The Effect of the Conservation Reserve Program on Land Values

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ABSTRACT. *This paper evaluates the effects of the Conservation Reserve Program (CRP) on land values. A theoretical model is presented to analyze the interaction between farmers' CRP participation decisions and land values. Empirical models are estimated to evaluate the effects of the CRP on land values. Results suggest that CRP participation had the largest effects in the Mountain, Southern Plains, and Northern Plains regions, where it increased average farmland values by 5% to 14%, 4% to 6%, and 2% to 5%, respectively. The CRP also had a statistically significant effect on developed land values, but the percentage increases were smaller. Implications of the results for the design of conservation programs are discussed.* (JEL Q24, Q28)

I. INTRODUCTION

The Conservation Reserve Program (CRP), one of the largest conservation programs in U.S. history, was established by the Food Security Act of 1985 and was reauthorized in all subsequent farm bills. Under this program, farmers convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover such as native grasses, trees, or filter strips; in return, they receive an annual rental payment for a contract period of 10 to 15 years. By 2004, over 34 million acres of cropland had been enrolled in the CRP, with an annual rental payment of approximately $2 billion (USDA 2004). In some counties more than 20% of cropland has been converted to vegetative cover under the CRP.

The economic and environmental benefits of the CRP have been well documented (e.g., Young and Osborn 1990; Osborn and Konyar 1990; Feather, Hellerstein, and Hansen 1999; Wu 2000; and Kirwan, Lubowski, and Roberts 2005). For example, based on 1997 enrollments, the CRP is credited with reducing soil erosion by 224 million tons annually, generating a total of $500 million of on-site and off-site economic benefit per year (Sullivan et al. 2004, 22–23). With about 8% of the nation's cropland enrolled into the CRP, this program may also have an impact on land values. However, only a few studies have examined the effects of the CRP on farmland values, and their results seem inconsistent. Shoemaker (1989) analyzed the first five CRP sign-ups, from 1986 to 1987, and found that CRP participation provided a huge windfall to farmers but had little effect on farmland values. Goodwin, Mishra, and Ortalo-Magné (2003) evaluated the effect of the CRP and other farm programs on farmland values; their results indicate that CRP payments correlated with lower farmland values. Lence and Mishra (2003) used county-level data from 1996 to 2000 to examine effects of the CRP and other farm payment programs on cash rental rates in Iowa; their results indicate that the effect of the CRP was positive or zero, depending on the models used.

Many studies, however, have examined the effects of government commodity programs on farmland values (Rosine and Helmberger 1974; Castle and Hoch 1982; Alston 1986; Goodwin and Ortalo-Magné 1992; Clark, Klein, and Thompson 1993; Barnard et al. 1997; Ryan et al. 2001; Schmitz and Just 2002). The conventional

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wisdom is that because the supply of agricultural land is highly inelastic, government payments are largely capitalized into farmland value. Recently, Kirwan (2008) presented a direct test of this theory using farm-level data and found that only 20 to 25 cents of the marginal subsidy dollar is reflected in increased rental rates, whereas tenant net returns rise by 70 to 75 cents. Roberts, Kirwan, and Hopkins (2003) found that each dollar of government payments increases land rents between 34 and 41 cents. Several studies have examined the proportion of land value that can be attributed to government subsidies. For example, Barnard et al. (1997) examined the effect of eliminating the Federal Agricultural Improvement and Reform Act of 1996 (FAIR) on cropland values in the United States and found that cropland values would be reduced by 12% to 69% in the eight examined regions if government programs were eliminated. Just and Miranowski (1993) found that government payments accounted for 15% to 25% of farmland values.

Although many previous studies have evaluated the effects of government commodity programs on farmland values, relatively few have focused on the effect of the CRP. Furthermore, no study, to our knowledge, has examined the effect of the CRP or any other government commodity programs on developed land values. The lack of analysis is surprising given that (1) farmland is a main asset of the agricultural sector, (2) the opportunity cost of farmland represents a major production expense (Lence and Mishra 2003), (3) the CRP is the largest land retirement program in U.S. history, and (4) how farmland values are affected is a critical issue in farm policy debates (Goodwin, Mishra, and Ortalo-Magné 2003).

The primary objective of this study is to evaluate the effects of the CRP on prices of farmland and developed land. To achieve this objective, we first present a theoretical model to guide our empirical investigation. The model integrates Capozza and Li's (1994) land price model with an optimal bidding behavior model (Latacz-Lohmann and van der Hamsvoort 1997). Under the CRP, any farmers with highly erodible land or other environmentally sensitive acreage could submit an application for CRP participation by indicating the parcels they wish to enroll in the CRP and the annual rental payments they require. However, the higher the rental rate a farmer requires, the less likely it is his application will be accepted. Thus, farmers' CRP rental rates, the probability of CRP participation, and the impact of the CRP on land values are treated as endogenous variables that are simultaneously determined in our model. In previous studies, government payments are typically treated as exogenous variables in farmland value equations. Based on the theoretical analysis, empirical models are then estimated to evaluate farmers' CRP participation decisions and the resulting effects on values of farmland and developed land.

Results suggest that the CRP increased the average farmland value by between $18 and $25 per acre in the United States in 1997. The effect was largest in the Mountain, Southern Plains, and Northern Plains regions, where it increased the average farmland values by between 5% and 14%, 4% and 6%, and 2% and 5%, respectively. The CRP also had a statistically significant effect on developed land values; however, the percentage increases were smaller, although the absolute increases were larger. Agricultural returns accounted for about 40% of total farmland values in the United States, and growth premium and option value accounted for the remaining 60%. Implications of the results for the design of conservation programs are explored below.

II. THE THEORETICAL MODEL

Under the current CRP rules, any farmers with highly erodible land or other environmentally sensitive acreage can apply for CRP participation during a sign-up period by indicating the parcels they wish to enroll and the annual rental payments they require. Whether an application will be accepted depends on the rental rate the farmer requires and the level of potential environmental benefits the parcel offers if converted to vegetative cover. Potential environmental benefits may include wildlife habitat, water quality, reduced soil erosion, improved air quality, and conservation priority area (USDA 1997). Based on these benefits, an environmental score (S) is calculated for each offered parcel via a formula established by the U.S. Department of Agriculture (USDA), which is then combined with the farmer's bid rent (B) to obtain an environmental benefit index" (EBI): $EBI = g(S,B)$, where $\partial EBI/\partial S > 0$, $\partial EBI/\partial B < 0$. Bids with an EBI above a cutoff level X are accepted, and bids with an EBI below X are rejected.

Because a farmer does not know the cutoff level, X, in preparing his application, he faces a trade-off in choosing his bid rent; if the bid rent is too high, it will not be accepted; if the bid is too low, he will lose the opportunity to receive a higher rental rate. It is plausible to assume that each farmer forms expectations about X, which can be characterized by the density function $f(X)$ and the distribution function $F(X)$. The probability that a bid is accepted equals

$$Pr = \text{prob}(X \leq EBI) = F(EBI). \qquad [1]$$

If the bid is accepted, the farmer's annual net return will be B; if it is rejected, the farmer's annual net return will be the agricultural rent A. If the farmer is risk neutral, he will choose B to maximize expected net payoff: $BF(EBI) + A[1 - F(EBI)]$. The first-order condition of this maximization problem implicitly defines the optimal bid rent B^* for the farmer:

$$B^* = A - \frac{F(EBI)}{f(EBI)g_B(S,B)}. \qquad [2]$$

The optimal bid consists of two components: the foregone agricultural rent and the information premium, which depends on the farmer's private information about the cutoff level of EBI as described by $f(X)$ and $F(X)$. For example, farmers may form their expectation of X based on the accepted rental rates in past CRP sign-ups.

