinants of the net return to urbanization. Following, the open-city model of Brueckner, we assume that the preferences of urban residents can be represented by the utility function  $U(C_l, C_{nl}, P)$ , where  $C_l$  is consumption of land,  $C_{nl}$  is consumption of a numeraire non-land good and  $P$  is urban population. Assuming that individual land consumption is fixed at one unit per person the budget constraint becomes  $R_u + C_{nl} + k\delta = M$ , where  $M$  denotes income,  $R_u$  is urban land rent, and  $k\delta$  is the commuting cost from a residence to the CBD of the city, with  $\delta \leq \delta^b$  denoting this distance. Solving for this utility maximization problem, the returns to urbanization should satisfy

$$R_u = R_u(\delta, P) \tag{14}$$

where urban land rent is a decreasing function of distance to the CBD. The effect of population on urban rent can be either negative or positive depending on whether the disamenity effect (Brueckner) is greater or lower than the positive effect induced by increased demand for land.

Consequently, Equations 5, 12 and 14 specify a recursive system of equations that form our empirical model of farmland valuation across space. This farmland valuation model is at the parcel level of analysis, where farmland is located around a monocentric city and farmers commute their products to the CBD of the city. Further, we have assumed that distance to the

CBD, net returns to agriculture, and development are constant over time. Since our empirical analysis is based on two years of county data with each county containing both residential and agricultural land, we convert this model into a county model where multiple cities may be observed and allow rents and distance to change over time. Therefore, we consider the following farmland valuation model at time  $t$  and location  $\delta$

$$V_A(t, \delta) = F_1(R_A(\delta(t), S(t)), R_U(\delta(t), P(t), M(t)), \lambda(\theta(t), \delta(t))) \quad (15)$$

$$R_{AG}(t, \delta) = F_2(\delta(t), S(t)) \quad (16)$$

$$R_U(t, \delta) = F_3(\delta(t), P(t), M(t)) \quad (17)$$

Following Plantinga, Lubowski, and Stavins we define  $R_{AG}(t, \delta)$  as the average (per acre) net return to agriculture in the vicinity of  $\delta$ . Thus,  $R_{AG}(t, \delta)$  is county-specific. Similarly,  $V_A(t, \delta)$  and  $R_U(t, \delta)$  are defined as the average farmland value (per acre) and net return to development, respectively. The probability of conversion  $\lambda(\theta, \delta)$  has been defined as a function of population and distance to a CBD. We replace the simple distance measure  $\delta$  with an accessibility measure that accounts for the average distance of any given location in a county to multiple cities and is weighted by the population of each city.<sup>5</sup> A similar measure is used by O’Kelly and Horner. In Equation 16,  $S(t)$  denotes the average soil characteristics in the county, while in the net returns to development, Equation 17, we include residential income ( $M(t)$ ) as an exogenous variable to relax the homogeneous income assumption.

## Empirical Analysis

The theoretical model developed above is the basis for our econometric model, which we apply to county data for the contiguous United States. We employ two cross-sections of observations for the Agricultural Census years 1992 and 1997. To control for differences between these years



due to changes in interest rates or other variables that have a common effect in all observations, we use a time-specific fixed-effects approach. That is, we include a year dummy variable that allows for a different intercept for each year of the sample. To correct for inflation we converted all the economic variables to real 2000 dollars using the personal consumption expenditures component of the implicit GDP deflator. The data were collected from the Census of Agriculture, the Census of Population and Housing, the Economic Research Service of the United States Department of Agriculture, the National Climatic Data Center, and the Bureau of Economic Analysis. Details for the source and nature of the data are provided in the Appendix.

Since we lack data on key variables such as net returns to agriculture or development and farmland value at the parcel level for counties in the United States, we estimate the model outlined above using county level data for the 1992 and 1997 agricultural census years. However, we recognize that a parcel level analysis would provide more variation, since aggregate county level data may not be representative of the soil characteristics, land values and returns to agriculture, especially for very large counties.<sup>6</sup> Yet, we support our specification with results of Clark, Fulton, and Scott who suggest that land markets in different regions of the country may be quite different implying that a cross-sectional comparison should be performed. Thus, results of studies at the parcel level of analysis for a specific region cannot be generalized over all the counties in the United States.

The first equation of our econometric model is based on Equation 15 and decomposes the farmland value for county  $i$  in year  $t$  into agricultural and development components

$$V_A(i,t) = a_0 + a_1 R_{AG}(i,t) + a_2 H(i,t) + a_3 AC(i,t) + a_4 N(t) + u_v(i,t) \quad (18)$$

where  $V_A(i,t)$  is the average market value of farmland and buildings in county  $i$  in year  $t$  (in dollars per acre);  $R_{AG}(i,t)$  is the average net returns from agriculture including government

payments (in dollars per acre);  $H(i,t)$  is the median value of single-family houses (in dollars);  $AC(i,t)$  is the index of accessibility of any given location within the county to the nearest urban centers (within 50 miles);  $N(t)$  is a dummy variable which takes the value 1 for the year 1997 and 0 for 1992; and  $u_A(i,t)$  is a random error term that follows a spatial autoregressive process. Given the implicit non-linearity of Equation 5, all variables in Equation 18 are transformed in logarithmic form except for the year dummy and the net returns to agriculture ( $R_{AG}$ ). The latter variable was specified as linear, given the existence of negative net returns to agriculture for many counties for both years in the sample. Further, this specification allows for separability between the agricultural and development components of farmland values.

Since demand for housing is the most important use of urban land (Brueckner and Fansler) we used the county median value of single-family homes without a business on the property, as a proxy for the returns to urbanization at the urban fringe.<sup>7</sup> By using this variable we make an implicit assumption that single-family homes are constructed at the urban boundary. This proxy serves also in capturing implicitly the cost of converting farmland to residential use, since its value reflects both the price of the land and the house.

The probability of conversion measure,  $AC(i,t)$ , for each county  $i$  is a population-weighted sum of inverse distances within 50 miles of any given location in the county. Formally, we let  $AC_s$  be the accessibility at location  $s$  in county  $i$ ,  $\theta_j$  the population at area  $j$ , and define  $\delta_{sj}$  as a matrix of straight-line distances between area centroids. Then the accessibility index of area  $s$  in county  $i$  is given by  $AC_s = \sum_{j, j \neq s} \theta_j \delta_{sj}^{-1}$ . To impose a threshold to delimit which areas may count in the area's accessibility index, we specify a maximum radius of 50 miles (see

O’Kelly and Horner). The county accessibility index  $AC(i,t)$  is then an average value for all locations  $s$  in the county.

