A Theoretical and Empirical Analysis of Conservation Reserve Program Participation under Uncertainty

by

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Abstract

This paper develops theoretical and empirical models to understand how farmers formulate their participation strategies when deciding to enroll in the Conservation Reserve Program (CRP) under uncertainty. A theoretical model is employed to obtain the impacts of various factors on the optimal bidding strategies. A selectivity-based econometric model is then used to estimate the probability of enrollment and determinants of rental payments. The theoretical results indicate that the optimal bid is positively related to the expected farming income and environmental benefit scores, and it is negatively related to the degree of risk aversion and the variability of returns. The econometric model shows that land benefits, land attributes, farmer characteristics, and variability of climate variables impact the enrollment probabilities and rental rates received. These results have important policy implications for the design and implementation of conservation programs.

Key Words: conservation programs, land retirement, risk aversion, uncertainty.

1. Introduction

The Conservation Reserve Program (CRP) is a voluntary land retirement program that aims at protecting the nation's most environmentally sensitive cropland. Farmers enter into 10- to 15-year contracts with U.S. Department of Agriculture and receive annual rental payments and cost-share assistance for establishing conservation practices in their land. The CRP enrolls land through a bidding process, in which contracts are accepted based on a county-level soil-specific maximum acceptable bid and an Environmental Benefit Index (EBI) that is composed of a set of environmental criteria[1]. This index is then combined with the farmer's bid (cost factor) to obtain the cost-adjusted index (the total EBI) and the rankings used to decide program participants (FSA). Each bidder is given a fact sheet about the scoring rules for each environmental category, the total environmental scores, and the applicable bid cap, but not the cost factor. The formula for converting bids into the cost factor points as well as the weight of the cost factor in the total EBI are not known to farmers prior to the submission of bids.

Several authors pointed out that the CRP has made some contributions in improving the quality of natural environment in the United States (Ribaudo; Feather, Hellerstein, and Hansen; Smith). However, there are still various concerns regarding the rationale in the bidding process, environmental effectiveness of the program, and determinants of land rental payments (GAO; Classen et al.; Yang and Isik; Khanna et al.). Because public policies are increasingly relying on the use of land retirement programs to achieve environmental policy goals, it is important to understand the factors affecting farmer participation and the determinants of rental rates received in the CRP. This information could be useful in improving the CRP bidding process, estimating the program costs, and examining and enhancing the cost-effectiveness of the program.

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[1] The environmental scores of EBI consist of six separate categories each expressing different attributes such as wildlife, water quality, soil erosion, enduring benefits, air quality, and state or national conservation priority area.

Farmers' enrollment decisions in the CRP involve various sources of uncertainty. Especially, a farmer's bidding strategy is influenced by two sources of uncertainty; farming income and the CRP bidding process and rules. The decision to participate in the CRP must be made in the face of the well-known revenue uncertainty of agricultural production resulting from variability in output prices and crop yields. Producers are also faced with uncertainty about the CRP bidding process and rules including their ignorance of the environmental scoring rules, combining scores to rank bidders, and other bidders' strategies. In particular, they formulate their bidding strategies in the presence of uncertainty about the trade-off between bids and environmental scores and the weight of the cost factor in the total EBI.

The purpose of this paper is to develop a model of farmer decision-making to understand how farmers formulate their participation strategies when deciding to enroll in the CRP under uncertainty. The theoretical model determines the impacts of various factors on the optimal bidding strategies. A selectivity-based econometric model that incorporates land characteristics, farmer attributes, and uncertainty about agricultural production is then used to estimate the probability of enrollment in the CRP and determinants of rental payments received.

Several empirical studies have examined the factors affecting farmer participation in the CRP and wetland reserve programs (Konyar and Osborn; McLean, Hui, and Joseph; Skaggs, Kirksey, and Harper; Kalaitzandonakes and Monson; Cooper and Osborn; Goodwin and Smith; Parks and Kramer)[2]. Previous studies identified various factors affecting farmer participation in these programs. They pointed out that socioeconomic variables such as farmer tenure and age, economic factors such as returns and costs, bid cap, soil erosion rate, and location of counties influence the probability of the CRP participation. Most of these studies employed discrete

[2] A few studies examined CRP bidding behavior in the early sign-up periods (Shoemaker; Reichelderfer and Boggess). They showed that asymmetric information about farmers learning the bid cap caused the submitted bids to approach the bid cap.

choice models with the survey data to examine the determinants of farmer participation. However, these studies assume deterministic decision-making, and therefore do not take into account uncertainty and risk aversion of farmers in estimation of the participation probabilities.

