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VALUING FARMLAND: SPATIAL PRODUCTIVITY DIFFERENCES AND FINANCIAL SOLVENCY

Invited paper submitted by the United States of America*

Abstract. The valuation of farmland is used for several purposes in the development of agricultural and trade policy. Farmland values have historically represented 68 percent of the agricultural balance sheet in the United States. In addition, farmland values are important considerations in the calculation of index numbers used to analyze changes in productivity and competitiveness. Farmland values, however, may be affected by factors tangential to agricultural policy concerns. This study examines two such impacts. First, the study examines the effect of changes in sector solvency on farmland valuation. Second, the study examines the potential impact of spatial differences in productivity. Measurement of these impacts may be complicated by the presence of urban sprawl in the United States. The effect of solvency is important due to concept of the decoupling of farm program payments.

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1. Farmland values in the United States represent a major component of the agricultural balance sheet. For the United States as a whole, farmland values accounted for an average of 68 percent of total agricultural assets between 1960 and 1999 (see figure 1). This is important for three reasons. First, the opportunity cost on farmland values represents a major production expense**.** Second, the sector's solvency is intimately linked to farmland valuation. Finally, related to the opportunity cost of farmland, the valuation of farmland has a significant effect on the estimation of productivity and competitiveness across regions. In addition, the linkage between farmland values and sector solvency raises an additional avenue for farm programs to affect farmland values. Specifically, the linkage between sector solvency and farmland values may increase the coupling of farm program payments to production. Urban pressures have also affected farmland values in the United States. Growth in urban areas in the United States (typically referred to as urban sprawl) has two affects on farmland values. First, urbanization increases the demand for farmland for conversion into urban uses (housing, malls, etc.). Second, the growth of urban areas may cause alternative agricultural markets to emerge such as nurseries, sod farms, and vegetable production. The difference in the two urban affects is significant. Specifically, increases in land value that result from the opportunity for conversion do not represent changes in productivity, while the growth of alternative high value crops implies increased agricultural productivity. This study presents some empirical results for the effect of solvency and urban pressures on farmland in the United States. Both sets of results highlight the use of agricultural panel data (both variation across space and across time).

2. The remainder of this paper is organized into four sections. The first section develops an overall model for agricultural asset valuation. Following the development of the general model, we then present the empirical results of the effect of solvency on farmland valuation. These results are taken from a more extensive study by Mishra, Moss and Erickson (2001). The third section then presents the empirical model and the impact of urban growth on productivity. These results are taken from a more extensive study by Livanis et al. (2001).

Modeling Farmland Values

3. The rental price of farmland is based on the shadow value of farmland. The profit maximization problem facing the farm firm is to maximize profit subject to intermediate investments and land. If the shadow value of farmland is above the annualized market price of farmland, the producer chooses to purchase additional acres. We assume that the purchase of farmland will be financed by issuing new debt (taking out a loan). The model of farm profit then becomes:

$$\begin{aligned} \max_{y,x,D,A,I} \boldsymbol{p} &= py - wx - r(D,v)D \\ st \quad & f(y,x,A,I) = 0 \\ & I \leq I_0 \\ & D = D_0 + (A_0 - A)v \end{aligned} \qquad (1)$$

where p is the vector of output prices, y is the vector of outputs, w is the vector of input prices, x is the vector of inputs, $r(D,v)$ is the interest rate paid on agricultural debt, D is the level of agricultural debt, v is the value of farmland, $f(y,x,A,I)$ is a technological envelope of production possibilities, I is the level of intermediate capital, I_0 is the fixed level of intermediate capital, D_0 is the level of initial debt, and A_0 is the initial land holding.

4. To impose the assumption that additional capital is raised through debt, we begin by specifying equity using the accounting identity.

$$E_0 = A_0 v + I_0 - D_0 \text{ . (2)}$$

By the same concept, the value of equity for the current level of land and debt are determined by A, I_0, D and the value of land

$$E = Av + I_0 - D \text{ . (3)}$$

Taken together equations 2 and 3 imply the capital constraint in equation 1 given that E=E_0 which must be true if we eliminate pure arbitrage (if we assume that the farmer cannot instantaneously make him or herself better off simply by purchasing farmland). The capital restriction is then implicit in the last constraint in equation 1.

5. Given the maximization problem in equation 1, we form the Lagrangian:

$$L = py - wx - r(D,v)D - m_1\left(f\left(y,x,A,I\right)\right) + m_2\left(I_0 - I\right) + m_3\left(D - D_0 - \left(A_0 - A\right)v\right) \text{ (4)}$$

where ì$_1$ is the shadow value of the technological envelope, ì$_2$ is the shadow value of intermediate assets, and ì$_3$ is the shadow value of new debt. Focusing on the first order conditions with respect to land and debt yields:

$$\begin{aligned} \frac{\partial L}{\partial D} &= \frac{\partial r(D,v)}{\partial D}D + r(D,v) - m_3 = 0 \Rightarrow m_3 = \frac{\partial r(D,v)}{\partial D}D + r(D,v) \\ \frac{\partial L}{\partial A} &= -m_1\frac{\partial f\left(y,x,A,I\right)}{\partial A} - m_3 v = 0 \end{aligned} \qquad (5)$$