The second equation of our econometric model relates the average net returns to agriculture to the full set of productive and locational attributes of the farmland in the county. This equation is

$$R_{AG}(i,t) = b_0 + b_1 AC(i,t) + b_2 S(i) + b_3 PIR(i,t) + b_4 PDSI(i,t) + b_5 N(t) + u_R(i,t) \quad (19)$$

where all variables are specified as linear;  $R_{AG}(i,t)$ ,  $AC(i,t)$  and  $N(t)$  are the same variables as in Equation 18 but now  $AC(i,t)$  is linear; and  $S(i)$  is a vector of soil characteristics<sup>8</sup> that captures effects due to soil properties and quality across counties (see Table 3). To further control for heterogeneity across counties we included the percent of irrigated acres ( $PIR(i,t)$ ) that is expected to have a positive effect on  $R_{AG}(i,t)$ . In addition, climatic differences across counties are captured by the Palmer Drought Severity Index ( $PDSI$ ). In particular, for each year in the analysis we incorporated for each county 3 average values of the  $PDSI$  that correspond to the planting, harvesting and fallow seasons.

The explanatory variable of primary interest in Equation 19 is the distance to the markets where producers ship their products. If there was a single market, distance could be measured by actual transport cost or physical distance. However, in a region such as United States it is generally unknown who supplies whom (Benirska and Binkley). Thus, we use the accessibility index in each county as a measure of distance. Since this index is a measure of urban pressure within 50 miles of any given location in the county, it should matter mostly to high-valued crops. However, a comparison across counties will show how urban pressure affects net returns to agriculture.

As shown in the previous section, returns to urbanization are conditional on income, population and distance to the CBD. Thus, based on Equation 17, a log-linear specification for returns to urbanization is given by:

$$H(i,t) = c_0 + c_1 M(i,t) + c_2 AC(i,t) + c_3 DPD(i,t) + c_4 N(t) + c_5 RD(i) + u_H(i,t) \quad (20)$$

where  $H(i,t)$ ,  $AC(i,t)$  and  $N(t)$  are the same variables as in Equation 18,  $M(i,t)$  is the median household income in county  $i$  at time  $t$ , and  $DPD(i,t)$  is the average residential population growth rate in county  $i$  during the five years preceding 1992 and 1997. To control for unobserved differences across counties that affect property values, we included a set of nine regional dummies ( $RD(i)$ ) which represent the geographical and historical development of the United States (Theil and Moss). We used the Lower Mississippi region (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Missouri and Tennessee) as a base. All the variables were specified in logarithmic form, except for the residential population growth and regional dummies, which were specified as linear.

The comparison between the impacts of urban pressure on productivity versus the effect of urban sprawl is captured by the coefficients on accessibility in Equations 19 and 20. For instance, if increased accessibility causes a change in the relative crop mix, or in the price for a particular crop, this effect will be manifested through coefficient  $b_1$  in Equation 19. However, if the impact of accessibility comes only through urbanization, it will be captured in the  $c_2$  coefficient in Equation 20. Also, the direct effect of accessibility on farmland value is captured by coefficient  $a_3$  in Equation 18, while coefficient  $a_2$  captures the opportunity cost of farmland.

The system of Equations 18-20 is block-recursive and is estimated with 3010 counties for each year, resulting in a total of 6020 observations. Writing this system in a compact form

$$Y = ZB + U, \text{ with } E[U'U] = \Sigma \quad (21)$$

where  $Y$  contains the variables  $V_A(i, t)$ ,  $R_{AG}(i, t)$  and  $H(i, t)$ ,  $Z$  contains the explanatory variables in Equations 18-20,  $B$  the stacked parameters of the three equations, and  $U$  the stacked disturbances.

Tests for diagonal  $\Sigma$  such as the likelihood-ratio test and Breusch-Pagan test (Greene, pg. 621) rejected the null hypothesis that  $\Sigma$  is diagonal at the 0.01 level of confidence. Since  $\Sigma$  must be estimated, a system estimator such as three-stage least squares (3SLS) or an iterated SUR is more plausible (Lahiri and Schmidt).

Given the cross-sectional nature of the data and the results of other spatial studies of farmland values (Benirschka and Binkley, Hardie, Narayan, and Gardner, and Plantinga, Lubowski, and Stavins), we allow for spatial autocorrelation of errors. Specifically we assume that the disturbances are determined by the following first-order, spatially autoregressive process

$$U = (\rho \otimes W)U + U^* \text{ or } u_k = \rho_k W u_k + u_k^*, k = V, R, H \quad (22)$$

where  $\rho$  is a  $3 \times 3$  diagonal matrix containing the spatial autocorrelation parameters  $\rho_k$ ,  $U$  is the spatially autocorrelated matrix of residuals,  $W$  is a  $2n \times 2n$  (where  $n = 3,010$  is the number of counties in each year) contiguity matrix summarizing all the information about the spatial structure of the data, and  $U^*$  is the matrix of uncorrelated residuals. Since our model is a balanced panel of two years the weight matrix  $W$  is defined as

$$W = \begin{bmatrix} W_n & 0 \\ 0 & W_n \end{bmatrix}$$

$W$  is constructed so that the  $(i, j)$  element of  $W_n$  is one if counties are contiguous and zero if not. Further, all diagonal elements of  $W_n$  are set to zero implying that counties are not contiguous to themselves.

A Cochrane-Orcutt transformation of Equation 22 yields

$$\left[ I - (\rho \otimes W) \right] Y = \left[ I - (\rho \otimes W) \right] ZB + U^* \quad (23)$$

where  $E[U^*] = 0$  and  $E[U^* U^{*'}] = \Sigma \otimes I_{2n}$ . Parameter estimates can be obtained by maximizing the likelihood function. However, this estimator is not computationally feasible for large numbers of observations. To estimate the system we use the stepwise generalized spatial 3SLS estimator (GS3SLS) developed by Kelejian and Prucha. First, we apply a two-stage least squares (2SLS) to Equation 18. Equations 19 and 20 were estimated by ordinary least squares since there is no endogeneity problem in these equations. Second, the residuals of each equation are then used to estimate the spatial autoregressive parameters  $\rho_k$  with a generalized moments procedure. While the asymptotic distribution of  $\rho_v$  is unknown, the spatial autocorrelation coefficients of Equations 19 and 20 follow an asymptotic normal distribution.<sup>9</sup> Third, using the estimate of  $\hat{\rho}_k$  the system is transformed (Equation 23) and the disturbances of this transformation are used to estimate  $\hat{\Sigma}$ . Fourth, this  $\hat{\Sigma}$  matrix is used to estimate the GS3SLS specification.<sup>10</sup>