As an alternative to CRP participation, a farmer could convert his cropland to development. The value of one unit of farmland at location z and time t equals the present value of the expected net returns to farmland up to the date of conversion plus the present value of the expected returns to developed land, minus the conversion cost:

$$p^a(t,z) = E\{ \int_t^{t+s} R^{CRP} e^{-r(\tau - t)} d\tau + \int_{t+s}^{\infty} R(\tau,z) e^{-r(\tau - t)} d\tau - Ce^{-rs} | R(t,z)\}, \qquad [3]$$

where R^{CRP} is the expected net return to the parcel before it is converted to development at $t+s$; R^{CRP} equals $PrB^* + (1 - Pr)A$ if the parcel is eligible for the CRP, and A if not. Because both B^* and Pr are explained variables, R^{CRP} is endogenous. $R(\tau,z)$ is the expected net return to the parcel after it is converted to development, C is the one-time conversion cost, r is the discount rate, $E\{\}$ is the expectation operator. Following Plantinga, Lubowski, and Stavins (2002), $R(\tau,z)$ is specified as $R(t,z) = R(t) + R(z)$, where the temporal component $R(t)$ follows the Brownian motion process with upward drift g and variances σ^2: $R(t) = gt + \sigma B(t)$, and the spatial component $R(z)$ is specified as a function of amenities at location z, $a(z)$, and other locational characteristics such as the distance to the nearest city center, $d(z)$: $R(z) = R[a(z), d(z)]$.

Assuming that the landowner chooses the conversion time $(t+s)$ to maximize the expected value of land, the optimal decision rule can be derived following Cappozza and Helsley (1990): convert the parcel to development if

$$R(t,z) \geq R^* \equiv R^{CRP} + rC + \frac{(r - \alpha g)}{\alpha r}, \qquad [4]$$

where $\alpha = [(g^2 + 2\sigma^2 r)^{1/2} - g]/\sigma^2$. The value of farmland can be derived as

$$p^a(t,z) = \frac{1}{r} R^{CRP} + \frac{g}{r^2} e^{-\alpha[R(z^*)-R(z)]} + \frac{r-\alpha g}{\alpha r^2} e^{-\alpha[R(z^*)-R(z)]}, \quad [5]$$

where z^* is the "boundary" of the developed area and is defined by $R(t,z) = R^*$. The value of farmland has three components: the value of net returns from agriculture or the CRP, growth premium, and option value. Similarly, following Capozza and Helsley (1990), the value of developed land can be derived as

$$p^d(t,z) = \frac{R^{CRP}}{r} + C + \frac{g}{r^2} + \frac{r-\alpha g}{\alpha r^2} + \frac{R(z)-R(z^*)}{r}. \quad [6]$$

The value of developed land consists of five components, which have been referred to as the net return from agriculture or the CRP, conversion cost, growth premium, irreversibility premium, and amenity and accessibility premium. The irreversibility premium represents the loss of option value once a parcel is developed. The amenity and accessibility premium represents the value of amenities and other locational advantages (e.g., proximity to work).

Although the CRP always increases the first component of equations [5] and [6], it reduces the growth premium and option value of farmland because the CRP slows the pace of land development. With the CRP, less land is developed, and the growth premium and option value for an undeveloped parcel are reduced. Similarly, the CRP reduces the accessibility premium of developed land because it reduces the comparative advantage of a developed parcel over an undeveloped parcel located at the boundary, which is closer to the city center with the CRP.

Values of farmland and developed land are also affected by the spatial component of urban land rents $R(z)$, which is a function of amenities and other locational characteristics. Equations [5] and [6] suggest that locations with better amenities, easy access, and lower transportation costs have higher land values regardless of whether they are agricultural or developed land. Amenities affect farmland values because they affect growth premium and option value.

III. EMPIRICAL MODELS

Specification

Equations [1], [2], [5], and [6], which describe the relationship between farmers' CRP participation decisions and land values, provide a theoretical foundation for our empirical analysis. The empirical counterparts of these equations are specified as follows:

$$Pr = F(EBI) = \frac{e^{\mathbf{X}_1\boldsymbol{\beta}_1+\varepsilon_1}}{1+e^{\mathbf{X}_1\boldsymbol{\beta}_1+\varepsilon_1}}, \quad [7]$$

$$B^* = f_2(\mathbf{X}_2,\boldsymbol{\beta}_2)+\varepsilon_2, \quad [8]$$

$$p^a = f_3(\mathbf{X}_3,\boldsymbol{\beta}_3)+\varepsilon_3, \quad [9]$$

$$p^d = f_4(\mathbf{X}_4,\boldsymbol{\beta}_4)+\varepsilon_4, \quad [10]$$

where $\mathbf{X}_1$, $\mathbf{X}_2$, $\mathbf{X}_3$, and $\mathbf{X}_4$ are vectors of variables affecting the probability of bid acceptance, the optimal CRP bid rent, farmland value, and developed land value, respectively; $\boldsymbol{\beta}$'s are vectors of parameters; and ε's are error terms. Variables included in $\mathbf{X}_1$, $\mathbf{X}_2$, $\mathbf{X}_3$, and $\mathbf{X}_4$ and the functional forms of f_i (i = 2, 3, 4) are specified based on equations [1], [2], [5], and [6].

As shown by equation [1], the variables affecting the probability of CRP acceptance include the environmental score (S), the bid rent (B^*), and a farmer's expectation about the cutoff level of EBI (as described by $F(\cdot)$). The variables affecting the farmer's expectation about the cutoff level of EBI may include the average CRP rental rate in previous CRP sign-ups (B_{-1}) and the percentage of cropland already enrolled in the CRP in the county (CRP_{-1}). The percentage of cropland already enrolled matters because the USDA often faces political pressure to spread CRP dollars across geographical regions. For example, in CRP sign-up 26, the USDA kept the acceptance rates in Montana, North Dakota, South Dakota, and Texas artificially low (by setting a higher cutoff level of *EBI*) to ensure that more CRP acres were allocated to other states (USDA 2003). Thus, we assume $\mathbf{X}_1 = (S, B^*, B_{-1}, CRP_{-1})$. Because not all variables affecting the probability of CRP acceptance are known to the researchers, an error term ε_1 is added in equation [7]. In a discrete choice model, $F(\cdot)$ is typically assumed to be a logistic or normal distribution function, and the choice between the two typically make little empirical difference. For easy estimation, discussed below, the probability of bid acceptance [1] is specified as a logit model.

Equation [2] reveals the variables affecting the optimal level of the CRP bid rent. These variables include the net return to farmland, A, the environmental score, S, and the variables affecting a farmer's expectation about the cutoff level of *EBI*, including B_{-1} and CRP_{-1}. Thus, the CRP bid rent is specified as a function of $\mathbf{X}_2 = (A, S, B_{-1}, CRP_{-1})$.

Equations [5] and [6] reveal the variables affecting values of farmland and developed land. These variables include the net return from agriculture or CRP participation (R^{CRP}), the growth rate of developed land rents (g), the variance of developed land rents (σ^2), amenities ($a(z)$), and other locational characteristics ($d(z)$). Thus, we include R^{CRP}, g, σ^2, $a(z)$, and $d(z)$ in $\mathbf{X}_3$ and $\mathbf{X}_4$. Previous studies of farmland values that include proxy variables for future development rents, amenities, or locational characteristics include those by Hushak and Sadr (1979), Chicoine (1981), Shonkwiler and Reynolds (1986), Palmquist and Danielson (1989), Vitaliano and Hill (1994), Shi, Phipps, and Colyer (1997), Hardie, Narayan, and Gardner (2001), and Cho, Wu, and Boggess (2003).[1]