In order to simplify the formulation, first note that by definition of the shadow values

$$-m_1\frac{\partial f\left(y,x,A,I\right)}{\partial A} = \frac{\partial \boldsymbol{p}}{\partial A} \text{ (6)}$$

Next, we substitute the first condition in equation 5 into the second first-order condition in equation 5 along with equation 6 to yield

$$\frac{\partial \boldsymbol{p}}{\partial A} - \left(\frac{\partial r(D,v)}{\partial D}D + r(D,v)\right)v = 0 \text{ (7)}$$

Equation 7 yields an implicit form of the demand equation for rented farmland. Specifically, taking the marginal interest rate as fixed by the capital market, equation 7 determines the price of farmland that will clear the rental market. Alternatively, with some minor rearrangements, this expression yields the capitalization formula

$$v = \frac{\dfrac{\partial \boldsymbol{p}}{\partial A}}{\dfrac{\partial r(D,v)}{\partial D} + r(D,v)} \text{ . (8)}$$

Assuming that agricultural interest rates are constant, equation 8 then yields the typical capitalization of future rents.

6. While the market equilibrium condition in equation 8 resembles the standard formulation of farmland values as the capitalized value of future rents, the formulation in equation 7 emphasizes the market content of the rental market for farmland. Specifically, following Ricardian notions, the equilibrium rental rate for farmland completely exhausts the profit accruing to the land. The remainder of this paper builds on this basic insight to develop two distortions to the farmland market. The first distortion involves impact of capital markets on the equilibrium rental rate for farmland and, hence, on farmland values. The second distortion involves the effect of urban pressures on the equilibrium rental rate.

The Effect of Solvency on Farmland Values

7. The seminal paper by Modigliani and Miller (1958) demonstrates that the form of ownership (debt or equity) does not affect the value of an asset if capital markets are in equilibrium. Specifically, a potential investor would issue equity to purchase debt or issue debt to purchase equity making the ownership structure of the assets irrelevant. The appropriateness of these arbitrage assumptions in the case of agricultural assets, however, is subject to considerable debate. Historically, equity has traditionally entered agriculture primarily through the debt market. Empirically, the results of Barry (1980) suggest that agricultural assets earn an expected rate of return over what can be explained by relative risk. Such a premium suggests the lack of effective arbitrage between agricultural and non-agricultural investments and casts doubt on the applicability of Modigliani-Miller results for agriculture in the United States.

8. One possible result of the arbitrage equilibrium is that infusions of equity, such as the infusions due to the production flexibility contracts (PFCs) under the FAIR Act of 1996 may affect production. The FAIR Act was originally heralded as a dramatic shift in agricultural policy in the United States. Previous agricultural programs paid farmers on the basis of current or past production. As such, these programs distorted markets by encouraging increased production in the domestic market. Following the Uruguay Round Agreement of the World Trade Organization, domestic policy makers faced an incentive to decouple agricultural support payments, or to develop policy instruments that did not encourage excess production. Under the FAIR Act the farmers received PFC payments regardless of production decisions. These payments were loosely akin to a “buy-out” of payments that would have been received under previous policies. In addition, farmers could choose to plant other crops without losing these payments. Given these characteristics, it was argued that the U.S. Farm Program had been decoupled.

9. The linkage between farmland values, equity, and the capital market, however, implied that the PFCs were not decoupled. Specifically, the infusion of equity through the PFCs induced investment in productive assets such as machinery and land. This section of the paper presents a model developed to examine the linkage between agricultural equity and the land market. The results indicate that farmland values are an increasing function of agricultural equity. This linkage can be primarily attributed to the effect of agricultural equity on the interest rate paid by farmers.

10. From an accounting standpoint, as depicted in the accounting identity, the PFC payments could be used to either purchase new assets or pay off accumulated debt. In either case, the aggregate debt-to-asset ratio for domestic agriculture would decline leading to a relatively more solvent sector. Assuming that banks use option pricing to price the interest rate, this decline in the debt-to-asset position implies that the optimal interest rate charged by the bank would decline due to a reduction in bankruptcy risk (Merton, 1974).

11. If we restrict the effect of additional debt on the interest rate to a multiplicative relationship, we can reformulate equation 8 as

$$v = \frac{\frac{\partial \boldsymbol{p}}{\partial A}}{r\,\boldsymbol{a}(D)}, \quad (9)$$

$$\text{where } \frac{\partial \boldsymbol{a}(D)}{\partial D} > 0, \boldsymbol{a}(0) \geq r_f \quad (10)$$

where r_f is some risk free rate. Using Merton's work we can argue that the interest rate on debt is only a function of the required rate of return, r_f, and the probability of default or debt solvency.

12. Taking the natural logarithm difference of each side of equation 9 yields

$$d\ln(v_t) = d\ln\left(\frac{\partial \boldsymbol{p}}{\partial A_t}\right) - d\ln(r_t) - d\ln(\boldsymbol{a}(D_t)). \quad (11)$$

Thus, to test for the importance of credit endogeneity, we can estimate

$$d\ln(v_t) = \boldsymbol{b}_0 + \boldsymbol{b}_1 d\ln(R_{At}) + \boldsymbol{b}_2 d\ln(r_t) + \boldsymbol{b}_3 d\ln(T_t) \quad (12)$$

where R_A is the rate of return to farmland, r is the average interest rate on farm borrowing, and T is a debt-servicing ratio[1]. To further examine the role of government support in the valuation of farmland, we append the government payments as a share of income to equation 12.