## Empirical Results

The estimated coefficients for the farmland equation are presented in Table 2. Before correcting for spatial autocorrelation the adjusted  $R^2$  of this equation is 0.75, indicating that this specification explains most of the variation in farmland values and that the likelihood of omitted variables is small. However, in the presence of spatial autocorrelation, the adjusted  $R^2$  has a limited interpretation (Anselin). The estimated spatial autocorrelation for Equation 18 is 0.097.<sup>11</sup>

The estimated parameters for each effect on farmland prices in Equation 18 are statistically significant at the 0.01 level of confidence and have the anticipated signs. Farmland values increase in response to an increase in the net return to agriculture, the median house value,

and the accessibility index. The dummy variable for 1997 is negative indicating that farmland values declined from 1992 to 1997 after all other factors are taken into account. However, since the estimated parameter is not statistically significant at any conventional confidence level, we conclude that farmland values at the two census years remained constant after adjusting for external effects, such as differences in net returns to agriculture and urban pressure.

Taking into account the semi-logarithmic form of Equation 18, the interpretation of the magnitude of the estimated parameters differs. Since farmland values, median single-family house values, and accessibility in Equation 18 are specified in natural logarithms, the respective parameters presented in Table 2 denote elasticities. However, given that the return to agricultural assets is specified as a linear variable in Equation 18, its coefficient is dependent on the scale of the endogenous variables. Hence, the estimated coefficient on the net return to farmland implies that a \$1 increase in the net return on farmland will cause farmland values to increase by \$5.81/acre given a sample average price of farmland of \$1,572/acre. This estimate is similar to the results of Plantinga, Lubowski, and Stavins who find that on average, a \$1 increase in net agricultural returns causes farmland values to increase by \$5/acre.

The direct effect of development opportunities in farmland values is captured by  $R_U$  which denotes the median value of a single-family home in the county. Its coefficient indicates that a one percent increase in the median house value results in a 0.40 percent increase in farmland values. Thus, at the sample average, a \$1,000 increase in the median house value results in a \$9.07/acre increase in farmland values.

Further, a one percent increase in the accessibility index results in a 0.22 percent increase in farmland values (Table 2). Since distance to urban centers appears in the denominator of the accessibility index, this result implies that farmland values close to urban areas are higher than

farmland values in rural areas, even after differences in the median house values have been taken into account. This result is also consistent with the findings of Archer and Lonsdale who found that farmland values in metro-adjacent (metropolitan) counties were about one-third (three times) higher than farmland values in rural areas from 1978 through 1992. This persistence, apart from differences in median house values, may be attributed to the speculative demand for development (i.e., the differences in the probability of conversion, or  $\lambda(\theta, \delta)$  in Equation 5).

Table 3 presents the estimated coefficients for the hedonic specification of the net return to agriculture specified in Equation 19.<sup>12</sup> The  $R^2$  of the estimates without correcting for spatial autocorrelation is 0.28, which is analogous to the  $R^2$  found in hedonic studies (0.22-0.55) using county-level data for different States of the U.S. (e.g., Miranowski and Hammes; Palmquist and Danielson; Roka and Palmquist). The estimated spatial autocorrelation coefficient  $\rho_R$  is 0.101 and assuming an approximate standard normal distribution, the  $z$ -statistic for this coefficient is 36. The latter implies that the null hypothesis of no spatial autocorrelation can be rejected at any conventional level of confidence.

Urban pressure can affect the value of farmland by affecting the productivity of farmland (i.e., through changes in the crop portfolio). The results in Table 3 support the significance of this effect. The estimated parameter for the effect of accessibility on the net return to agriculture is positive and statistically significant at the 0.01 level of confidence. Numerically a one percent increase in the accessibility index causes the net return to agriculture to increase by 0.17 percent. In dollar terms based on an average accessibility index of 163.25, a one percent increase in accessibility yields a \$12.90/acre increase in net returns to agriculture. Linking this result to the discussion above, a one percent increase in accessibility implies a \$74.95/acre (or 4.8 percent)



increase in the value of farmland independent of urban pressure from conversion or the speculative demand for farmland for eventual conversion.

The soil characteristics and Palmer Drought Severity Index in Equation 19 capture differences in land quality and weather, respectively. Most of these estimated coefficients are statistically significant at the 0.01 level of confidence and have the expected sign. Increases in cation-exchange capacity, soil texture, bulk density, permeability, and soil depth are associated with increased net returns to agriculture. Net returns to agriculture are also an increasing function of the percent of farmland irrigated at the 0.01 level of confidence. A one percent increase in the share of farmland irrigated increases the net return to agriculture by \$3.74/acre. Finally, the estimated coefficient for the 1997 dummy variable of \$23.00/acre is statistically significant at the 0.01 level of confidence. This estimate indicates that net returns to agriculture were significantly higher in 1997 than in 1992 even after such factors as increased urban pressures and differences in weather (through the Palmer Drought Severity Index) are taken into account.

The estimated coefficients for the inverse demand for housing, depicted in Equation 20, are presented in Table 4. Before adjusting for spatial autocorrelation, the  $R^2$  is 0.82 indicating that the specification explains most of the variation in house prices even with cross-sectional data. After correcting for spatial autocorrelation, the estimated spatial autocorrelation coefficient  $\rho_H$  is 0.102 with a  $z$ -statistic of 51, and so the null hypothesis of no spatial autocorrelation can be rejected at any reasonable level of confidence.

All the coefficients presented in Table 4 have the anticipated sign and are statistically significant at the 0.01 level of confidence. A one percent increase in the median household income yields a 0.82 percent increase in the median value of a single-family house, while a one percent increase in accessibility increases the median house value by 0.10 percent. In addition, a

one percent increase in residential population growth leads to a 4.12 percent increase in single-family house values.

The results presented in Table 4 also indicate regional differences in the effect of house values on farmland values. The estimated dummy variable for the Pacific region implies that the median house values in that region are \$41,538 higher than single-family house values in the Lower Mississippi region (the region in the intercept) with all other factors held constant. The dummy variable for the New England region indicates that median house values are \$35,301 higher in New England than in the Lower Mississippi region. Thus, farmland values are higher in both the Pacific and New England regions than in the Lower Mississippi region due to differences in the return to urbanization, all other factors held constant.

Finally, the estimated coefficient on the dummy variable for 1997 indicates that house values were significantly higher in 1997 than in 1992. This effect persists despite accounting for changes in other factors (i.e., changes in median income and population growth) and inflating both 1992 and 1997 median single-family house values to 2000 dollars.