This analysis differs from the previous work in several ways. First, this study provides a comprehensive model of program participation under uncertainty to formulate farmers' bidding strategies. Second, it utilizes a behavioral econometric model to estimate not only the factors affecting enrollment probabilities, but also the determinants of rental rates. Third, the analysis uses a national-level data set, instead of a single state or region, and considers various variables that are not considered by the previous studies and are likely to affect participation decision. Finally, it aims at determining the impacts of uncertainty about agricultural production on the participation decision and rental rates received. Thus, this paper contributes to the existing literature on the CRP participation by developing a framework to incorporate uncertainty in estimation of the enrollment probabilities and the determinants of rental rates received.

The results from the theoretical model indicate that the optimal bid is positively related to the expected farming income and environmental benefits and negatively related to the degree of risk aversion and the variability of returns. The results from the econometric model show that land benefits and attributes, farmer characteristics, and variability of climate variables have significant impacts on the enrollment probabilities and rental rates. Increases in production costs and bid caps, and decreases in value of crop production have positive impacts on the participation decisions. Lands with higher EBI have a higher probability of enrollment and higher rental rates. The variability of climate variables positively impacts the enrollment probabilities and negatively impacts the rental rates received. These results have important policy implications for conservation programs because public policies are increasingly relying on the use of land retirement and conversion programs to achieve environmental policy goals.

2. Theoretical Model

We develop a model to determine the factors affecting farmer participation in the CRP by extending the framework presented by Latacz-Lohmann and Van der Hamsvoort. Consider a risk-averse farmer who decides whether to participate in the CRP under uncertainty about agricultural returns. The farmer is assumed to have a von Neuman-Morgenstern utility function, *U(W)* defined on wealth *W* with $U_W > 0$ and $U_{WW} < 0$. The wealth is represented by the sum of the initial wealth (W_0) and returns from crop production. The returns could be uncertain due to uncertainty about prices, crop yields and weather conditions. The per-acre expected return is represented as: $E\pi(q;\eta)$, where *E* is the expectation operator, *q* is the land quality and η is the farmer characteristics such as age. Let the per-acre government payments received be represented by $G(q)$. The farmer has the option to participate in the CRP and can receive per-acre annual rental payments (*V*). Participation in the CRP creates non-stochastic income. The farmer is responsible for a portion of the annualized restoration costs, $(1-\alpha)K(q)$, and receives the remaining costs ($\alpha K(q)$) as incentive payments for participation. Thus, the landowner faces the choice of continuing production in the current land use, or converting it to the CRP land.

We determine the minimum rental rate that a farmer requires to participate in the CRP. The farmer's bidding strategy is guided by the notion of a maximum acceptable payment ($\overline{B}$), above which no bids will be accepted. Denote *B* as the unknown largest possible bid that the farmer can submit and win acceptance into the CRP. Assume that each farmer forms expectations about *B*. Farmers are informed about environmental benefit scores (*S*) of their cropland before placing their bids. Therefore, we assume that the environmental scores have an effect on these expectations. The expectations, conditional on *S*, can be characterized by the density function $h(B \mid S)$, with a support on $[0, \overline{B}]$, where $\overline{B}$ is the bid cap. Here, $h(B \mid S)$

summarizes the farmer's uncertainty about the CRP bidding process and rules, which results from the lack of knowledge about the environmental scoring rules, combining scores to rank bidders, and trade-off between bids and environmental scores. The probability that a bid is accepted can be expressed as: $P(V \leq B \mid S) = \int_{V}^{\overline{B}} h(B \mid S) dB = 1 - H(V \mid S)$. The density $h(B \mid S)$ is conditioned on S so that $S^1 > S^2 \Rightarrow H(V \mid S^1) < H(V \mid S^2)\ \forall V \in \left[0, \overline{B}\right]$ (i.e., $\frac{\partial H(V \mid E)}{\partial S} < 0$).