Two alternative functional forms are used in the estimation of the land value equations [5] and [6]. One simply specifies the values of farmland and developed land as a quadratic function of R^{CRP}, g, σ^2, $a(z)$, and $d(z)$. Although this specification allows us to estimate the impact of CRP participation on the values of farmland and developed land, it cannot be used to estimate the impact of CRP participation on individual components of land values. To do that, we must impose more structure on the functional forms of f_3 and f_4. Specifically, we rewrite the farmland value equation [5] as $p^a = R^{CRP}/r + (1/r\alpha)e^{\alpha[R(z) - R(z*)]}$, where the second term is the sum of the growth premium and the option value. Note that $(1/r\alpha)$ is a function of g and σa, and $e^{\alpha[R(z) - R(z*)]}$ is a function of R^{CRP}, g, σ^2, $a(z)$, and $d(z)$ because z^* depends on all these variables. Approximating $(1/r\alpha)$ and $e^{\alpha[R(z) - R(z*)]}$ by their first-order Taylor expansion, the farmland value equation can be specified as

$$\begin{aligned} p^a = {} & \beta_3^1 R^{CRP} + \beta_3^2 g R^{\mathrm{CRP}} + \beta_3^3 gg + \beta_3^4 g\sigma + \beta_3^5 g a(z) \\ & + \beta_3^6 g d(z) + \beta_3^7 \sigma R^{\mathrm{CRP}} + \beta_3^8 \sigma g + \beta_3^9 \sigma\sigma \\ & + \beta_3^{10} \sigma a(z) + \beta_3^{11} \sigma d(z) + \varepsilon_3, \qquad [11] \end{aligned}$$

where the first term ($\beta_3^1 R^{CRP} = R^{CRP}/r$) represents the values of net return from agriculture or CRP participation, and the rest of the terms represent the sum of growth premium and option value. Note that equation [11] does not include an intercept term because when R^{CRP}, g, and σ are all zero, p^a is also zero.[2] With this specification, the impact of CRP participation on farmland values can be estimated by

$$\begin{aligned} p^a_{CRP} - p^a_0 = {} & \hat{\beta}_3^1 (R^{CRP} - A) \\ & + [(\hat{\beta}_3^2 g + \hat{\beta}_3^7 \sigma)(R^{CRP} - A)], \qquad [12] \end{aligned}$$

where the first term measures the effect of the CRP on agricultural returns, and the second term measures the effect of the CRP

[1] Many previous studies have also examined the determinants of developed land prices or values, including those by Coulson and Engle (1987), Rosenthal and Helsley (1994), Colwell and Munneke (1997), Kowalski and Paraskevopoulos (1990), and McDonald and McMillen (1998).

[2] By definition, $\alpha = [(g^2 + 2\sigma^2 r)^{1/2} - g]/\sigma^2$. When $g = 0$, $(1/r\alpha) = \sigma/(r\sqrt{2r}) \rightarrow 0$ as $\sigma \rightarrow 0$.

on the growth premium and the option value.

Similarly, the developed land value equation [6] can be written as $p^d = \phi_1 p^a + \phi_2 R^{CRP} + \phi_3$, where $\phi_1 = e^{-\alpha[R(z)-R(z*)]}$, $\phi_2 = (1 - e^{-\alpha[R(z)-R(z*)]})/r$, and $\phi_3 = C + [R(z) - R(z^*)]/r$. Approximating ϕ_1, ϕ_2, and ϕ_3 by the first-order Taylor expansion, the developed land value equation can be specified as

$$p^d = \beta_4^0 + \beta_4^1 p^a R^{CRP} + \beta_4^2 p^a g + \beta_4^3 p^a \sigma + \beta_4^4 p^a a(z) + \beta_4^5 p^a d(z) + \beta_4^6 R^{CRP} R^{CRP} + \beta_4^7 R^{CRP} g + \beta_4^8 R^{CRP} \sigma + \beta_4^9 R^{CRP} a(z) + \beta_4^{10} R^{CRP} d(z) + \beta_4^{11} R^{CRP} + \beta_4^{12} g + \beta_4^{13} \sigma + \beta_4^{14} a(z) + \beta_4^{15} d(z) + \varepsilon_4. \quad [13]$$

The data and methods used in the estimation of the empirical models are discussed below.

Data

The empirical models are estimated using cross-section data from 2,851 counties in the contiguous United States in 1997. One hundred and ninety counties are omitted due to missing data or absence of agricultural land. Although individual CRP bid and contract information is available, corresponding parcel-level data are unavailable for values of farmland and developed land. We have, however, average values of farmland and developed land for the 2,851 counties.

CRP data are provided by the Economic Research Service (ERS) of the USDA.[3] The data contain individual bid and contract information for sign-up 15, which was held in March 1997. We could estimate the bid rent equation using the individual bid and contract data and then estimate the CRP acceptance equation as a discrete choice model using predicted values of B. However, we would not be able to address the issues of spatial autocorrelations because the relative locations of the offered parcels are unknown (locations and owners of CRP bids are confidential). In addition, because both the land value equations are estimated using county-level data, the parcel-level predictions of B and Pr would have to be aggregated to the county level to be used in the estimation of land value equations. For these reasons, we chose the following procedure to estimate the acceptance and bid rent equations. First, using individual bid data, we estimate the probability of acceptance in each county by calculating the ratio of the total accepted bids to total bids submitted in sign-up 15. With the data, we are able to convert the discrete choice model of CRP acceptance [7] to a continuous dependence variable model:

$$\ln\left(\frac{Pr_i}{1-Pr_i}\right) = \mathbf{X}_{1i}\beta_1 + \varepsilon_1 = \beta_1^0 + \beta_1^1 S_i + \beta_1^2 B_i^* + \beta_1^3 B_{-1i} + \beta_1^4 CRP_{-1i} + \varepsilon_{1i}, \quad [14]$$

where Pr_i is the percentage of total submitted bids accepted in county i estimated using the individual bid data, B_i^* is the average bid rent per acre in county i, which is calculated by $(\sum_{k=1}^{n} b_k * acre_k)/\sum_{k=1}^{n} acre_k$, where b_k is the per acre bid rent and $acre_k$ is acres offered by farmer k, and n is the total bids submitted in a county. Using the individual CRP bid data, the average environmental score (S_i) is computed for each county. The average past CRP rental rate (B_{-1i}) and percentage of land already enrolled in the CRP (CRP_{-1i}) are estimated using data from the ERS. The average past CRP rental rates are calculated using rental rates from all previous sign-ups (i.e., sign-ups 1–14). The percentage of land enrolled in the CRP is computed as the ratio of total land enrolled in the CRP by December 1996 to total cropland in a county. Percentage of cropland eligible for the CRP in each county is estimated using data from the 1997 National Resource Inventory. Similarly, we estimated the following bid rent equation using the county-level data:

$$B_i^* = \beta_2^0 + \beta_2^1 A_i + \beta_2^2 S_i + \beta_2^3 B_{-1i} + \beta_2^4 CRP_{-1i} + \varepsilon_{2i}. \quad [15]$$

[3] We thank Shawn Bucholtz of the Economic Research Service for providing the data.

Data on farmland values, developed land values, and annual net returns to farmland in 1997 were obtained from Plantinga, Lubowski, and Stavins (2002).[4] They calculated the average return to farmland, A, using Census of Agriculture data by $(TR + GP - TC)/TA$, where TR is the total revenues from the agricultural products sold, GP is the total government payments except CRP payments, TC is the total farm production expenses, and TA is the total farmland acres. The farmland value (p^a) is the county-level average of self-reported estimates by landowners. The developed land value (p^d) is a county-level estimate of the average per acre value of recently developed land for single-family houses (Plantinga, Lubowski, and Stavins 2002).

As in previous studies, we also divide land use into discrete classes: farmland and developed land. However, land use can span a spectrum of uses ranging from exclusively intensive agriculture, to smaller-scale and hobby types of farm operations, to something more like backyard gardening, to exclusively residential.[5] Farmland and developed land values depend not on these two discrete land uses, but rather on the capability of land to support a range of uses, the demands for land in those different ranges of uses, and the densities of development that are feasible and allowable under given circumstances. For these reasons, p^d does not necessarily represent true "developed land values" but rather serves only as a proxy for the value of land in more intensive developed uses. The percentage change in the value of land in less intensive uses (e.g., mixed uses with farmland and developed land) under the CRP is likely between those estimated for farmland and developed land in this study.