### **The Effect of Urbanization on Productivity and Land Values**

The model estimated in this study allows for the decomposition of the effect of urban sprawl on farmland values into three components: the effect of changes in non-farm opportunities as captured by the median house value variable in Equation 18, the speculative component of urban pressure as measured by the probability of conversion (i.e., accessibility coefficient in Equation 18), and the effect of urban pressure on productivity through changes in the crop portfolio (i.e. accessibility coefficient in Equation 19). In this section we examine the relative magnitude of each effect on farmland values, as well as the effect of urban sprawl on net returns to agriculture.

To determine the relative contribution of accessibility (i.e., von Thunen effect) compared with the effect of soil quality attributes in the determination of net returns to agricultural assets we divide the expected value of Equation 19 into two components

$$\begin{aligned}\hat{R}_{AG}(i,t) &= \tilde{R}_{AG}(i,t) + \hat{R}_{AG}(i,t) \\ \tilde{R}_{AG}(i,t) &= \hat{b}_0 + \hat{b}_2 S(i) + \hat{b}_3 PIR(i,t) + \hat{b}_4 PSDI + \hat{b}_5 N(t) \\ \hat{R}_{AG}(i,t) &= \hat{b}_1 AC(i,t)\end{aligned}\tag{25}$$

where  $\tilde{R}_{AG}(i,t)$  is the net return to agriculture that is explained by soil quality and climatic information,  $\hat{R}_{AG}(i,t)$  is the net return to agriculture that is explained by the von Thunen or productivity effect of urban pressure, and  $\hat{R}_{AG}(i,t)$  is the expected return to agricultural assets from both sources<sup>13</sup>.

Table 5 presents the state-level net-return on agricultural assets for each component ranked by the relative share of the von Thunen effect. These results indicate that the von Thunen component of net returns to agriculture is generally higher for states in the Northeastern region of the United States. This result is consistent with the general precepts of our model. Higher-valued agriculture appears more likely in the Northeastern region due to increased access to several large cities. For example, the estimate for New Jersey indicates that 41.9 percent of net returns to agriculture are attributable to increased market access. Similar results hold for states adjacent to the Northeastern region (e.g., Ohio with 23.3 percent, Michigan with 16.9 percent, Indiana with 15.5 percent, Virginia with 15.7 percent, and Tennessee with 15.5 percent).

South Dakota is an anomaly with 19.2 percent of net returns to agriculture explained by proximity to urban areas. To explain this anomaly we note that South Dakota has the lowest expected return to agricultural assets (of \$4.8/acre). Thus, even though the effect of proximity to urban areas is the second lowest in the sample (\$0.9/acre), the relative share of value attributed to the von Thunen effect is large.

The spatial effect of urban pressure on net returns to agriculture at the county level is depicted in Figure 1. Consistent with the results in Table 5, the urban effect of net returns to agriculture exceed 30 percent for most counties in the Washington, D.C. to Boston corridor. Other areas of significant urban pressure on net agricultural returns include the Pittsburgh, Toledo, Detroit regions of Pennsylvania, Ohio, and Michigan, the area between Chicago and Milwaukee of Illinois and Wisconsin, and the Dallas, Austin, Houston area in Texas. Interestingly, urban areas in California, Florida, Oregon, and Washington cast a relatively small footprint on net returns to agriculture despite the share of high valued crops in each area. In these cases the presence of high-valued crops are attributable primarily to hedonic characteristics of the region (i.e., soil and climatic of the region) and not the presence of urban areas.

To examine the relative dollar per acre magnitude of each effect on farmland values we define four measures. We define the response of farmland values with respect to a one percent change in, net returns to agriculture ( $\epsilon_1$ ), median house values ( $\epsilon_2$ ), speculative component of urban pressure ( $\epsilon_3$ ), and urban pressure through changes in productivity ( $\epsilon_4$ ) as:

$$\begin{aligned}\epsilon_1 &= \hat{a}_1 \hat{R}_{AG}(i,t) V_A(i,t) \\ \epsilon_2 &= \hat{a}_2 V_A(i,t) \\ \epsilon_3 &= \hat{a}_3 V_A(i,t) \\ \epsilon_4 &= \hat{a}_1 \hat{b}_1 AC(i,t) V_A(i,t)\end{aligned}\tag{26}$$

We estimate these elasticities for each county and aggregate the county estimates to the state level by using the share farmland in each county.

Table 6 presents the results of each component along with the current farmland values (denominated in real 2000, \$/acre) and ranked by the percentage change in median house values. As in the rankings of the effect of accessibility on net returns to agriculture, farmland values in the Northeastern United States are more sensitive to changes in the urban sprawl

components. New Jersey is the most sensitive where a one percent change in accessibility increases farmland values by \$15.46/acre followed closely by Connecticut with an increase of \$13.83/acre, Rhode Island with an increase of \$13.75/acre and Maryland with an increase of \$12.14/acre. In addition to their sensitivity to urban sprawl components, farmland values in these states are also sensitive to changes in net returns to agriculture. For example, a one percent change in net returns to agriculture causes an increase of \$59/acre in farmland values in New Jersey, a \$34/acre increase in farmland values in Connecticut, and a \$43/acre increase in farmland values in Rhode Island.

For many states on the top of the list, a one percent increase in net returns to agriculture will increase farmland values by more than a one percent increase in median house values. For instance, in New Jersey a one percent increase in median house values will increase farmland values by \$28/acre, while a one percent increase in the net returns to agriculture will result in a \$59/acre increase in farmland values. However, the pure agricultural (soil quality and climate) effect is smaller if one accounts for the effect of urban sprawl in farmland productivity and in turn to farmland values. That is, the response of farmland values to accessibility through net returns to agriculture is also large, mainly for the Northeastern United States. For instance, a one percent increase in accessibility is associated with a \$28/acre increase in farmland values through net returns in New Jersey, a \$15/acre increase in farmland values in Connecticut, a \$16/acre increase in farmland values in Rhode Island, and a \$15/acre increase in farmland values in Massachusetts. Thus, increases in farmland values from net returns to agriculture are not only connected with differences in soil productivity but also with urban pressure in the specific area.

## **Discussion and Implications**

This analysis examined the effect of urban pressure on farmland values nationwide, explicitly accounting for three effects of urban sprawl: changes in non-farm opportunities, speculative effect of urban sprawl, and conversion to high-valued agriculture. Traditionally studies of farmland values have emphasized the role of farmland as a factor of production. Following this formulation, farmland values have been modeled as the discounted returns to agricultural production. More recently, several studies have emphasized the effect of urban pressure on farmland values. These studies typically focus on the impact of converting farmland to urban uses on farmland valuation. This study blends the two approaches by examining the effect of urban pressure on the net returns to agriculture as well as through conversion to urban use.