13. We estimated the empirical model specified in equation 12 using a panel data approach. The data was developed from the U.S. Department of Agriculture, Economic Research Service state-level data for 46 states[2] (excluding Alaska, Hawaii, Pennsylvania and West Virginia), across 10 production regions and 46 states from 1960 to 1998. These annual data on land values, interest rates, returns to farm assets, government payments, and debt servicing ratios are derived from a variety of sources such as the Census of Agriculture.

14. The estimated results for this model are presented in table 1. The model was estimated using both the fixed and random effects techniques and in linear-logarithm form. Thus, parameter estimates directly correspond to elasticities. In each case, the Hausman test suggested that the fixed effects estimator was the correct specification. Standard F-tests of the fixed cross-sectional effects confirmed their statistical significance.

15. The results presented in table 1 are consistent with the theorized linkage between solvency and farmland values. In place of the debt-to-asset ratio, this study used the debt service ratio. The debt service ratio is the share of income required to service debt obligations. As the

debt to asset ratio increases, the debt service ratio rises. Thus, the negative estimated effect of the debt service ratio for the entire U.S. dataset is consistent with an overall solvency effect. In fact the estimated coefficient is only positive in the Appalachian states. Further, this coefficient is not statistically significant at any conventional confidence level.

Urban Sprawl Versus Productivity

16. A second modification to the standard land value problem involves the effect of urbanization. The rise in industry in the United States in the years after the 1900 saw a migration from the rural communities to urban centers as employment opportunities increased and mechanization replaced farm labor. While this trend continued following World War II, a counter-migration of laborers to the suburbs then started to affect agriculture in the United States. Recently the expansion of cities into farmland around cities has become the focus on increased policy concerns. Numerous state and local governments have passed regulations limiting the growth of urban areas. These regulations are intended to address a myriad of concerns associated with the loss of farmland from the loss of open spaces and environmental amenities to the potential loss of productive farmland.

17. Urban sprawl affects the analysis of farmland in two ways. First, the increased potential for conversion into urban uses increases the price of farmland. Second, the proximity to urban populations may increase the profitability of specialty crops such as nurseries, sod, and vegetables. Given that these specialty crops are more profitable than more commodity oriented crops, farmland values will also increase due to these opportunities. However, the increased profit opportunities due to specialty crops implies that the farmland has become more productive while the increased farmland values due to conversion into non-agricultural uses do not represent changes in productivity.

18. To develop a empirical model of these two effects, we begin by considering farmland values as the sum of economic rents from farming plus the value of future conversion to urban use:

$$V(t) = E\left[\int_t^\infty e^{-rs} R_{AG}(s)ds\right] + E\left[\int_t^\infty e^{-rs} R_U(s)ds\right] \quad (13)$$

where $R_{AG}(s)$ is the return to farmland in period s, $R_U(s)$ is the return to urbanization in period s, r is the discount rate and $E[.]$ is the expectation function. Breaking 13 down into parts,

$$E\left[\int_t^\infty e^{-rs} R_{AG}(s)\,ds\right] \quad (13a)$$

is the expected return on farmland from agricultural activities. This expectation is based on a variety of random variables including agricultural prices, weather, etc. In addition, for the purpose of this study, the expected value of agricultural production is a function of urbanization. More rigorously, we assume the existence of a random variable $z(t)$ that is equal to zero before urbanization and one after urbanization. The expectation function in 13a can then be rewritten as

$$\int_{t}^{\infty} e^{-rs} R_{AG}(s)\, z(s)\, f(z,s)\, ds \quad \text{(13a')}$$

where *f(z,s)* is the probability that urbanization occurs in period *s*. By extension, the second half of 13 represents the value of conversion of farmland into urban use. Taken together, the two halves of the equation form a switching function where the value of farmland is determined by the return in agriculture up to the point of urbanization plus the value of farmland for urbanization. In this formulation, we assume that the urbanization event itself is random[3].

19. If we assume that urbanization follows a Poisson arrival process, the probability of farmland remaining in agriculture is:

$$f(t,\mathbf{q}) = \mathbf{q}e^{-qt} \quad (14)$$

(Feller 1950, pp. 444-8). To derive the probability that urbanization occurs in period *t*, we assume that no urbanization has occurred until period *t*-ä. è is a parameter related to the expected time to urbanization. Specifically, the expected arrival time is 1/è. The probability that urbanization occurs in period *t* given that no urbanization has occurred to period *t*- ä, assuming that the two events are independent, becomes

$$g(t,\mathbf{q}) = f(t-\mathbf{d},\mathbf{q})\left(1 - f(t,\mathbf{q})\right) = \mathbf{q}e^{-q(t-d)}\left(1 - \mathbf{q}e^{-qt}\right) \quad (15)$$