Two alternative approaches are used to measure amenities in a county. One uses the amenity data generated by the National Outdoor Recreation Supply Information System (NORSIS),[6] developed and maintained by the USDA's Forest Service Wilderness Assessment Unit, Southern Research Station. The amenity data include more than 250 variables describing climate, natural amenities, man-made amenities, and geographic information across counties in the United States. To synthesize the information contained in the large number of variables, we use principal component analysis to calculate amenity scores for each county, following Deller et al. (2001). Principal component analysis is an approach to compress higher-dimension variables into a single scalar, which is, in essence, a linear combination of the original variables with weights being the eigenvectors of the correlation matrix for the factor variables. Because the principal component is sensitive to scale, all variables used in principal component analysis are standardized to zero mean and unit variance, and the amenity score is calculated by $Score = \sum_{l=1}^{L} \lambda_l \tilde{x}_l$, where λ_l is the eigenvector computed from the variance-covariance matrix of the original data, $\tilde{x}_l$ is the standardized amenity variable, and L is the number of variables in a category. The main advantage of this approach is that variables are not removed from the empirical analysis due to multicollinearity problems or limited degree of freedom (Wagner and Deller 1998).

We constructed three amenity scores for each county to measure amenities derived from temperate climate (e.g., the number of sunny days in January, low humidity in July), man-made recreation facilities (e.g., the numbers of golf courses, swimming pools, campgrounds), and natural recreational resources (e.g., total outstanding river miles, whitewater miles). The amenity scores for climate and natural recreational resources are constructed using 4 variables, and the amenity score for man-made recreation facilities is constructed using 14 variables.[7]

[4] We thank Andrew Plantinga for providing the data.

[5] We thank an anonymous referee for pointing this out.

[6] We thank Steve Deller of the University of Wisconsin for providing the NORSIS data.

[7] Variables in each category and their corresponding eigenvector are available upon request.

An alternative measure of natural amenities used in this analysis is the natural amenity scale created by the ERS. The ERS natural amenity scale was constructed based on six factors: warm winter (average January temperature), winter sun (average January days of sun), temperate summer (low winter-summer temperature gap), summer humidity (low average July humidity), topographic variation (topography scale), and water area (water area proportion of total county area).

In addition to amenities, other locational characteristics that affect land values include accessibility, transportation costs, and development pressure. Two alternative variables are used to reflect accessibility and development pressure in a county. One is the total mileage of interstate and other principal arterial roads (for example, state highways) in a county. The other is the Urban Influence Code (UIC) developed by the ERS to capture an area's geographic context and economic opportunities based on population and commuting data. The 1993 UIC, the most recent available before 1997, was obtained from the ERS. The 1997 road mileage data were obtained from the U.S. Bureau of Transportation Statistics.

Based on work by Capozza and Helsley (1990), we used the growth and variance of real income to approximate g and σ^2 in each county because time series data on values of farmland and developed land are unavailable; g and σ^2 were calculated using the 1993–1997 data on county median household income from the U.S. Census Bureau.

Dummy variables for the farm production regions defined by the ERS are included in the equations to reflect regional differences not captured by the explanatory variables. The 10 farm production regions defined by the ERS are the Pacific, Mountain, Northern Plains, Southern Plains, Lake States, Corn Belt, Delta States, Northeast, Appalachian, and Southeast regions.[8] The Southeast was chosen as a reference region. CRP acres are concentrated in the Great Plains (Northern Pains and Southern Plains) and the western Corn Belt, with some increases in the Mountain region since the fifteenth sign-up. The descriptive statistics of all variables used in the empirical analysis are listed in Table 1.

Estimation Methods

Three econometric issues arise in the estimation of equations [11], [13], [14], and [15]. First, these equations are not independent. The dependent variable of [15] appears on the right-hand side of [14] as an explanatory variable because the level of the bid rent B^* affects the probability of bid acceptance Pr. In addition, both B^* and Pr affect the values of farmland and developed land because the expected net return to farmland, $R^{CRP} = (1-m)A + m[PrB^* + (1-Pr)A]$, is affected by B^* and Pr, where m = 1 if the parcel is eligible for the CRP and zero otherwise. These endogeneity issues must be addressed. Second, the error terms (ε) may be correlated. For example, because farmers' expectation about the cutoff level of *EBI* affects both the probability of bid acceptance and the bid rent, if a variable affecting the expectation is omitted, the error terms ε_1 and ε_2 would be correlated. Likewise, ε_3 and ε_4 may be correlated because there may be an omitted variable that affects both the values of farmland and the values of developed land. These contemporaneous correlations must be taken into account in the estimation. Finally, spatial autocorrelation may exist because counties located near each other may be affected by the same omitted variables (e.g., Bockstael 1996). Spatial autocorrelations have been identified in previous studies of land values (e.g., Bell and Bockstael 2000; Irwin 2002; Irwin and Bockstael 2001).

These econometric issues (endogeneity, contemporaneous correlations, and spatial autocorrelation) are addressed using generalized spatial three-stage least squares (GS3SLS) developed by Kelejian and Prucha (2004). In the first stage, the model parameters are estimated using two-stage

[8] An alternative way to define the regional dummies is to use the farm resource regions defined by the ERS.

TABLE 1
VARIABLES AND DESCRIPTIVE STATISTICS

Variable	Description	Mean	St. Dev.
b_{-1}	Average CRP rental rate for sign-ups 1–14 ($)	54	16.16
A	Net returns to farmland ($)	77	78.45
R^{CRP}	$\text{Max}\{A, A(1-m)+m[pb+(1-p)A]\}$	81	74.10
p^a	Farmland values ($)	1,362	961.93
p^d	Developed land values ($)	48,837	45,052.50
b	Average bid rent per acre at sign-up 15 ($)	50	22.46
P	Probability of acceptance at sign-up 15	0.65	0.31
S	Sum of environmental scores	140	34.90
y	Median household income in 1997 ($)	32,377	7,514.83
g	Mean of annual real income growth, 1993–1997	640	2,161.27
σ^2	Variance of income growth, 1993–1997	3,420	2,402.17
Natural amenity	Natural amenity scale created by ERS	−0.60	1.83
Climate	Amenity score for temperate climate	0	1.00
Man-made amenity	Amenity score for man-made recreational facilities	0	1.00
Recreation resource	Amenity score for natural recreational resources	0	1.00
CRP_{-1}	Percentage of farmland enrolled in CRP in sign-ups 1–14	4.20	4.70
m	Percentage of land eligible for CRP participation	45.30	29.40
Roads	Interstate and principal arterial roads (1,000 miles)	58	86.43
UIC	1993 Urban Influence Code	5.60	2.64
r1	1 if counties in Pacific, 0 otherwise	0.04	0.20
r2	1 if counties in Mountain, 0 otherwise	0.08	0.27
r3	1 if counties in Northern Plains, 0 otherwise	0.11	0.31
r4	1 if counties in Southern Plains, 0 otherwise	0.11	0.31
r5	1 if counties in Lake States, 0 otherwise	0.08	0.27
r6	1 if counties in Corn Belt, 0 otherwise	0.17	0.38
r7	1 if counties in Delta States, 0 otherwise	0.07	0.26
r8	1 if counties in Northeast, 0 otherwise	0.07	0.26
r9	1 if counties in Appalachian, 0 otherwise	0.16	0.36
r10	1 if counties in Southeast, 0 otherwise	0.10	0.31

Note: CRP, Conservation Reserve Program; ERS, U.S. Department of Agriculture Economic Research Service.

least squares (2SLS) and instrumental variable techniques. All exogenous variables are chosen as instrumental variables. The residuals from the 2SLS estimates are used to test for spatial autocorrelation in each equation using Moran's I-statistic, $I=N(\hat{\mathbf{e}}'\mathbf{W}\hat{\mathbf{e}})/\mathbf{M}(\hat{\mathbf{e}}'\hat{\mathbf{e}})$, where N is the number of observations, $\hat{\mathbf{e}}$ is the vector of estimated residuals, $\mathbf{W}$ is the spatial weight matrix indicating spatial structure of the data, and $\mathbf{M}$ is the standardization factor equal to the sum of the elements of $\mathbf{W}$. We assume the error structure takes the form $\varepsilon=\rho\mathbf{W}\varepsilon+\mathbf{v}$, where ρ is a scalar and $\mathbf{v}$ is a vector of spherical disturbance with zero mean. $\mathbf{W}$ is constructed in ArcView 3.2 using rook contiguity criteria, which uses common boundaries to define neighbors.