Optimal Bidding Strategy under Uncertainty

The farmer will enroll in the CRP if the expected utility in case of participation in the CRP exceeds the expected utility without participation:

$$\begin{aligned} &EU\left(W_0 + V - (1-\alpha)K(q)\right)\left[1 - H(V \mid S)\right] + EU\left(W_0 + \pi(q;\eta) + G(q)\right)H(V \mid S) \\ &> EU\left(W_0 + \pi(q;\eta) + G(q)\right) \end{aligned}. \tag{1}$$

Equation (1) indicates that the balance between the net payoffs and the acceptance probability. A higher bid increases the net payoffs, but reduces the probability of winning, and vice versa. The farmer faces the problem of determining the optimal bid that can win acceptance into the CRP under uncertainty. To derive explicit analytical results, we replace the expected utility with the certainty equivalent income as in Latacz-Lohmann and Van der Hamsvoort. We derive the certainty equivalent income from the expected utility by obtaining the risk premium (R) from $EU\left(W_0 + \pi(q;\eta) + G(q)\right) = U\left(W_0 + E\pi(q;\eta) - R\right)$ (Isik). Using a second-order Taylor series approximation, R at the mean wealth $\overline{W}$ is obtained as: $R(\overline{W}) = \phi(\overline{W})Var(\pi)/2$, where $Var(\pi)$ is the variance of the profit and $\phi(\overline{W}) = -U_{WW}/U_W$ is the Arrow-Pratt measure of absolute risk aversion (Isik). Note that the risk premium under the CRP, $R(V)$, is zero because there is no uncertainty associated with the annual income received.

The farmer's decision is to determine the optimal bid as[3]

$$\underset{V}{Max}\ \Psi = \left[V - (1-\alpha)K(q) - E\pi(q;\eta) - G(q) + R(\overline{W})\right]\left[1 - H(V \mid S)\right]. \tag{2}$$

The first-order condition is

$$\left[1 - H(V \mid S)\right] - h(V \mid S)\left[V - (1-\alpha)K(q) - E\pi(q;\eta) - G(q) + R(\overline{W})\right] = 0. \tag{3}$$

The optimal bid formula is then determined from (3) as:

$$V^* = \left[E\pi(q;\eta) + G(q) + (1-\alpha)K(q) - R(\overline{W})\right] + \frac{\left[1 - H(V^* \mid S)\right]}{h(V^* \mid S)}. \tag{4}$$

This solution is unique maximum if $\overline{B}$ exceeds V^* and the second-order condition, $\Delta = 2h(V^* \mid S) + \frac{\partial h(V^* \mid S)}{\partial V^*}\left[V^* - (1-\alpha)K(q) - E\pi(q;\eta) - G(q) + R(\overline{W})\right] > 0$, is satisfied.

The optimal bid in (4) compromises the sum of forgone profits ($E\pi(q;\eta)$), the government payments ($G(q)$) and the restoration costs ($(1-\alpha)K(q)$) minus the risk premium ($R(\overline{W})$) plus a premium ($\frac{\left[1 - H(V^* \mid S)\right]}{h(V^* \mid S)} > 0$). We can interpret the premium as the inverse of hazard rate or the inverse of the probability that a bid will be accepted in a short interval of V given that the bid has not exceeded the largest possible bid that can win acceptance previously (at V^*). The farmer's entire uncertainty about the CRP bidding process adds the premium to the optimal bid as a mark-up above the opportunity cost of participation ($E\pi(q;\eta) + G(q) + (1-\alpha)K(q) - R(\overline{W})$). When the opportunity cost exceeds the bid cap, the farmer has no motivation to participate in the CRP. If the rules for the CRP bidding process are known with certainty, $1 - H(\overline{B} \mid S) = 1$, and $V^* = E\pi(q;\eta) + G(q) + (1-\alpha)K(q) - R(\overline{W})$. In this

[3] The model developed here can be extended by incorporating the farmer's input-use decision. Such a model can be solved in a two-stage framework. In the first stage, the farmer determines the optimal input use (F) by maximizing $EU\left(W_0 + \pi(q,F;\eta) + G(q)\right)$ and then finds $EU\left(W_0 + \pi(q,F^*;\eta) + G(q)\right)$. In the second stage, the optimal bid is determined using equation (2) with $EU\left(W_0 + \pi(q,F^*;\eta) + G(q)\right)$ and $E\pi(q,F^*;\eta)$.

case, since any bid below $\overline{B}$ is accepted, the farmer bids at $\overline{B}$ or does not bid. Thus, revealing the rules for the CRP bidding process would increase the optimal bid to $\overline{B}$. This also leads the farmer with low opportunity costs to bid at $\overline{B}$, providing a premium for the farmer.