Taking the limit as ä approaches zero then yields

$$g(t,\mathbf{q}) = \mathbf{q}e^{-qt} - \mathbf{q}^2 e^{-2qt} \quad (16)$$

Assuming that the rate of return to agriculture and the return to urbanization are constant over time and substituting equations 14 and 16 into equation 13 yields

$$V(t) = \frac{\mathbf{q}e^{-t(r+q)}}{r+\mathbf{q}} R_{AG} + \frac{e^{-t(r+2q)}\mathbf{q}\left(\mathbf{q}(r+\mathbf{q}) - (r+2\mathbf{q})e^{-tq}\right)}{(r+\mathbf{q})(r+2\mathbf{q})} R_U \quad (16)$$

Evaluating this expression at *t*=0 yields

$$V(0) = \frac{\mathbf{q}}{r+\mathbf{q}} R_{AG} + \frac{\mathbf{q}\left(r + 2\mathbf{q} - r\mathbf{q} - \mathbf{q}^2\right)}{(r+\mathbf{q})(r+2\mathbf{q})} R_U \quad (17)$$

20. Breaking this expression down into parts, the first part of equation 17 is the discounted value of agricultural returns. As in the standard farmland pricing formula, the value of farmland is an increasing function of the return to agriculture and a decreasing function of the discount rate. In addition, the value of farmland is now a function of the è parameter in the exponential distribution. Note that since the expected value of the exponential distribution is 1/è, the discounted value of agricultural returns is inversely related to the expected length of time to urbanization. Dividing equation 17 through by its left-hand side, this implies that the longer the expected time to urbanization the larger the percent of farmland value contributed by agricultural returns. The second term on the right-hand side of equation 17 is the discounted expected time of development.

21. Taking the variation around equation 17 at t=0 and holding the discount rate constant yields:

$$V'(0)=\frac{q}{r+q}dR_{AG}+\frac{q\left(r+2q-rq-q^2\right)}{(r+q)(r+2q)}dR_U+$$
$$\left[-\frac{2q+r}{(r+q)^2(r+2q)^2}R_{AG}+\frac{r^2(1-2q)+2r^2(2-3q)+2r(2-3q)-2q^4}{(r+q)^2(r+2q)^2}R_U\right]dq \quad (19)$$

The results from equation 19 can then be used to form a first-order Taylor series expansion of farmland values:

$$\begin{aligned} V &= a_0+a_1\left(R_{AG}-\overline{R}_{AG}\right)+a_2\left(R_U-\overline{R}_U\right)+a_3\left(q-\overline{q}\right)+O\left(\Delta^2\right) \\ &= \tilde{a}_0+\tilde{a}_1R_{AG}+\tilde{a}_2R_U+\tilde{a}_3q+O\left(\Delta^2\right) \end{aligned} \quad (20)$$

where the ás are estimated parameters and $O(\ ^2)$ is a second order approximation error.

22. Thus, equation 20 relates cross-sectional changes in farmland values to changes in agricultural returns, changes in the value of urbanization and changes in the probability of urbanization. The next step is to construct a model of farmland values that is consistent with the von Thunen effect on agricultural prices. We begin by maximizing profit presented in equation 1. Given that we are typically interested in the decisions at the farm level, we assume that the input and the output prices are exogenous. However, given that we are interested in the spatial variation of farmland prices, we expand the formulation in equation 1 as

$$\begin{aligned} &\max_{y,x,D}\ \left(p-t(d)\right)'y-w'x-rD \\ &st\qquad f(y,x,A,I)=0 \\ &\qquad\quad I\le I_0 \\ &\qquad\quad D=D_0+\left(A_0-A\right)v \end{aligned} \quad (22)$$

where ô (ä) is the transportation cost associated with each commodity and ä is some measure of distance. Forming the Lagrange multiplier of equation 23 yields

$$\begin{aligned} L=&\left(p-t(d)\right)'y-wx-r(D,v)D-m_1\left(f(y,x,A,I)\right)+ \\ &m_2\left(I_0-I\right)+m_3\left(D-D_0-\left(A_0-A\right)v\right) \end{aligned} \quad (23)$$

From this formulation, we want to develop the marginal value of each unit of output given the transportation cost and the marginal value of farmland. Focusing on the marginal value of each output first

$$\frac{\partial L}{\partial y_i}=\left(p_i-t_i(d)\right)-m_1\frac{\partial f(y,x,A,I)}{\partial y_i}=0 \quad (24)$$

This equation 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 imply a relative reduction in the output of that commodity. Equating the shadow value of production across all outputs yields

$$m_1 = \frac{\left(p_1 - \boldsymbol{t}_1(\boldsymbol{d})\right)}{\dfrac{\partial f\left(y,x,A,I\right)}{\partial y_1}} = \cdots = \frac{\left(p_n - \boldsymbol{t}_n(\boldsymbol{d})\right)}{\dfrac{\partial f\left(y,x,A,I\right)}{\partial y_n}} \quad (25)$$

Differentiating the shadow value with respect to distance then yields

$$\frac{\partial m_1}{\partial \boldsymbol{d}} = -\frac{\dfrac{\partial \boldsymbol{t}_i(\boldsymbol{d})}{\partial \boldsymbol{d}}}{\dfrac{\partial f\left(y,x,A,I\right)}{\partial y_i}} \leq 0 \quad (26)$$

as long as the transportation cost is an increasing function of distance. Thus, the economic rent from production declines with the increase in transportation costs consistent with the von Thunen framework.