Thus, our study makes two important contributions in the literature. First, we provide a theoretical justification and empirical evidence on the effect of urban sprawl in net returns to agriculture. We start from the standard formulation of farmland values in urban growth models, as the present value of future returns to agriculture and potential development rents. Unlike previous studies we assume that at each point of time there is a Poisson probability for conversion of farmland. This probability of conversion depends on population and distance from urban centers and reflects the speculative component of the effect of urban sprawl. This analysis provides a model for the value of farmland that depends on three components: net returns to agriculture, median house values, and probability of conversion. It is apparent from this formulation that both net returns to agriculture and to future development are endogenous. Thus, using the concept of von Thunen we show that there is a potential for farmland located close to urban centers to convert into higher-valued crops. That is, the increased market access of these areas implies not only reductions in transportation costs (which are small) but also to conversion to high-value crops. A first indication of this result was given in Table 1, which shows states

with higher values of accessibility have a larger farmland share of high-valued crops. Figure 1 reveals that the urban component of net returns to agriculture has a substantial share in areas located close to urban centers. For instance, the urban effect on the net agricultural returns exceeds 30 percent for most counties in the Washington, D.C. to Boston corridor. Other areas of significant urban pressure on net agricultural returns include counties around major urban centers in Pennsylvania, Ohio, Michigan, Illinois and Texas.

The possible differences in urban effects on farmland values (e.g., the effect of increased farmland values due to conversion rather than increased returns) raise several issues. For example, urban effects manifested only in the conversion of farmland into urban uses increase the wealth of farmers without increasing their income stream. The only way for farmers to access this increased wealth is either through selling farmland or by borrowing against the increased asset values. However, increases in farmland values that result from changes in the crop portfolio accrue through increased net returns to agriculture. In the first scenario, an increase in farmland values from increased demand for farmland in urban use implies an increase in the opportunity cost of production agriculture. In the second scenario urban pressure results in increased returns, which enhances the farmer's profitability and productivity.

The second contribution of this study is the decomposition of these effects in determining farmland values along with the effect of the speculative component of urban sprawl and the effect of net returns to agriculture. We found that at the sample average, a \$1 increase in the net return on farmland will cause the farmland values to increase by \$5.81/acre, while a \$1,000 increase in median house values increase farmland values by \$9.07/acre. The speculative component of urban sprawl is also significant, a one percent increase in the accessibility index results in a \$3.45/acre increase in farmland values per acre. Concerning the effect of the

accessibility index on net returns to agriculture, a one percent increase causes the net return to agriculture to increase by 0.17 percent. In dollar terms, a one percent increase in accessibility yields a \$12.90/acre increase in net returns to agriculture and a \$74.95 /acre increase in the value of farmland independent of direct urban pressure for conversion or the speculative demand for farmland for eventual conversion. The latter effect is mostly evident in the Northeastern United States where farmland values are more sensitive to changes in the urban sprawl components. In those States, an increase in farmland values from net returns to agriculture is not only connected with differences in soil productivity but also with urban pressure in the specific area.

While our analysis provides a new method to decompose the effects of urban sprawl in farmland values, it is still based on a static, cross-sectional framework. A topic for future research would be the inclusion of the present model in a dynamic framework. Further, we have shown that it is possible for an increase in the probability of conversion to lead to a decrease in farmland values. It was justified by a potential negative externality effect, such as competition over natural resources or pollution through increased population. Although, our data do not support this effect at the county level of the United States, it may be evident in a parcel of land level of analysis.



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## Endnotes

<sup>1</sup> A formal definition is provided in the Empirical Analysis section of the present paper.

<sup>2</sup> Although returns to development are expected to be increasing over time, alternative specifications allowing for linear rate of changes in returns to urbanization or as a composite term consisting of a spatial and a temporal component that follows a Brownian motion (Capozza and Helsley 1990) led to an intractable model. In the econometric specification of the model the assumptions of constant returns to agriculture and urbanization will be relaxed.

<sup>3</sup> Since we focus on changes in the value of parcels of farmland in different locations we assume that distance  $\delta$  is exogenous with respect to time. An endogenous formulation of the distance (i.e.,  $\delta(t)$ ) would be more plausible but it would unnecessarily complicate the analysis.

<sup>4</sup> In this formulation it is possible to get a negative effect on farmland values when  $R_{AG} > R_U$ . A possible justification is negative externalities, since an increase in the probability of conversion could also imply increased pollution and competition over natural resources. This is an interesting topic but beyond the scope of this paper, and so it is left for future research.

<sup>5</sup> This accessibility index has been developed by Breneman at the USDA using Geographical Information Systems (GIS) county data.

<sup>6</sup> We would like to thank one of the reviewers of this paper for this comment.

<sup>7</sup> While a per-acre median house value would be more plausible for the model, we lack data on the mean lot size and the value that this lot represents in the median house value. Such data are reported only for the four main census regions of US. Thus, as in Hardie, Narayan, and Gardner, we used median house values.

<sup>8</sup> The same data set of soil characteristics was utilized for both years in the sample.

<sup>9</sup> See Kelejian and Prucha: <http://www.econ.umd.edu/~prucha/STATPROG/OLS/desols.pdf>.

<sup>10</sup> The procedures were written in Gauss and are available by the authors upon request.

<sup>11</sup> To test for the fragility of the estimated parameters, we estimated the system of equations including dummy variables for each of the ten USDA/ERS production regions in the farmland value equation. Neither the estimated coefficients from Equation 18 nor the estimated spatial autocorrelation coefficient change significantly with this respecification. Thus, the estimated coefficients presented in Table 2 are robust with respect to regional specifications.

<sup>12</sup> Again, to test for the fragility of the estimated accessibility coefficient, which is the main variable of interest, we estimated the system of equations including dummy variables for each of the ten USDA/ERS production regions in the net returns to agriculture equation. The estimated coefficient did not change significantly with this respecification.

<sup>13</sup> We include the intercept and year-dummy terms in the effect of soil characteristics, since any other specification would yield implausibly large von Thunen components for many rural and greatly agricultural counties. For a similar justification see Plantinga, Lubowski, and Stavins.