Factors Affecting the Optimal Bid

We now examine the factors affecting the optimal bid given in (4). The optimal bid is positively related to the expected return, the government payments, and the restoration costs. The bid is negatively related to the risk premium ($R(\overline{W}) = \phi(\overline{W})Var(\pi)/2$). The greater the risk aversion and/or the greater the variability of returns, the higher the risk premium, and therefore the lower the optimal bid price ($\frac{dV^*}{d\phi} = -\frac{h(V \mid S)Var(\pi)}{2\Delta} < 0$ and $\frac{dV^*}{d(Var(\pi))} = -\frac{h(V \mid S)\phi}{2\Delta} < 0$). Risk-averse farmers tend to increase the probability of acceptance by lowering their bids. Under risk-neutrality, $V^* = [E\pi(q;\eta) + G(q) + (1-\alpha)K(q)] + \frac{[1 - H(V^* \mid S)]}{h(V^* \mid S)}$. These results indicate that risk-averse farmers usually bid lower than risk-neutral farmers in the CRP.

We determine the impact of an increase in the environmental benefit scores of the cropland offered to the CRP on the optimal bid by totally differentiating (3) as:

$$\frac{dV^*}{dS} = -\frac{\Omega}{\Delta}. \tag{5}$$

where $\Omega = \frac{\partial H(V^* \mid S)}{\partial S} + \frac{\partial h(V^* \mid S)}{\partial S}[V^* - (1-\alpha)K(q) - E\pi(q;\eta) - G(q) + R(\overline{W})]$. The sign of (5) depends on the sign of Ω. Given that $\Delta > 0$ and $\frac{\partial H(V \mid E)}{\partial S} < 0$, $\frac{dV^*}{dS} > 0$ if $\Omega < 0$. This condition holds when the bid changes at a bounded rate and the density does not increase dramatically in any region of the support. Hence, the higher the environmental scores, the higher the optimal bid. *Ceteris paribus*, the farmer will bid higher for the fields with the higher environmental scores than the fields with the lower scores.

The land quality also affects the farmer participation. Assuming that the environmental scores are a function of the land quality, $S(q)$, we examine the impact of an increase in q on the optimal bid by totally differentiating (3) as:

$$\frac{dV^*}{dq} = -\frac{\frac{\partial S}{\partial q}\Omega + h(V^* \mid S)\Lambda}{\Delta} \tag{6}$$

where $\Omega < 0$ and $\Lambda = \left[-(1-\alpha)\frac{\partial K(q)}{\partial q} - \frac{\partial E\pi(q;\eta)}{\partial q} + \frac{\partial E\pi(q;\eta)}{\partial q}\frac{\partial R(\overline{W})}{\partial \pi} - \frac{\partial G(q)}{\partial q} \right]$. Since $E\pi(q;\eta) > R(\overline{W})$, $\frac{\partial E\pi(q;\eta)}{\partial q} > \frac{\partial E\pi(q;\eta)}{\partial q}\frac{\partial R(\overline{W})}{\partial \pi}$. Given that $\frac{\partial G(q)}{\partial q} > 0$, $\Lambda < 0$ if $\frac{\partial K(q)}{\partial q} \geq 0$. However, if $\frac{\partial K(q)}{\partial q} < 0$, we expect $\Lambda < 0$ because $\frac{\partial K(q)}{\partial q}$ is likely to be small. If $\frac{\partial S}{\partial q} \geq 0$, (6) is positive, indicating that the bid is positively related to the land quality. If $\frac{\partial S}{\partial q} < 0$, then the impact of an increase in the land quality on the optimal bid is indeterminate because of the two countervailing effects of the land quality. Thus, the optimal bid increases with an increase in the land quality, unless the land quality is negatively related to the environmental scores.

Farmer characteristics (η) would also affect the optimal bid through influencing $E\pi(q;\eta)$. The impact of η on the optimal bid is determined as: $\frac{dV^*}{d\eta} = \frac{h(V^* \mid S)}{\Delta}\left[\frac{\partial E\pi(q;\eta)}{\partial \eta}\left(1 - \frac{\partial R(\overline{W})}{\partial \pi}\right)\right]$, which depends on the sign of $\frac{\partial E\pi(q;\eta)}{\partial \eta}$. Note that $\frac{dV^*}{d\eta} \geq (<) 0$ if $\frac{\partial E\pi(q;\eta)}{\partial \eta} \geq (<) 0$. Thus, the optimal bid is positively (negatively) related to a farmer characteristic if that characteristic increases (decreases) the expected return.