23. Taking the partial derivative of equation 23 with respect to debt and asset values yields similar results to those presented in equation 5. Specifically, the equilibrium price of farmland becomes

$$v = \frac{-m_1 \dfrac{\partial f\left(y,x,A,I\right)}{\partial A}}{r} \quad (27)$$

Noting that the partial of the multiproduct production function with respect to land is negative, equation 27 is the same value as found in equation 17 if conversion to urban use never occurs. In particular, we are interested in specifying the return to agricultural activities in equation 17 as

$$R_{AG} = -m_1 \frac{\partial f\left(y,x,A,I\right)}{\partial A} \quad (28)$$

Merging the results of equation 14, we have

$$R_{AG} = -\frac{\left(p_i - \boldsymbol{t}_i(\boldsymbol{d})\right)}{\dfrac{\partial f(y,x,A,I)}{\partial y_i}} \frac{\partial f\left(y,x,A,I\right)}{\partial A} = \left(p_i - \boldsymbol{t}_i(\boldsymbol{d})\right)\frac{dy_i}{dA} \quad (29)$$

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

24. Given the results from equation 29 and assuming the quality of farmland is constant, we conclude that the 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,

$$\frac{dy_i}{dA} = \frac{\frac{\partial f(y, x, A, I)}{\partial A}}{\frac{\partial f(y, x, A, I)}{\partial y_i}} . \quad (30)$$

The solution depicted in equation 30 assumes that all crops are produced continuously throughout the region. The formulation in equation 22 could be changed to guarantee that only nonnegative quantities of crops could be chosen.

25. The empirical model of farmland values given the existence of a von Thunen effect both on agricultural output and urbanization is a simultaneous three equation system based on equation 20 above, differences in soil characteristics that give rise to differences in productivity, and an equation that models the value of conversion. Equation 20 is used to model the value of farmland as the sum of the value of land in production agriculture, plus the value of land at the point of urbanization.

$$V_c = a_0 + a_1 R_{AG,c} + a_2 H_c + a_3 DP_c + a_4 DL_c + \varepsilon_{1c} \quad (31)$$

where V_c is the value of farmland in county c, $R_{AG,c}$ is the gross revenue per acre for agriculture in county c, H_c is the housing value in county c, DP_c is the population growth rate in county c, DL_c is the rate of farmland loss in county c, and ε_{1c} is the error term. Within this formulation, we assume that the gross revenue to farmland, and the housing value are endogenously determined.

26. The value of land in production agriculture is equal to the gross return on each acre of farmland. This gross value is computed as the sum of the share of farmland in each crop times the gross revenue for each crop.

$$R_{AG,c} = \sum w_{ic} \left(p_{ic} q_{ic} \right) \quad (32)$$

where w_{ic} is the acreage share of crop i in county c, p_{ic} is the price of the output for crop i in county c, and q_{ic} is the quantity of crop i produced in county c. Following the hedonic pricing literature (Miranowski and Hammes 1984, Ball et al. 2000) for farmland, the gross revenue for agriculture in each county is modeled as a function of land characteristics:

$$R_{AG,c} = b_0 + b_1 Ac_c + \sum_{j=2}^{m} b_j x_c + \varepsilon_{2c} \quad (33)$$

where Ac_c is a measure of accessibility for county c, and the variables $x_{i,c}$ i=2,…m are a set of soil characteristics.

27. Finally, the house value in county c is modeled as a function of the accessibility variable, income, and the tax rate.

$$H_C = c_0 + c_1 Y_c + c_2 Ac_c + c_e T_c + \varepsilon_{3c} \quad (34)$$

where H_c is the house value in county c, Y_c is the income in county c, T_c is the real estate tax in county c, and ε_{3c} is an error term.

28. Cross sectional data yielded 2,965 counties. The difference in the actual number of counties can be explained by the fact that the states of Alaska and Hawaii were excluded and data are not reported in the *Census* if reporting violates confidentiality (usually less than 4 observations). Equations 31, 33 and 34 were estimated **using** three stage least squares, although the simultaneity of the model is mitigated by the block recursive nature of the system. The parameters estimated were then used to predict the average farmland value in each state. These estimates are presented in table 2. Column (a) of table 2 presents the estimated farmland values for each state holding the urban pressures (from equation 34) constant at the sample average and letting the hedonic coefficients and von Thunen effect on crop selection vary, column (c) presents the estimated farmland values holding both urban pressure and soil characteristics constant, and the results presented in column (e) present the observed market value of farmland in each state. Columns (b), (d), and (f) present the respective market values normalized by dividing the value of farmland in each case by the value of farmland in Alabama.

29. These results indicate that urbanization has a significant impact on land values that must be removed to depict changes in productivity. Specifically, the results presented in table 2 indicate that farmland values in Connecticut are 4.087 times those in Alabama. However, holding urban pressures equal to the sample average, farmland values are only 1.082 times those in Alabama. A portion of this decline is attributable to changes in soil quality (hedonic factors). If all the hedonic factors are held constant along with urbanization pressures, farmland values in Connecticut increase to 1.133 times Alabama. Thus, Connecticut does experience a von Thunen effect on crop selection. The impact of these effects can be contrasted with the results for Florida. Farmland values in Florida are 1.559 times those in Alabama. However, adjusting for urban pressures only causes the relative farmland values in Florida to decline to 1.510 times Alabama. Further, most of this premium can be attributed to hedonic factors since farmland in Florida is only 1.037 times those in Alabama once the hedonic factors are held constant.