**Table 1. Share of High-Valued Crops, Ranked by Accessibility Index**

Number of Counties	1997		1992	
	Accessibility range	Average share of high-valued crops	Average share of high-valued crops	Accessibility Change
84	7492.8 - 1005.7	0.202	0.185	0.101
122	996.2 - 500.5	0.124	0.115	0.150
384	493.6 - 200.6	0.092	0.085	0.146
572	199.5 - 100.0	0.050	0.043	0.124
815	99.9 - 45.0	0.035	0.030	0.104
940	44.9 - 0.47	0.016	0.015	0.070

Note: Quintile grouping of the counties does not alter the qualitative results.

**Table 2 Generalized Spatial 3SLS Estimates for the Farmland Value Equation**

Variable	Description	Coefficient estimate	Standard error
<b>Dependent variable: Logarithm of farmland value <math>V_A(i,t)</math>, (\$/acre)</b>			
	Intercept	1.4021 <sup>a</sup>	0.2228
$R_{AG}(i,t)$	Net returns to agriculture (\$/acre)	0.0037 <sup>a</sup>	0.0001
$\ln(H(i,t))$	Median single-family house value (\$)	0.4021 <sup>a</sup>	0.0216
$\ln(AC(i,t))$	Accessibility index (see text)	0.2223 <sup>a</sup>	0.0067
Year	Year dummy, 1997=1	-0.0118	0.0205
$\rho_V$	Spatial autocorrelation coefficient	0.0972	

<sup>a</sup>denotes statistical significant estimate at the 0.01 level of confidence.

**Table 3 Generalized Spatial 3SLS Estimates for the Net Agricultural Returns Equation**

Variable	Description	Coefficient estimate	Standard error
<b>Dependent variable: Net Returns to Agriculture <math>R_{AG}(i,t)</math> (\$/acre)</b>			
	Intercept	48.1907 <sup>a</sup>	14.4112
AC	Accessibility index (see text)	0.0789 <sup>a</sup>	0.0035
text	Soil texture (index)	3.6493 <sup>a</sup>	1.3312
catex	Cation exchange capacity (meg/100g)	0.4066 <sup>c</sup>	0.2660
ph	Soil reaction (pH)	-13.8290 <sup>a</sup>	1.7549
om	Organic matter (%)	1.1201 <sup>c</sup>	0.8674
tfact	T-factor erosion tolerance (index)	0.1689	1.2197
calcarb	Calcium carbonate (%)	-0.2435	0.4875
wattabd	Water table depth (inches)	-9.5319 <sup>a</sup>	1.3591
bulkd	Bulk density (grams/ccm)	41.5655 <sup>a</sup>	8.4489
perm	Permeability(inches)	4.5167 <sup>a</sup>	0.8364
slinity	Salinity (mmhos/cm)	-5.3150 <sup>a</sup>	1.7122
drainage	Drainage (index)	-0.0331	1.1777
soild	Soil depth (inches)	0.7751 <sup>a</sup>	0.2172
rock3	Three-inch rocks (%)	-0.1199	0.3961
PIr	Irrigated acres (%)	3.7443 <sup>a</sup>	0.1387
PSDI1	Palmer index – Planting season	-3.6486 <sup>b</sup>	1.5812
PSDI2	Palmer index – Harvesting season	-0.9827	1.1719
PSDI3	Palmer index – Fallow season	1.1570	1.7241
Year	Year dummy, 1997=1	23.0089 <sup>a</sup>	5.5553
$\rho_R$	Spatial autoregressive coefficient	0.1007	

<sup>a</sup>, <sup>b</sup> and <sup>c</sup> denote statistical significance at the 0.01, 0.05, and 0.10 level of confidence, respectively.

**Table 4 Generalized Spatial 3SLS Estimates for the House Value Equation**

Variable	Description	Coefficient estimate	Standard error
<b>Dependent variable: Logarithm of Median House Value <math>H(i,t)</math> (\$)</b>			
	Intercept	1.8576 <sup>a</sup>	0.1554
$\ln(M(i,t))$	Median household income (\$)	0.8271 <sup>a</sup>	0.0155
$\ln(AC(i,t))$	Accessibility (index)	0.1000 <sup>a</sup>	0.0031
$DPD(i,t)$	Residential population growth	4.1281 <sup>a</sup>	0.1885
NEN	Dummy for New England region	0.5066 <sup>a</sup>	0.0287
MAT	Dummy for Middle Atlantic region	0.2115 <sup>a</sup>	0.0223
SAT	Dummy for South Atlantic region	0.1825 <sup>a</sup>	0.0165
GLA	Dummy for Great Lakes region	0.1219 <sup>a</sup>	0.0155
NCE	Dummy for North Central region	0.0944 <sup>a</sup>	0.0171
SCE	Dummy for South Central region	0.0770 <sup>a</sup>	0.0175
MOU	Dummy for Mountain region	0.4520 <sup>a</sup>	0.0182
PAC	Dummy for Pacific region	0.5961 <sup>a</sup>	0.0230
Year	Year dummy, 1997=1	0.0218 <sup>b</sup>	0.0098
$\rho_H$	Spatial autoregressive coefficient	0.1021	

<sup>a</sup> and <sup>b</sup> denote statistical significant estimate at the 0.01 and 0.05 level of confidence, respectively.

**Table 5 The Contribution of Soil Productivity/Quality and Von Thunen Components to the 1997 Values of US Net Agricultural Returns, by State (in Real 2000, Dollars per Acre)**

State	Soil productivity/quality component (\$/acre)	von Thunen component (\$/acre)	von Thunen share of net returns to agriculture (percent)
New Jersey	125.6	90.4	0.419
Connecticut	80.0	54.7	0.406
Rhode Island	115.8	66.2	0.364
Massachusetts	110.0	58.2	0.346
Maryland	97.1	41.5	0.299
Pennsylvania	76.4	27.2	0.262
Ohio	69.8	21.2	0.233
South Dakota	3.9	0.9	0.192
New York	80.3	16.7	0.172
Michigan	95.5	19.4	0.169
Virginia	70.0	13.1	0.157
Indiana	89.7	16.5	0.155
Tennessee	67.5	12.4	0.155
Arizona	21.0	3.8	0.154
Delaware	157.5	26.4	0.144
New Hampshire	102.1	17.1	0.143
Kentucky	65.0	10.6	0.140
South Carolina	81.5	12.7	0.134
North Carolina	106.8	16.3	0.132
Illinois	85.1	12.9	0.131
West Virginia	58.0	7.9	0.120
Alabama	68.8	8.9	0.114
Texas	44.9	5.7	0.113
Oklahoma	36.7	4.7	0.113
Wisconsin	87.9	10.9	0.110
California	161.2	18.8	0.104
Florida	182.3	20.5	0.101
Vermont	59.4	6.7	0.101
Georgia	98.2	9.9	0.091
Missouri	78.6	6.4	0.076