Denoting heterogeneity in the land quality and farmer characteristics in a county by subscripting q and η with i, we can state that there will be some farmers with $V_i^* \le \overline{B}$ and others with $V_i^* > \overline{B}$. In a county, the farmers with $V_i^* \le \overline{B}$ will submit their bids to the program while the remaining farmers will not bid. Let the farmers be numbered in increasing order by their optimal bids, such that V_1^* represents the lowest bid and V_N^* represents the highest bid. In a county with N farmers, M farmers with $V_1^*, V_2^*, ..., V_M^* \le \overline{B}$ will submit their bids to the program while the remaining farmers will not bid. After all the farmers submit their bids, the offers with $V_i^* \le \overline{B}$ are evaluated and ranked using the cost-adjusted environmental scores of the land offered (T_i). This cost-adjusted index depends on the environmental scores of the EBI and the cost factors (farmers' bids) as: $T_i = g(V_i^*, S_i)$ with $\frac{\partial g}{\partial V_i^*} < 0$ and $\frac{\partial g}{\partial S_i} > 0$. Each eligible offer is ranked based on T_i in comparison to all the other offers and selections are made from that ranking. All the offers with the cost-adjusted index higher than the cutoff (threshold) index (T_i^C) are accepted. In the next section, we develop an econometric model to analyze the factors affecting enrollment in the CRP and the determinants of rental rates received.

3. Econometric Model

We now develop a selectivity-based econometric model to identify factors affecting enrollment in the CRP and determinants of rental rates received based on the theoretical analysis. Participation by landowners in the CRP is measured using the proportion of county cropland enrolled in the CRP (as in Parks and Kramer; Goodwin and Smith). Each county is analyzed as a representative farm that possesses the average characteristics of that county. The econometric model is used to determine the factors affecting the probability of cropland enrolled in the CRP and the rental rates received.

Determinants of Enrollment Probabilities

The choice to accept a tract of agricultural land to the CRP depends on whether the cost-adjusted environmental scores of the land are higher than the threshold scores. Let $T_i^C(q,\eta,\pi)$ describe the per-acre threshold cost-adjusted environmental scores relevant to county *i*. The probability of some parcels drawn from county *i*, with the vector of observable characteristics $\mathbf{x_i}$, has a probability of enrolling (P_i), which is defined as the probability that $T_i = g(\mathbf{x_i}\boldsymbol{\delta})$ is greater than $T_i^C(q,\eta,\pi)$. Here, $T_i = g(\mathbf{x_i}\boldsymbol{\delta})$ is the cost-adjusted environmental scores of the land with the attributes $\mathbf{x_i}$. Note that the vector $\mathbf{x_i}$ would include factors affecting both V_i^* and S_i as identified in the theoretical analysis above. These factors consist of land characteristics, land quality, expected returns, government payments, socio-economic factors, environmental scores, bid cap, and variables related to the variability of returns. The vector $\mathbf{x_i}$ is specified so that the probability of a land with the vector of attributes $\mathbf{x_i}$ drawn randomly from the land base enrolled in the CRP in county *i* is $P_i = \Pr\{T_i^C \le g(\mathbf{x_i}\boldsymbol{\delta})\}$, where $\boldsymbol{\delta}$ is the parameter vector to be estimated. This probability is bounded by zero and one. The relationship between T_i and P_i is assumed to form a standard normal cumulative distribution function[4]:

$$P_i = \Pr\{T_i^C \le g(\mathbf{x_i}\boldsymbol{\delta})\} = \Phi(g(\mathbf{x_i}\boldsymbol{\delta})). \tag{7}$$

This yields the probit model (Johnston and Dinardo, p. 418). We solve (7) for $g(\mathbf{x_i}\boldsymbol{\delta})$ to approximate the probability with the proportion of the land acres enrolled in the CRP (f_i) in county *i*. We then use the minimum χ^2 methods in grouped data to estimate the probability of enrollment as (Maddala; Johnston and Dinardo, p. 433-434):

[4] An alternative model is to use a tobit specification as in Goodwin and Smith. However, this probit specification performed better than the tobit specification.

$$\Phi^{-1}(f_i) \cong g(\mathbf{x_i}\boldsymbol{\delta}) + u_i. \tag{8}$$

The grouping was done across producers with eligible lands as in Parks and Kramer. The parameter vector $\boldsymbol{\delta}$ is estimated using observations on f_i, which is consistent with the approach used by Parks and Kramer. A linear function of parameters is estimated, i.e., $g(\mathbf{x_i}\boldsymbol{\delta}) = \mathbf{x_i}\boldsymbol{\delta} + u_i$. Maddala's correction was used for the heteroscedasticity exhibited by u_i. These parameter estimates allow the probability of enrollment in the CRP to be estimated for each county. We also calculate the elasticity of probability for some of the explanatory variables.