Conclusions

30. This study examines the impact of sector solvency and urban sprawl on farmland values in the United States. The potential effect of these factors is an important consideration in the development of agricultural and trade policy**.** Since farmland represents nearly 70 percent of farm sector assets, changes in farmland values significantly affect balance sheet and financial ratio estimates. Furthermore, changes in farmland values also impact the calculation of index numbers used to estimate changes in productivity and competitiveness. The empirical results indicate that farmland values are increasing functions of sector solvency. Thus, agricultural policies that transfer equity to agriculture will lead to increased output even when the payment scheme does not directly increase the marginal input price. In other words, all farm programs are coupled through the capital constraint. In addition, farmland values vary spatially due to urbanization pressures, differences in hedonics, and differences in market opportunities due to different proximaties to urban markets. The relative share of farmland values due to conversion to urban uses appears to be significant for some states such as Connecticut. However, in other states, such as Florida, the largest spatial variation is attributable to hedonic characteristics.

NOTES

[1] Approximating $d\ln(n_t) = \ln(n_t) - \ln(n_{t-1})$ as in Moss.

[2] Complete dataset for these states were not available.

[3] The assumption that urbanization is a random event is used here as a convenience to derive a tractable econometric model. A more rigorous development involves the formulation of an optimal control model with a discontinuous or "Bang-Bang" control (Kamien and Schwartz 1982, pp. 186-91). In this formulation, the farmer maximizes the present value

$$\max_{\delta_i} E\left[\sum_{t=0}^{\infty} \beta^t \left(\{1-\delta_t\} R_{AG,t} + \delta_t R_{u,t}\right)\right]$$

where δ_t is the decision to convert farmland and β is the discount rate. For explanatory purposes, the Bellman formulation (Kamien and Schwartz pp. 238-49) becomes

$$\begin{aligned}\max_{\delta_0}\left[E\left(V_{AG,0}\right), E\left(R_{U,0}\right)\right] &= \max_{\delta_0}\left[E\left(R_{AG,0} + \max_{\delta_1}\left\{V_{AG,1}, R_{U,1}\right\}\right), E\left(R_{U,0}\right)\right] \\ &= \max_{\delta_0}\left[E\left(R_{AG,0} + \max_{\delta_1}\left\{\beta R_{AG,1} + \max_{\delta_2}\left\langle V_{AG,2}, R_{U,2}\right\rangle, R_{U,1}\right\}\right), R_{U,0}\right].\end{aligned}$$

This equation can be reformulated so that agricultural asset values follow a mixed Wiener and Poisson process similar to the portfolio process developed by Merton (Malliaris and Brock 1982, pp. 228-30) where the Wiener process represented the variation in returns to agriculture and the Poisson process depicted the jump process in urbanization. Specifically, the Bellman formulation can be rewritten as

$$\begin{aligned}&\max_{\delta_0} E\left[(1-\delta_0)\left(R_{AG,0} + bV^*\left\langle R_{AG,t}, R_{U,t}, \delta_t^*, t\right\rangle\right) + \delta_0 R_{U,0}\right] \\ &dR_{AG,t} = \alpha_{11}dt + \alpha_{12}dz_1 + \alpha_{13}d\xi_1 \\ &dR_{U,t} = \alpha_{21}dt + \alpha_{22}dz_2 + \alpha_{23}d\xi_2\end{aligned}$$

where $V^*\left\langle R_{AG,t}, R_{U,t}, \delta_t^*, t\right\rangle$ is the value of farmland remaining in agriculture for an additional year given that the optimal future conversion (δ_t^*) occurs, dz_1 and dz_2 are normal Brownian motion deviations for returns to agriculture and returns to urbanization, respectively, and $d\xi_1$ and $d\xi_2$ are Poisson deviations for the return to agriculture and the return to urbanization, respectively. In this application, we assume that the future returns to agriculture are known with certain, so the only variation is in the urbanization process. Finally, since conversion from agriculture to urban uses implies irreversibility, this valuation would be modified using the Dixit-Pindyck investment rules discussed in Purvis et al.

Table 1: Regression Results for Change in Farmland Values in U.S. and Other Selected Regions (1960-1998)