**Table 5 The Contribution of Soil Productivity/Quality and Von Thunen Components to the 1997 Values of US Net Agricultural Returns, by State (in Real 2000, Dollars per Acre) (continued)**

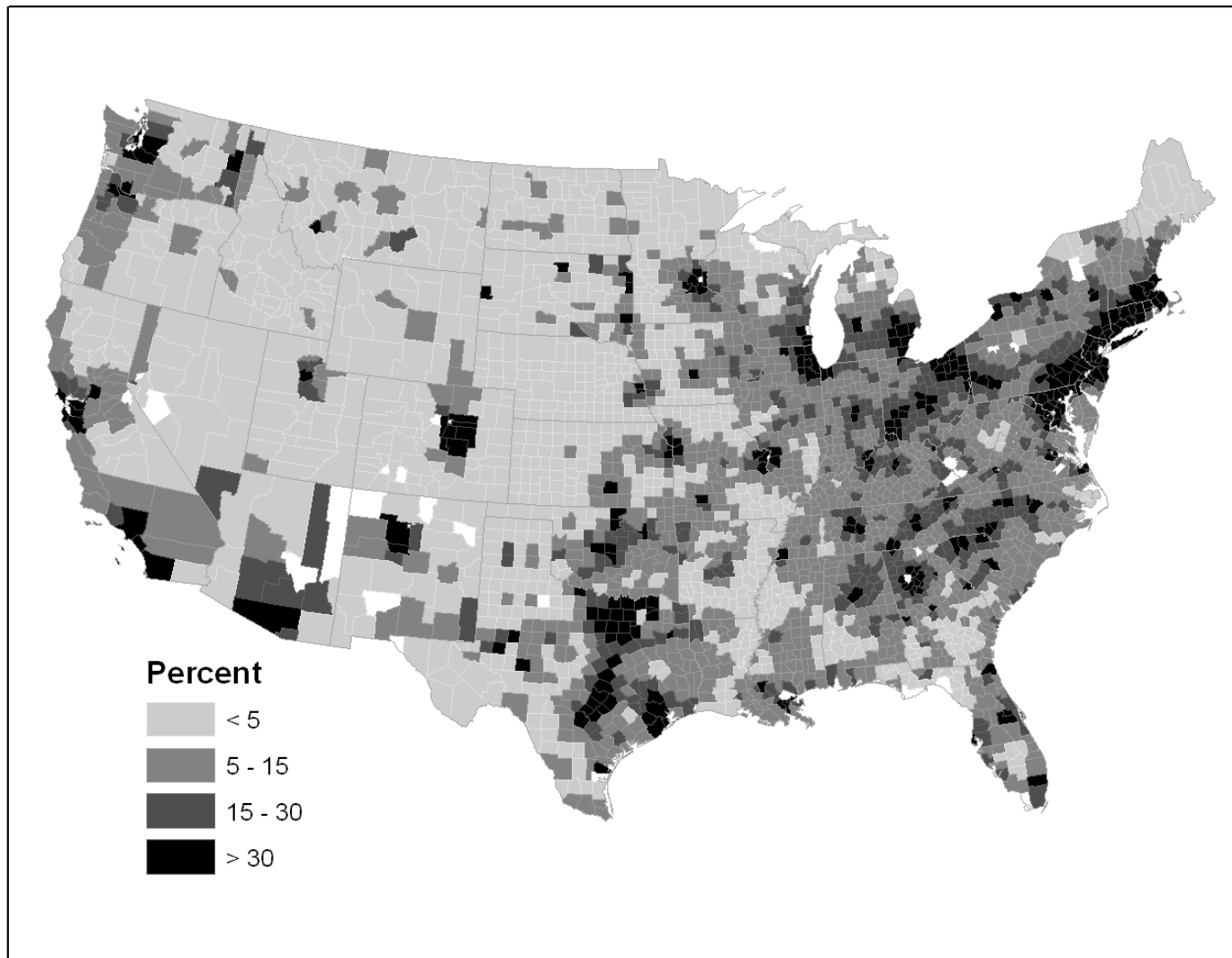
State	Soil productivity/quality component (\$/acre)	von Thunen component (\$/acre)	von Thunen share of net returns to agriculture (percent)
Iowa	69.8	5.4	0.072
Minnesota	74.0	5.7	0.071
New Mexico	21.5	1.5	0.066
Washington	59.1	4.2	0.066
Colorado	57.4	4.0	0.065
Louisiana	125.4	8.1	0.061
Utah	50.6	3.0	0.056
Maine	99.3	5.3	0.051
Mississippi	117.4	6.2	0.050
Oregon	61.9	2.9	0.044
Kansas	68.4	3.0	0.043
Arkansas	174.6	5.7	0.032
Montana	16.9	0.6	0.032
North Dakota	32.9	0.9	0.028
Wyoming	26.0	0.6	0.024
Idaho	125.0	2.8	0.022
Nebraska	90.0	2.0	0.022
Nevada	66.7	1.1	0.017

**Table 6 The Contribution of Urban and Agricultural Components to the 1997 U.S. Farmland Values, by State (in Real 2000, Dollars per Acre)**

State name	Value of Farmland (\$/acre)	Change in Farmland Value (\$/acre) in 2000 from 1% Change in			
		$R_{AG}$ (\$/acre)	$R_U$ (\$/acre)	Speculative Urban pressure (\$/acre)	von Thunen (\$/acre)
New Jersey	6,956	58.99	27.97	15.46	27.98
Connecticut	6,221	34.47	25.02	13.83	14.97
Rhode Island	6,186	43.09	24.88	13.75	15.79
Massachusetts	5,462	38.31	21.97	12.14	15.00
Maryland	3,316	17.94	13.34	7.37	6.45
Delaware	2,784	19.26	11.20	6.19	3.18
California	2,768	21.40	11.13	6.15	2.59
Pennsylvania	2,501	10.63	10.06	5.56	3.59
New Hampshire	2,385	11.49	9.59	5.30	2.03
Florida	2,372	20.09	9.54	5.27	2.34
Illinois	2,235	8.47	8.99	4.97	1.36
North Carolina	2,186	10.11	8.79	4.86	1.57
Indiana	2,172	8.83	8.74	4.83	1.49
Ohio	2,150	7.74	8.65	4.78	2.02
Virginia	2,027	6.52	8.15	4.51	1.26
Tennessee	1,901	5.72	7.64	4.22	1.12
Iowa	1,786	5.06	7.18	3.97	0.39
Michigan	1,756	7.93	7.06	3.90	1.67
Vermont	1,595	3.95	6.41	3.54	0.43
Georgia	1,575	6.46	6.33	3.50	0.86
South Carolina	1,572	5.45	6.32	3.50	0.89
Kentucky	1,525	4.51	6.13	3.39	0.79
Alabama	1,513	4.46	6.09	3.36	0.60
New York	1,350	5.72	5.43	3.00	1.46
Wisconsin	1,309	4.98	5.26	2.91	0.69
Washington	1,271	3.89	5.11	2.82	0.41
Louisiana	1,268	6.16	5.10	2.82	0.47
Maine	1,257	5.00	5.06	2.79	0.36
Minnesota	1,225	3.82	4.93	2.72	0.39
Arkansas	1,216	7.99	4.89	2.70	0.29
West Virginia	1,150	2.90	4.62	2.56	0.41
Missouri	1,125	3.83	4.52	2.50	0.37