If spatial autocorrelation is identified, then in the second stage the residuals from the 2SLS are used to estimate the spatial autoregressive parameter ρ for each equation utilizing the generalized moment estimator (Kelejian and Prucha 2004). After the spatial autoregressive parameter ρ is estimated, data are transformed using the matrix $\hat{\mathbf{P}}=\mathbf{M}-\hat{\rho}\mathbf{W}$, where $\mathbf{M}$ is an N by N identity matrix. If spatial autocorrelation is not identified, no data transformation is performed. The final stage addresses the issue of contemporaneous correlations using seemingly unrelated regression estimators. Two simultaneous equation systems are estimated in this study, one includes the CRP acceptance equation [14] and the bid rent equations [15], and the other includes the land value equations [11] and [13]. These two sets of equations are estimated separately because we have different numbers of observations for land values and CRP data. We use the predicted values of B^* and Pr from the first equation system to estimate

R^{CRP}, which is then used in the estimation of the simultaneous equation system for land values.

IV. RESULTS

Econometric Estimates

The CRP acceptance and bid rent equations [14] and [15] are estimated using the data and methods described in the last two sections. The estimated coefficients are presented in the Appendix (Table A1). Spatial autocorrelations are detected and are adjusted for each equation. Specifically, Moran's I-statistic, with the standard deviation listed in parentheses, is 0.13 (0.0135) for the CRP acceptance equation and 0.45 (0.0135) for the bid rent equations. The null hypothesis of no spatial autocorrelation is rejected at the 1% level in each case. The spatial autocorrelation parameter ρ is estimated to be 0.30 and 0.68 for the two equations, indicating positive spatial autocorrelations. The system-weighted R-squared is 0.57. All coefficients except some regional dummies are statistically significant at the 1% level.

As expected, bids with higher environmental scores and lower annual rental rates are more likely to be accepted into the CRP. Specifically, a 1% increase in the bid rent reduces the probability of acceptance by 9%. A large amount of the existing CRP land in a county has a negative effect on the probability of acceptance because the USDA is more likely to target land for the CRP in areas with low participation rates. A CRP bid is more likely to be accepted in a county with a higher average CRP rental rate in previous sign-ups. One possible reason for this result is that counties with higher CRP rental rates in previous sign-ups may have fewer CRP applications because of higher opportunity costs of participation. Most regional dummies are statistically insignificant in the CRP acceptance equation, indicating that the probability of acceptance does not vary systematically across regions except for the variations explained by the explanatory variables.

All variables expected to affect CRP rental rates are statistically significant at the 1% level. Counties with higher average environmental scores tend to require lower rental rates. This may reflect that parcels with higher environmental scores tend to have lower land quality and lower opportunity costs of CRP participation. In contrast, counties with higher net returns to agriculture and higher average CRP rental rates in previous CRP sign-ups tend to require higher rental payments because the opportunity costs of CRP participation in those counties may be higher. Specifically, a \$1 difference in the average CRP rental rate in the previous CRP sign-ups leads to a \$0.75 difference in the current bid rents, whereas a \$1 difference in the average net return to agriculture leads to only a \$0.03 difference in the current bid rent. These results suggest that farmers rely heavily on previous CRP rental rates to determine their bid rents. Counties with a large amount of CRP land tend to have lower CRP bid rents.

Five versions of the land value equations are estimated. The results, labeled as Model I to Model V, are reported in the Appendix (Tables A2–A5). Model I is our basic model and is estimated using the functional forms specified in equations [11] and [13]. Models II to V are estimated using a quadratic functional form and alternative measures of amenities and other locational characteristics. Specifically, Models I, II, and III use our own constructed scores of amenities as explanatory variables, while Models IV and V use ERS's amenity index. Models I, II, and IV use the length of interstate and principal arterial roads to reflect accessibility and transportation costs, while Models III and V use ERS's UIC. Only the interaction terms that are shown to be possible by the theoretical mode are included in the developed land value equations.

Overall, all five models fit the data well, with a system-weighted R-squared being about 0.87 for all models. Most of the coefficients of interest are statistically significant at the 5% level or better. Spatial autocorrelations are detected in all models

TABLE 2
MARGINAL EFFECT OF SELECTED VARIABLES ON VALUES OF FARMLAND AND DEVELOPED LAND

Variable	Model I	Model II	Model III	Model IV	Model V
Marginal Effect on Farmland Values ($/acre)					
Natural amenity				42***	60***
Climate	45*	129***	93***		
Man-made amenity	199***	406***	206***		
Recreational resource	8	−44	7		
UIC			−60***		−67***
Marginal Effect on Developed Land Values ($/acre)					
Natural amenity				20	1,249**
Climate	293	2,191	2,312*		
Man-made amenity Recreation	16,229***	24,707***	4,671***		
Recreational resource	−2,090***	−121***	1,460*		
UIC			−5,543***		−5,425***

* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

and are adjusted accordingly. Because of interaction terms and nonlinear relationships, the sign and magnitude of individual coefficient do not have clear interpretations. For this reason, we calculate the marginal effect of amenity variables and *UIC* on values of farmland and developed land and report the results in Table 2. *F*-statistics for the null hypotheses that the marginal effects are zero were calculated to indicate the statistical significance (Judge et al. 1988).

Overall, amenities seem to have a positive and significant effect on the values of farmland and developed land. The results derived from the models that use the ERS natural amenity scàle and those using our own amenity scores are generally consistent. Climate appears to have a positive effect on land values, although it is insignificant in the developed land value equations in Models I and II. The positive sign suggests households prefer locations with better climate. Man-made recreation facilities have positive and significant effects on values of both farmland and developed land. The recreation facility index is determined by the number of parks, tennis courts, and golf courses, among other things. Counties with more man-made recreation facilities are more attractive to households. The coefficient on the index of natural recreational resources is sensitive to specification in both land value equations. Table 2 also reports the marginal effects of *UIC* on values of farmland and developed land. The effects of *UIC* on land values are negative and statistically significant, indicating that land located in counties with lower "urban influence" has lower values.

Effects of the CRP on Land Value

The effects of the CRP on the values of farmland and developed land are evaluated using each of the five models, and the results are reported in Tables 3 and 4. The CRP has a positive and statistically significant effect on farmland values in all regions. This result is robust in terms of the sign and relative magnitude of the effects. Nationwide, the CRP increased the average farmland values by between $18 and $25 per acre (1.3%–1.8%), with the largest effect in the Mountain, Southern Plains, and Northern Plains regions, where it increased average farmland values by between 5% and 14%, 4% and 6%, and 2% and 5%, respectively. These results are not surprising, given that more than 60% of CRP lands are located in these three regions and that CRP rental rates are considerably higher than net returns to agriculture in the three regions, which are generally below $30 per acre in the Mountain and the Southern Plains regions, and below $50 per acre in the Northern Plains region.