Region	Variables/Parameter Estimates						
	Intercept	Returns to Land	Interest Rate	Debt Service Ratio	Government Payments as a share of Income		Hausman Test Statistics
	b_0	b_1	b_2	b_3	b_4	R^2	
United States[1]	0.0806 ***[a]	0.0735***	-0.2825***	-0.4927***	0.0174***	0.79	16.85***
	(0.0148)[b]	(0.0070)	(0.0238)	(0.0800)	(0.0049)		
Cornbelt[2]	-0.0075	0.0514**	-9.4999**	-0.0359*	0.0273*	0.62	9.30**
	(1.1922)	(0.0238)	(3.9099)	(0.0199)	(0.0152)		
Northeast[3]	0.0281	0.0089	-1.0189***	-0.4873**	0.0149	0.59	22.30***
	(0.0296)	(0.0198)	(0.0387)	(0.2432)	(0.0140)		
Lake states[4]	0.0342	0.0379***	-4.2667**	-0.1600	0.0089	0.57	9.88**
	(0.6648)	(0.0155)	(2.1804)	(0.5926)	(0.0058)		
Northern plains[5]	0.0581	0.0769***	0.1092	-0.4112*	0.0381***	0.62	7.21*
	(0.1725)	(0.0170)	(0.6128)	(0.2362)	(0.0135)		
Appalachian states[6]	-0.0295	0.0202*	-0.3187***	0.1473	0.0068	0.57	15.35*
	(0.0322)	(0.0109)	(0.0978)	(0.1413)	(0.0094)		
Southeast[7]	0.0519	0.2736***	-0.5262***	-0.2979	0.1455*	0.63	37.76***
	(0.0610)	(0.0331)	(0.0927)	(0.3879)	(0.0698)		
Delta[8]	0.0898***	0.5775**	-0.6699***	-0.4835***	0.0619*	0.69	22.42***
	(0.0249)	(0.0216)	(0.0446)	(0.1161)	(0.0344)		
Southern plains[9]	0.2716***	0.0015	-0.3722***	-1.3217***	0.0003	0.57	8.66**
	(0.0857)	(0.0062)	(0.1317)	(0.1771)	(0.0026)		
Mountain states[10]	0.0816***	0.0686***	-0.7407***	-0.5007***	0.0238***	0.77	13.00**
	(0.0339)	(0.0156)***	(0.1687)	(0.1535)	(0.0095)		
Pacific states[11]	0.0979***	-0.0057	-0.9568***	-0.3537***	0.0229***	0.74	14.60**
	(0.0237)	(0.0155)	(0.0487)	(0.1571)	(0.0078)		

[a] Single, double, and triple asterisks indicate significance at the 10%, 5%, 1% level of significance, respectively.

[b] Numbers in parenthesis denote standard errors.

[1] Includes 46 states excluding AK, HI, PA, and WV. [2] Includes IL, IN, IA, MO, and OH. [3] Includes CT, DE, MA, MD, ME, NH, NJ, NY, RI, and VT, excludes PA. [4] Includes MI, MN, and WI. [5] Includes KS, NE, ND, and SD. [6] Includes KY, NC, TN, and VA, excludes WV. [7] Includes AL, FL, GA, and SC. [8] Includes AR, LA, and MS. [9] Includes OK and TX. [10] Includes AZ, CO, ID, MT, NV, NM, UT, and WY. [11] Includes CA, OR, and WA.

Table 2. Hedonically Adjusted Land Values Based on Agronomic and Von Thunen Affects

States	Hedonic and von Thunen Valuation		Von Thunen Valuation		Market Value of Farmland	
	Value ($s/Acre) (a)	Normalized Value (b)	Value ($s/Acre) (c)	Normalized Value (d)	Value ($s/Acre) (e)	Normalized Value (f)
			Northeast			
CT	1,814.759	1.082	2,004.369	1.133	5,917.772	4.087
DE	1,978.408	1.179	1,708.386	0.966	2,648.603	1.829
MA	2,042.471	1.217	2,033.184	1.149	5,097.978	3.521
MD	1,892.090	1.128	1,844.137	1.042	3,154.621	2.179
ME	1,583.005	0.943	1,548.851	0.875	1,196.100	0.826
NH	1,774.219	1.057	1,650.584	0.933	2,268.421	1.567
NJ	2,361.841	1.408	2,268.020	1.282	6,616.483	4.570
NY	1,556.160	0.927	1,656.924	0.937	1,284.179	0.887
PA	1,628.248	0.970	1,752.088	0.990	2,378.607	1.643
RI	1,949.034	1.162	2,000.825	1.131	5,884.741	4.064
VT	1,490.808	0.888	1,559.457	0.881	1,516.792	1.048
			Lake States			
MI	1,438.462	0.857	1,218.664	0.689	1,672.159	1.155
MN	1,241.318	0.740	1,093.586	0.618	1,165.498	0.805
WI	1,224.523	0.730	1,138.038	0.643	1,245.427	0.860
			Corn Belt			
IA	1,350.933	0.805	1,364.611	0.771	1,698.648	1.173
IL	1,367.298	0.815	1,430.060	0.808	2,132.501	1.473
IN	1,628.317	0.970	1,462.116	0.826	2,072.685	1.432
MO	1,357.026	0.809	1,370.937	0.775	1,067.502	0.737
OH	1,575.077	0.939	1,509.789	0.853	2,045.431	1.413