Determinants of Rental Rates

We use the Heckman's two-step estimator that considers a model consisting of two equations (Greene, 1997, p. 974-981). The first equation is the selection equation defined by (7). The second equation is the linear model of the determinants of rental rates received: $y_i = \mathbf{z_i}\boldsymbol{\beta} + e_i$, where y_i is the rental payment received by farmers, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, $\mathbf{z_i}$ is a vector of exogenous variables, and e_i is a random disturbance with the variance σ^2. Let the correlation between e_i and u_i be represented by ρ.

A selectivity problem arises because y_i is observed only when $f_i > 0$ and the observed rental rates represent the accepted bids. In such a situation, the ordinary least squares estimator of $\boldsymbol{\beta}$ is biased and inconsistent. A consistent estimator is the two-step procedure suggested by Heckman and clarified by Greene (1981). The basis for this estimation procedure is the conditional regression function:

$$y_i = E[y \mid f_i > 0] + v_i = \mathbf{z_i}\boldsymbol{\beta} + \beta_\gamma \gamma_i + v_i \tag{9}$$

where $\beta_\gamma = \rho\sigma$, $\gamma_i = \frac{\phi(\mathbf{x_i\delta})}{\Phi(\mathbf{x_i\delta})}$ is the inverse Mill's ratio, $\phi(\cdot)$ is the standard normal probability density function evaluated at the argument, $\Phi(\cdot)$ is the cumulative distribution function for a standard normal random variable evaluated at the argument, and v_i is the random disturbance. Because the regression error v_i is heteroskedastic, the standard errors of the regression are obtained by using the methods proposed by Heckman and Greene (1981) who derive the covariance matrices in selectivity models. First, we use the standard Heckman two-step estimation procedure to estimate equations (8) and (9). Those estimators are consistent, but may not be fully efficient. Thus, we also estimate the models using maximum likelihood as in Détang-Dessendre et al. In this case, we do not estimate $\beta_\gamma = \rho\sigma$ but rather ρ and σ (the estimation is done in one step) (Détang-Dessendre et al.). Identification problems may arise in sample selection analysis using two-step regression. When the elements of $\mathbf{x_i}$ are the same as, or a subset of, the elements of $\mathbf{z_i}$, it is only the nonlinearity of $\frac{\phi(\mathbf{x_i\delta})}{\Phi(\mathbf{x_i\delta})}$ as a function of $\mathbf{x_i\delta}$ that makes the parameters of the second step regression identifiable (Davidson and MacKinnon, p. 545).

4. Data

Enrollment in the CRP is measured using the proportion of the cropland enrolled in the CRP during the signup 20 in 2000. The data covers all the counties in the United States that have CRP land up to that signup period. Of the 1,729 counties in the data set, the bids from 1,577 counties were accepted during the signup 20. This cross-section data is merged at the county level with the economic, climate condition, land quality, and farmer characteristics data identified in the theoretical analysis. Descriptive statistics of the data used in the estimation are presented in Table 1. To be eligible for the CRP participation the land must be: (a) cropland that was planted or considered planted to an agricultural commodity on hydric soils; or (b) marginal pastureland that is suitable for practices such as riparian buffers, filter strips, grassed waterways, or field windbreaks. Eligible land data are obtained from the 1997 National Resources Inventory.

The data on the land acres enrolled in the CRP during the signup 20 of the CRP are obtained from U.S. Department of Agriculture, Farm Service Agency (FSA). The average rental rates (RENT), maximum acceptable rental rate (MAXBID) and the average EBI of each county were also obtained from Farm Service Agency. Farm Service Agency bases the maximum acceptable rental rates on the relative productivity of the soils within each county and the average of the past 3 years of dryland cash rent or cash-rent equivalent rental rates adjusted for site-specific, soil-based productivity factors.