The CRP also increased farmland values in the Corn Belt, Appalachian, and Pacific regions. However, the percentage increases

TABLE 3
THE EFFECTS OF THE CONSERVATION RESERVE PROGRAM ON FARMLAND VALUES, BY REGION

	Changes in Farmland Values ($/acre)				
Region	Model I	Model II	Model III	Model IV	Model V
Pacific	36*** (2.25)	44*** (2.74)	35*** (2.18)	35*** (2.18)	18*** (1.12)
Mountain	60*** (9.79)	85*** (13.87)	52*** (8.48)	55*** (8.97)	32*** (5.22)
Northern Plains	28*** (4.52)	33*** (5.32)	24*** (3.87)	17*** (2.74)	11*** (1.87)
Southern Plains	40*** (6.41)	29*** (4.65)	23*** (3.69)	35*** (5.60)	30*** (4.81)
Lake States	3*** (0.22)	6*** (0.43)	6*** (0.43)	2*** (0.15)	2*** (0.15)
Corn Belt	24*** (1.35)	26*** (1.46)	23*** (1.29)	17*** (0.96)	18*** (1.91)
Delta States	18*** (1.62)	12*** (1.08)	9*** (0.81)	12*** (1.08)	10*** (0.90)
Northeast	8*** (0.33)	9*** (0.37)	8*** (0.33)	7*** (0.29)	7*** (0.29)
Appalachian	28*** (1.51)	24*** (1.30)	21*** (1.13)	21*** (1.13)	21*** (1.13)
Southeast	18*** (1.19)	11*** (0.73)	9*** (0.59)	11** (0.73)	11*** (0.73)
United States	25*** (1.84)	25*** (1.84)	22*** (1.61)	18*** (1.32)	18*** (1.32)

Note: Percentages are in parentheses.
** Significant at the 5% level; *** significant at the 1% level.

were relatively small. The small effects were a result of lower CRP participation rates and smaller difference between CRP rental rates and net returns to crop production in these regions. The CRP effects account for only a small percentage of farmland values, because farmland is more productive and valuable in these regions, with average farmland values higher than $1,600 per acre in most counties. The effect of the CRP on farmland values was smallest in the Lake States and the Northeast regions. In the Lake States, there was little difference between CRP rental rates and net returns to agriculture. The Northeast had the smallest CRP enrollment among the 10 regions. Only about 0.5% of CRP land is located in the Northeast region.

The CRP also had a positive and statistically significant effect on developed land values. However, the percentage increases were small in every region. Nationwide, the CRP increased the average value of developed land by between $6 and $274 per acre, which accounts for less than 0.6% of developed land values. The CRP had relatively large effects in the Mountain, Southern Plains, Appalachian, and Corn Belt regions. It is not surprising that effects of the CRP on developed land values are relatively large in the Mountain and Southern Plains regions, where the positive and

TABLE 4
EFFECTS OF THE CONSERVATION RESERVE PROGRAM ON DEVELOPED LAND VALUES, BY REGION

	Changes in Developed Land Values ($/acre)				
Region	Model I	Model II	Model III	Model IV	Model V
Pacific	540*** (0.31)	549*** (0.12)	203*** (0.12)	715*** (0.41)	158*** (0.09)
Mountain	843*** (0.78)	809*** (0.74)	341** (0.31)	901*** (0.83)	233** (0.21)
Northern Plains	275*** (0.60)	277*** (0.60)	−20 (−0.04)	−139** (−0.30)	−191*** (−0.41)
Southern Plains	244** (0.61)	202** (0.50)	19 (0.05)	368*** (0.92)	249*** (0.59)
Lake States	63 (0.15)	75*** (0.18)	31*** (0.07)	−57*** (−0.14)	−33 (−0.08)
Corn Belt	277*** (0.67)	271*** (0.65)	155*** (0.37)	10** (0.02)	78 (0.30)
Delta States	118*** (0.45)	119*** (0.45)	15 (0.06)	45 (0.17)	33 (0.05)
Northeast	186*** (0.26)	184*** (0.26)	137*** (0.19)	42 (0.06)	53*** (0.07)
Appalachian	347*** (0.98)	297*** (0.84)	205*** (0.58)	64 (0.18)	125*** (0.35)
Southeast	150 (0.44)	114*** (0.33)	57* (0.17)	79** (0.23)	94*** (0.27)
United States	274*** (0.56)	273*** (0.56)	155*** (0.32)	6 (0.01)	73 (0.15)

Note: Percentages are in parentheses.
* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

TABLE 5
THE EFFECTS OF THE CONSERVATION RESERVE PROGRAM (CRP) ON DIFFERENT COMPONENTS OF FARMLAND VALUES, BY REGION

	Value of Agricultural Returns		Growth Premium and Option Value		CRP Effect on Value of Agricultural Returns		CRP Effect on Growth Premium and Option Value	
Region	$/acre	% of Land Value	$/acre	% of Land Value	$/acre	% Increase	$/acre	% Increase
Pacific	813	50.7	792	49.3	51	6.3	−15	−1.9
Mountain	261	42.5	353	57.5	83	2.2	−23	−6.5
Northern Plains	364	58.6	256	41.4	42	11.7	−14	−5.4
Southern Plains	229	36.8	397	63.2	59	6.2	−19	−4.8
Lake States	588	43.0	782	57.0	7	1.2	−4	−0.5
Corn Belt	655	36.8	1,125	63.2	39	6.0	−13	−1.1
Delta States	535	48.2	575	51.8	25	4.7	−7	−1.2
Northeast	762	31.6	1,648	68.4	15	2.0	−7	−0.4
Appalachian	688	37.2	1,165	62.8	38	5.6	−10	−0.9
Southeast	608	40.1	903	59.9	24	4.0	−6	−0.7
United States	542	39.8	820	60.2	37	6.9	−12	−1.5

larger effects of the CRP on farmland values directly contribute to the large increases in developed land values. However, the relatively large effect of the CRP on developed land values in the Appalachian and the Corn Belt regions is unexpected, given the effects of the CRP on farmland values are moderate there. One possible explanation is that Appalachia and much of the Corn Belt (Ohio, Indiana, and Illinois) are highly developed and are also concentrated with highly productive farmland. A small reduction in developable land caused by the CRP translated into a relatively large increase in developed land values in those regions.

Table 5 reports the decomposition of farmland value and the effect of the CRP on agricultural and development components values based on Model I. Agricultural returns (the first term of equation [11]) account for 40% of U.S. farmland value, and growth premium and option values (the sum of all terms in equation [11] except the first and the error term) account for the other 60%. Our estimate of the share of growth premium and option value is higher than that by Plantinga, Lubowski, and Stavins (2002), who estimated that the future rents from development account for only 10% of the U.S. agricultural land value. The difference between the estimates is caused mainly by their decision to include the intercept term in the agricultural components (see their footnote 27). When the intercept shifters for New Jersey, Connecticut, and Massachusetts are included in the development component, their estimated shares of development components in the agricultural land value for those three states are 82%, 81%, and 65%, respectively. As they pointed out in their paper, whether to include the intercept term in the agricultural or development component is somewhat arbitrary. In this study, we do not face this arbitrary decision because Model I, which was specified based on the theoretical model and was used to estimate the shares of agricultural and development components in farmland value, does not include an intercept term.

Of the 10 regions, the share of agricultural returns in farmland value is the largest in the Northern Plains, where most farmland faces low development pressure. Growth premium and option value account for about 68% of farmland values in the Northeast, highest among all regions. This estimate is comparable with Plantinga, Lubowski, and Stavins's estimate for Massachusetts (65%). Consistent with the theory, the CRP had a positive impact on agricultural returns, but a negative impact on growth premiums and option values. Specifically, the CRP increases the value of agricultural returns by about

$37 per acre in the United States, but reduces growth premiums and option values by $12 per acre.

V. CONCLUSIONS

As the largest conservation program in U.S. history, the CRP has been evaluated in a number of studies for its economic and environmental benefits. However, the effects of the CRP on land values have received relatively little attention. This paper develops theoretical and empirical models to evaluate the effects of the CRP on values of farmland and developed land. The theoretical results suggest that the CRP increases agriculture returns but decreases growth premium and option value. Based on theoretical analysis, empirical models are then estimated to quantify the effect of the CRP on values of farmland and developed land. Results suggest that the CRP increased the average farmland value by between 1.3% and 1.8% in the United States in 1997. The effects were largest in the Mountain, Southern Plains, and Northern Plains regions, where the CRP increased farmland values by 5.2% to 14.0%, 3.7% to 6.4%, and 2.7% to 5.3%, respectively. The CRP also had a positive effect on developed land values; however, the percentage increases were relatively smaller, although the absolute increases were much larger. Agricultural returns were estimated to account for about 40% of the total farmland values in the United States, and growth premium and option value together account for the remaining 60%. Climate and recreation amenities have positive effects on farmland values because they increase both growth premium and option value.