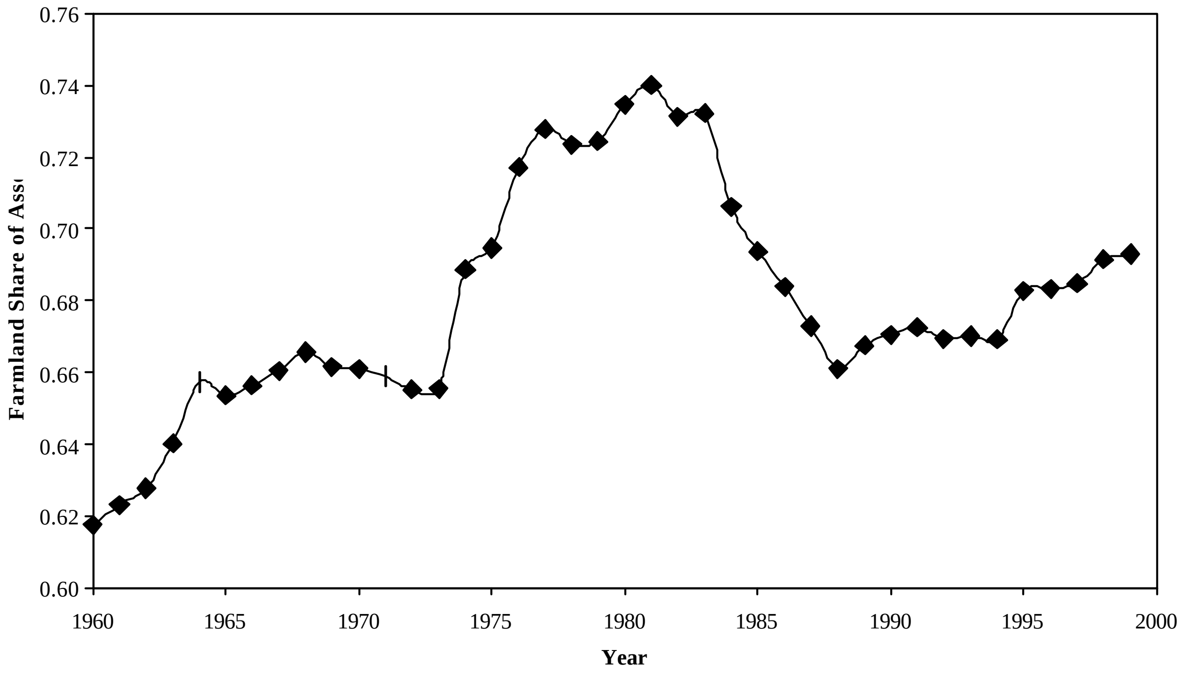
Table 2. Hedonically Adjusted Land Values Based on Agronomic and Von Thunen Affects (Continued)

States	Hedonic and von Thunen Valuation		Von Thunen Valuation		Market Value of Farmland	
	Value ($s/Acre) (a)	Normalized Value (b)	Value ($s/Acre) (c)	Value ($s/Acre) (d)	Normalized Value (e)	Value ($s/Acre) (f)
			Northern Plains			
KS	1,299.043	0.774	1,498.255	0.847	578.340	0.399
ND	1,523.838	0.908	1,480.195	0.837	401.463	0.277
NE	1,498.857	0.893	1,489.448	0.842	650.169	0.449
SD	1,407.809	0.839	1,479.684	0.836	350.961	0.242
			Appalachian			
KY	1,682.629	1.003	1,684.366	0.952	1,450.527	1.002
TN	1,660.627	0.990	1,691.985	0.956	1,808.077	1.249
VA	1,514.038	0.902	1,697.495	0.959	1,924.098	1.329
WV	1,550.598	0.924	1,663.503	0.940	1,093.690	0.755
NC	1,934.711	1.153	1,725.200	0.975	2,089.517	1.443
			SouthEast			
AL	1,678.000	1.000	1,769.186	1.000	1,447.878	1.000
FL	2,534.205	1.510	1,835.336	1.037	2,256.799	1.559
GA	1,712.236	1.020	1,770.462	1.001	1,506.777	1.041
SC	1,747.639	1.042	1,797.295	1.016	1,495.796	1.033
			Delta States			
AR	1,392.234	0.830	1,484.690	0.839	1,156.732	0.799
LA	1,644.454	0.980	1,508.922	0.853	1,198.032	0.827
MS	1,479.410	0.882	1,489.954	0.842	1,051.402	0.726

Table 2. Hedonically Adjusted Land Values Based on Agronomic and Von Thunen Affects (Continued)

States	Hedonic and von Thunen Valuation		Von Thunen Valuation		Market Value of Farmland	
	Value ($s/Acre) (a)	Normalized Value (b)	Value ($s/Acre) (c)	Value ($s/Acre) (d)	Normalized Value (e)	Value ($s/Acre) (f)
Southern Plains						
OK	1,238.567	0.738	1,267.411	0.716	609.591	0.421
TX	1,225.309	0.730	1,275.282	0.721	622.696	0.430
Mountain States						
AZ	1,275.166	0.760	1,391.893	0.787	360.722	0.249
CO	1,263.321	0.753	1,395.766	0.789	616.600	0.426
ID	1,248.167	0.744	1,385.954	0.783	1,029.301	0.711
MT	1,182.574	0.705	1,369.422	0.774	294.059	0.203
NM	1,492.374	0.889	1,373.630	0.776	198.665	0.137
NV	1,441.798	0.859	1,372.533	0.776	405.688	0.280
UT	1,568.029	0.934	1,522.657	0.861	577.235	0.399
WY	1,459.306	0.870	1,505.375	0.851	222.270	0.154
Pacific						
CA	2,608.848	1.555	2,550.736	1.442	2,633.263	1.819
OR	2,076.764	1.238	2,418.139	1.367	959.777	0.663
WA	2,262.695	1.348	2,429.760	1.373	1,208.852	0.835

Figure 1. Farmland as a Share of Total Agricultural Assets



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