**Table 6 The Contribution of Urban and Agricultural Components to the 1997 U.S. Farmland Values, by State (in Real 2000, Dollars per Acre) (continued)**

State name	Value of Farmland (\$/acre)	Change in Farmland Value (\$/acre) in 2000 from 1% Change in			
		$R_{AG}$ (\$/acre)	$R_U$ (\$/acre)	Speculative Urban pressure (\$/acre)	von Thunen (\$/acre)
Mississippi	1,105	5.06	4.44	2.46	0.28
Idaho	1,070	5.97	4.30	2.38	0.16
Oregon	1,009	3.40	4.06	2.24	0.42
Nebraska	683	3.20	2.75	1.52	0.10
Colorado	648	1.81	2.61	1.44	0.15
Oklahoma	641	1.10	2.58	1.42	0.16
Texas	628	1.35	2.53	1.40	0.29
Kansas	608	1.69	2.44	1.35	0.12
Utah	607	1.82	2.44	1.35	0.20
Arizona	469	1.61	1.89	1.04	0.18
North Dakota	422	0.55	1.70	0.94	0.02
Nevada	413	1.71	1.66	0.92	0.04
South Dakota	366	0.18	1.47	0.81	0.02
Montana	309	0.32	1.24	0.69	0.01
Wyoming	234	0.36	0.94	0.52	0.01
New Mexico	208	0.24	0.84	0.46	0.02



Note: Counties with white color indicate missing observations, and the label defines the urban share of net returns to agriculture.

**Figure 1 Estimated Share of Urban Influence on Net Returns to Agriculture**

## Appendix: Data Sources and Variables Definition

$V_A(i, t)$  is the average market value (dollars) of farmland (all land in farms) and buildings in county  $i$  per unit of land (acres) in 1992 and 1997. These data are reported in the Census of Agriculture 1997 as a county average (dollars per acre).  $V_A(i, t)$ , as all the economic variables were converted to real 2000 dollars using the personal consumption expenditures index (PCE).

$H(i, t)$  is the median value (dollars) for specified owner-occupied housing units in county  $i$  in 1992 and 1997. It consists of the owner-occupied single-family homes on less than 10 acres without a business or medical office on the property. These data were taken from the decennial Census of Population and Housing (Summary Tape File 3), which are reported in 1990 and 2000 at the county level (<http://factfinder.census.gov>). We used the House Price Index ( $HPI$ ) provided by the Office of Federal Housing Enterprise Oversight (OFHEO) and linear extrapolation and interpolation to project the 1990 and 2000 values to 1992 and 1997. This index is reported quarterly at the state level (<http://www.ofheo.gov/>) and tracks changes in the price of single-family homes. A median lot size for single-family homes is not available at the county level but only at the four regions of U.S. and so any attempt to project these lot sizes in order to get the median house value per acre would add considerable measurement error.

$R_{AG}(i, t)$  is the average net return (dollars per acre) to agriculture in county  $i$  in 1992 and 1997. The data were taken from the Agricultural Census and  $R_{AG}(i)$  at time  $t$  is computed as  $(TR_i - TC_i - GP_i) / A_i$ , where  $TR_i$  is the dollar value of all agricultural products sold,  $TC_i$  is the total farm production expenses,  $GP_i$  are the total government payments received by farmers and  $A_i$  is the approximate land in farms (acres).

$S(i)$  is a vector of soil characteristics in county  $i$  and is the same for both years in the sample. It was obtained from ERS and a formal definition of each variable can be found at the website of the National Resources and Conservation Service (<http://soils.usda.gov/>) of the USDA.  $Plr$  is the percent of irrigated acres in each county as reported in the Agricultural Census.

PDSI is the palmer severity drought index, for county  $i$ , where we have estimated 3 average values for each county at a given year corresponding to the planting (April-July), harvesting (August-November) and fallow season (December-March). This is a water balance index that considers water supply (precipitation), demand (evapotranspiration) and loss (runoff) for each county. It was obtained from the NCDC at <ftp://ftp.ncdc.noaa.gov/pub/data/cirs/> and is reported by climatic divisions of each state.

$M(i, t)$  is the median household income in county  $i$  in 1992 and 1997 (in dollars). These data were taken from the decennial Census of 1990 and 2000, where are reported in 1989 dollars for the year 1990 and in 1999 dollars for the year 2000. To find the corresponding 1992 and 1997 median household incomes we used as an index the per capita personal income ( $PCI$ ) in each county of the US for all the years in the period 1989-2000. These data were available online at the Bureau of Economic analysis website, through the Regional economic information system (REIS) cd-rom (<http://www.bea.gov>). We followed a similar interpolation as in the case of median house values.

$DPD(i, t)$  is the average residential population growth rate in county  $i$  during the five years preceding 1992 and 1997 and it was normalized in people per 1000 acres in each county. Data on county residential population were taken from the Census cd-rom (USA Counties 1998) for the period 1987-1997. Then for each county we divided total county population by the total

land area (in 1000 acres) available for the Agricultural Census. To estimate the growth rate of residential population in 1992 and 1997, we used the arithmetic mean of the growth rate for five years before the years in question.

*RD* is a set of regional dummies as were classified in Theil and Moss (2000). Specifically, it consists from the following regions: New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont), Middle Atlantic (Delaware, Maryland, New Jersey, New York, Pennsylvania), South Atlantic (Florida, Georgia, North and South Carolina, Virginia, West Virginia), Great Lakes (Illinois, Indiana, Michigan, Ohio, Wisconsin), North Central (Iowa, Minnesota, Nebraska, North and South Dakota), South Central (Kansas, Oklahoma, Texas), Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming), Pacific (California, Oregon, Washington) and the lower Mississippi region that was dropped as a base.