These results provide useful information for the design of land conservation programs. By retiring highly erodible cropland and other environmentally sensitive acreage for 10 to 15 years, the CRP provides significant environmental benefits. However, a permanent easement program has an obvious advantage. In recent years, several states including Minnesota and Maryland have used the Conservation Reserve Enhancement Program (CREP) and other USDA programs to convert short-term easements to permanent conservation. It has been suggested that since the present discount value of rental payments during a 15-year contract equals about 76% of the value of a perpetual program (assuming a 10% discount rate), states need to pay only about 25% more to secure permanent easements. Even if a 5% discount rate is assumed, states need to pay only 48% more. Our results suggest that such calculations are flawed, and 25% additional funding is generally not enough to convert a 15-year contract to a permanent easement.

CRP payment is calculated based on the relative productivity of soils within the county and the local dry land cash rent. Thus, the CRP payments reflect only the stream of agricultural returns, not growth premium and option value. Our results show that agricultural returns account for only 40% of the total farmland value, and growth premium and option value account for the remaining 60%. This suggests that CRP rental payments during the contract period account for only about 30% to 21% ($0.40 \times 76\%$ to $0.40 \times 52\%$) of land value, where 76% and 52% represent the percentage of agricultural returns covered by CRP payments during a 15-year contract for a 10% and 5% discount rate, respectively. The remaining 70% to 79% of land value must be compensated to convert a 15-year CRP contract to a permanent easement. That would be 2.6 to 3.8 times of the total CRP payment ($70\%/30\% = 2.6$). Thus, in areas where land has large growth premium and option value, governments would need to pay much more than 25% to convert a 15-year contract to a permanent easement. However, in remote areas where land has little growth premium and option value, 25% additional funding may be sufficient to secure a permanent easement, particularly from landowners with a high discount rate.

APPENDIX

TABLE A1

PARAMETER ESTIMATES OF THE PROBABILITY OF ACCEPTANCE EQUATION AND THE OPTIMAL BID RENT EQUATION

	Acceptance Equation		Bid Rent Equation	
Variable	Coefficient	St. Dev.	Coefficient	St. Dev.
Intercept	−5.19***	0.349	2.85***	0.443
S	0.08***	0.002	−0.02***	0.005
B^*	−0.10***	0.019	—	—
A	—	—	0.03***	0.002
CRP_{-1}	−4.00***	1.406	−12.79***	4.604
B_{-1}	0.06**	0.024	0.75***	0.023
$r1$	0.12	0.486	−5.56***	1.867
$r2$	−0.27	0.336	−1.88	1.274
$r3$	0.15	0.294	−0.31	1.364
$r4$	−0.31	0.307	−0.17	1.192
$r5$	0.06	0.322	1.39	1.384
$r6$	−1.15***	0.331	11.93***	1.363
$r7$	0.16	0.338	−3.16**	1.406
$r8$	0.29	0.380	0.93	1.566
$r9$	−0.13	0.290	2.51**	1.154

Note: Number of observations = 2,206. System-weighted $R^2 = 0.57$.
** Significant at the 5% level; *** significant at the 1% level.

TABLE A2

Parameter Estimates of the Farmland Value Equation, Model I

Variable	Coefficient	St. Dev.
$\hat{R}^{CRP}$	6.6769***	0.2667
$g \times$ *Roads*	−7.16e–6***	0.0001
$g \times y$	2.4e–6***	7.76e–7
$g \times g$	5.0e–6*	2.65e–6
$G \times \hat{R}^{CRP}$	−0.0007***	4.6e–5
$g \times$ *Climate*	0.0386***	0.0100
$g \times$ *Man-made amenity*	0.0263***	0.0110
$g \times$ *Recreation resource*	−0.0047	0.0066
$g \times r1$	0.2081***	0.0367
$g \times r2$	0.0513*	0.0283
$g \times r3$	0.0377	0.0287
$g \times r4$	−0.0275	0.0234
$g \times r5$	0.0584	0.0343
$g \times r6$	0.0158	0.0248
$g \times r7$	0.0047	0.0273
$g \times r8$	0.0209	0.0313
$g \times r9$	−0.0249	0.0214
$\sigma \times$ *Roads*	−0.0064	0.0051
$\sigma \times y$	0.0010***	0.0001
$\sigma \times \sigma$	−0.2271***	0.0167
$\sigma \times \hat{R}^{CRP}$	−0.0304***	0.0041
$\sigma \times$ *Climate*	0.2820	0.5023
$\sigma \times$ *Man-made amenity*	3.3102***	0.4262
$\sigma \times$ *Recreation resource*	0.1636	0.2687
$\sigma \times r1$	−2.4834	2.0121
$\sigma \times r2$	−6.4826***	1.5631
$\sigma \times r3$	−7.9109***	1.4745
$\sigma \times r4$	−3.4203**	1.3269
$\sigma \times r5$	−5.8818***	1.8168
$\sigma \times r6$	−1.8051	1.3335
$\sigma \times r7$	0.2520	1.5160
$\sigma \times r8$	8.2746***	1.1676
$\sigma \times r9$	3.6615***	1.1730
$\sigma \times g$	0.0004*	0.0003

Note: $\hat{R}^{CRP}$ is calculated using the predicted bid rents and the predicted probability of acceptance. The farmland value equation reported in this table and the developed land value equation reported in Table A3 are estimated using generalized spatial three-stage least squares (GS3SLS). Number of observations = 2,851. System-weighted R^2 = 0.87.

* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

TABLE A3

Parameter Estimates of the Developed Land Value Equation, Model I

Variable	Coefficient	St. Dev.
Intercept	−2,757.18	2,547.00
$p^a \times$ *Roads*	0.0317***	0.0107
$p^a \times y$	0.0004***	0.0001
$p^a \times g$	−0.0005***	0.0002
$p^a \times \sigma$	−0.0235	0.0216
$p^a \times \hat{R}^{CRP}$	−0.0114	0.0061
$p^a \times$ *Climate*	−2.9862**	1.0399
$p^a \times$ *Man-made amenity*	−6.3869***	0.9050
$p^a \times$ *Recreation resource*	1.9253**	0.9361
$\hat{R}^{CRP} \times$ *Roads*	−0.3720***	0.1258
$\hat{R}^{CRP} \times y$	0.0007	0.0007
$\hat{R}^{CRP} \times g$	0.0063**	0.0033
$\hat{R}^{CRP} \times \sigma$	0.0377	0.2894
$\hat{R}^{CRP} \times$ *Max*	0.0430	0.0243
$\hat{R}^{CRP} \times$ *Climate*	5.1441	9.4251
$\hat{R}^{CRP} \times$ *Man-made amenity*	61.6576***	10.5946
$\hat{R}^{CRP} \times$ *Recreation resource*	3.7066	8.2816
Roads	−12.6217	19.6437
y	0.9562***	0.1755
Climate	3,324.58*	1,745.20
Man-made amenity	21,679.98***	2,096.20
Recreation resource	−4,966.70***	,434.40
r1	39,878.5***	5,926.10
r2	71,433.5***	4,598.50
r3	14,793.9***	4,398.30
r4	9,657.0**	4,060.60
r5	−12,048.5**	5,280.20
r6	−4,365.1	4,110.70
r7	6,096.9	4,341.90
r8	−4,884.6	5,106.70
r9	−3,621.5	3,688.10

Note: The farmland value equation reported in Table A2 and the developed land value equation reported in this table are estimated using generalized spatial three-stage least squares (GS3SLS). Number of observations = 2,851. System-weighted R^2 = 0.87.

* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

TABLE A4

PARAMETER ESTIMATES FOR THE FARMLAND VALUE EQUATION, MODELS II–V

Variable	Estimate			
	Model II	Model III	Model IV	Model V
Intercept	247.94***	224.04***	194.83***	248.81***
$\hat{R}^{CRP}$	4.41***	6.14***	2.66***	6.11***
g	6.05e–3	0.01	−5.01e–3	0.03*
σ	0.02**	0.06***	7.60e–3	0.04***
Natural amenity			51.23***	126.35***
Climate	227.90***	215.83***		
Man-made amenity	252.44***	358.06***		
Recreation resource	49.15	−1.84		
Roads	0.85		2.04***	
UIC		27.32		−24.46
$\hat{R}^{CRP2}$	−7.00e–5***	−9.00e–5***	2.00e–6	−7.00e–5***
g^2	−6.35e–6**	−7.87e–6***	−9.67e–6***	−7.67e–6***
σ^2	1.29e–6**	1.24e–6**	2.36e–6***	1.65e–6***
Natural amenity^2			5.51**	1.52
Climate^2	66.18***	60.76***		
Man-made amenity^2	−76.21***	−10.18***		
Recreation resource^2	−7.64	−8.40*		
Roads^2	−0.01***		−7.70e–4**	
UIC^2		−2.32***		1.67
$\hat{R}^{CRP} \times g$	− 2.10e–4***	1.50e–4***	−2.50e–4***	−1.8e–4***
$\hat{R}^{CRP} \times \sigma$	1.47e–4***	1.26e–4***	1.82e–4***	1.39e–4***
$\hat{R}^{CRP} \times$ *Natural amenity*			0.43***	0.15***
$\hat{R}^{CRP} \times$ *Climate*	−1.27***	−1.28***		
$\hat{R}^{CRP} \times$ *Man-made amenity*	0.70***	0.08		
$R^{CRP} \times$ *Recreation resource*	−0.68***	−0.55***		
$R^{CRP} \times$ *Roads*	−4.59e–3**		4.58e–3***	
$R^{CRP} \times$ *UIC*		−0.46***		−0.57***
$g \times \sigma$	−1.69e–6*	5.02e–7	−6.47e–7	6.91e–7
$g \times$ *Natural amenity*				
$g \times$ *Climate*	−8.40e–3	−2.37e–3		
$g \times$ *Man-made amenity*	0.02**	0.02**		
$g \times$ *Recreation resource*	−1.82e–3	−4.66e–3		
$g \times$ *Roads*	1.01e–4		2.67e–4***	
$g \times$ *UIC*		5.88e–4		−3.32e–3
$\sigma \times$ *Natural amenity*			−7.16e–3***	−6.64e–3***
$\sigma \times$ *Climate*	2.92e–3	4.92e–4		
$\sigma \times$ *Man-made amenity*	5.00e–3	−4.16e–3		
$\sigma \times$ *Recreation resource*	−5.40e–4	7.27e–4		
$\sigma \times$ *Roads*	1.47e–4***		8.2e–5	
$\sigma \times$ *UIC*		−7.29e–3***		−5.74e–3***
Roads × *Natural amenity*			−0.26***	
Roads × *Climate*	−1.10			
Roads × *Man-made amenity*	1.17***			
Roads × *Recreation Resource*	0.17			
UIC × *Natural amenity*				−10.55***
UIC × *Climate*		−3.53		
UIC × *Man-made amenity*		−28.18***		
UIC × *Recreation Resource*		9.55*		
rl	935.61***	793.48***	642.28***	685.39***

table continued on following page

TABLE A4
PARAMETER ESTIMATES FOR THE FARMLAND VALUE EQUATION, MODELS II–V
Continued

Variable	Estimate			
	Model II	Model III	Model IV	Model V
r2	160.56	118.21	−29.11	90.69***
r3	−104.41	−87.58	−92.06	−16.94
r4	−324.87***	−309.14***	−90.17	−68.70
r5	278.46**	250.33*	319.19**	398.91***
r6	601.30***	572.09***	688.39***	716.95***
r7	−5.31	36.63	177.76	195.03
r8	1,640.10***	1,616.72***	2,095.62***	2,027.49***
r9	708.56***	707.32***	770.56***	760.79***

Note: The farmland value equation reported in this table and the developed land value equation reported in Table A5 are estimated using generalized spatial three-stage least squares (GS3SLS) for each model. Number of observations = 2,851. System-weighted $R^2 = 0.87$ for each model.

* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

TABLE A5

PARAMETER ESTIMATES FOR THE DEVELOPED LAND VALUE EQUATION, MODELS II–V

	Estimate			
Variable	Model II	Model III	Model IV	Model V
Intercept	11,886.58***	32,700.81***	6,849.01***	39,437.21***
$\hat{R}^{CRP}$	61.58***	111.10***	12.34	108.13***
g	−2.18***	− 0.96**	−2.74***	− 1.34***
σ	2.72***	1.57***	2.87***	1.44***
g^2	2.31e–4	3.39e–4**	1.50e–4	0.42e–4***
σ^2	−8.00e–	−8.00e–5**	7.00e–5**	−1.00e–4***
$g \times \sigma$	−1.60e–4**	−1.60e–4**	−1.20e–4**	−1.30e–4***
Natural amenity			−1,258.77**	4,031.25***
Climate	4,963.67***	−1,952.48		
Man-made amenity	17,786.51***	20,396.41***		
Recreation resource	−1749.59	−1,872.00		
Roads	82.40***		194.99***	
UIC		−2,1086.50***		−25,281.40***
$\hat{R}^{CRP}$	−2.70e–3***	−3.40e–3***	−6.80e–4*	−3.31e–3***
Natural amenity^2			732.89***	818.07***
Climate^2	−1,125.00	1,864.22**		
Man-made amenity^2	−4,769.40***	−359.80***		
Recreation resource^2	−277.41	−372.33*		
Roads^2	−0.42***		−0.09***	
UIC^2		1,495.91***		1,862.91***
$\hat{R}^{CRP}$ × *Natural amenity*			25.30***	12.06***
$\hat{R}^{CRP}$ × *Climate*	−14.10*	−11.52*		
$\hat{R}^{CRP}$ × *Man-made amenity*	26.44***	2.49		
$\hat{R}^{CRP}$ × *Recreation resource*	10.80	14.49**		
$\hat{R}^{CRP}$ × *Roads*	−0.21**		0.07	
$\hat{R}^{CRP}$ × *UIC*		−14.81***		
Roads × *Natural amenity*			1.84	−15.59***
Roads × *Climate*	−28.10**			
Roads × *Man-made amenity*	82.83***			
Roads × *Recreation resource*	13.03			−496.14***
UIC × *Natural amenity*				
UIC × *Climate*		927.94***		
UIC × *Man-made amenity*		−2,844.45***		
UIC × *Recreation resource*		385.45		
r1	160,295.60***	161,634.40***	123,496.40***	133,580.80***
r2	85,559.43***	100,585.80***	64,044.16***	87,345.16***
r3	21,190.61***	30,427.77***	13,566.22***	27,505.60***
r4	8,077.42*	15,395.77***	8,102.67*	19,246.03***
r5	6,969.76	14,190.87***	2,699.35	14,891.74***
r6	9,380.34**	15,595.50***	10,059.34**	16,544.13***
r7	1,553.03	11,147.64**	4,159.05	13,820.66***
r8	17,926.73***	23,784.98***	33,193.82***	37,402.49***
r9	2,707.72	12,918.97***	5,117.96	12,326.99***

Note: The farmland value equation reported in Table A4 and the developed land value equation reported in this table are estimated using generalized spatial three-stage least squares (GS3SLS) for each model. Number of observations = 2,851. System weighted R^2 = 0.87 for each model.

* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

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