The EBI also plays a role in determining suitability of the land for enrollment in the CRP. The EBI depends on six environmental factors and a cost component. The environmental factors are determined based on the following point system: wildlife habitat benefits, 0-100 points; water quality benefits, 0-100 points; on-farm benefits, 0-100 points; long-term benefits, 0-50 points; air quality benefits, 0-35 points; and conservation priority area, 0-25 points (FSA). The cost component of the EBI consists of 15 points for requested rental payment relative to the maximum acceptable payment for soils offered, 10 points if no cost-share for cover establishment is requested, and up to 125 points depending on the per-acre rental payments requested. We use only the total environmental component of the EBI to avoid endogeneity associated with the cost component in the estimations.

The opportunity cost of participation in the CRP for farmers is made up of the returns from crop production and farm program payments. The data related to the opportunity cost are obtained from the 1997 U.S. Census of Agriculture. This data include revenues, production costs, and government payments. Crop revenues per acre (VALCROP) consist of the value of crops sold in a county. Crop costs per acre (COST) include the costs of seed, fertilizers, chemical, petroleum, electricity, labor, and other customwork costs. Per-acre government payments other than the CRP payments received by farmers (GOVPAY) are also considered as opportunity costs of participation. We also calculate the proportions of cropland allocated to corn and soybeans (CORNSOY), wheat, barley and oats (WHBR), and rice and cotton (RICOT) production in each county. These variables are used to take into account the impacts of regional differences in crop production patterns on the participation decision and rental rates received.

Land quality indices for each county include the proportion of land in Land Capability Classes (LCCs) I and II, the slope of the agricultural land (SLOPE), and the proportion of the cropland irrigated (IRLAND). These measures are obtained from the 1997 National Resources Inventory data base. LCCs I and II represent well-suited land for crop production. The vector η for a county includes the characteristics of land users in the county. Farmer characteristics for a county from the 1997 U.S. Census of Agriculture include the average age of the farm operators (AGE) and the proportion of the cropland operated by full-time owners (FULL) in that county.

We use the mean temperature (MTEM) and precipitation (MPER) as indicators of climate condition in each county. As an alternative measure of climate condition, we also employ a drought index, Palmer Drought Severity Index (MPAL). This is a meteorological drought index indicating the severity of dry or wet spells of weather. It is based on the principles of a balance between moisture supply and demand. The index generally ranges from -6 to 6, with negative values denoting dry spells and positive values indicating wet spells. These variables are included in the analysis because they are likely to affect the expect returns. To take into account the impacts of the risk premium of crop production, we estimate the variability of climate variables. The standard deviations of temperature (STEM), precipitation (SPER), and the drought index (SPAL) are calculated using the time series data for each county. The climate data is obtained from the National Climatic Data Center. The variability of the climate variables could serve as a proxy for the variability of agricultural returns.

5. Results

Factors Affecting Enrollment Probabilities

Table 2 presents the results of two alternative models for the determinants of proportion of the cropland enrolled in the CRP. Model I includes the precipitation and temperature levels as climate variables and their standard deviation as a proxy for the variability of agricultural returns. We also use an alternative measure of an indicator for climate conditions, the drought index. Model II includes the drought index and its standard deviation instead of the precipitation and temperature levels and their standard deviation.

Most of the variables in the estimated models are statistically significant. The climate variables and their variability are found to impact the enrollment probabilities in the CRP. The mean temperature (MTEM) has a negative impact and the mean precipitation (MPER) has a positive impact on the participation probabilities. As a proxy for the uncertainty about agricultural production, we include the variability of climate variables in Model I. The variability of temperature (STEM) and precipitation (SPER) positively impacts the participation probabilities. The estimated elasticities of these variables are 0.93 and 0.28, respectively. These results are consistent with the analytical results obtained above. The standard deviation of agricultural profits is likely to increase with an increase in the variability of climate variables. An increase in the variability increases the risk premium, reducing the threshold rental rates required to participate in the program. As an alternative measure of climate condition, we also employ Palmer Drought Index (MPAL) and its variability (SPAL) (Model II). Similarly, the variability of this index has a positive impact on the enrollment probabilities. The estimated elasticities of MPAL and SPAL are 0.12 and 0.14, respectively

As expected, the bid cap (MAXBID) has positive impacts on the proportion of cropland enrolled in the CRP. This result occurs because the CRP contracts are accepted based on a county-level bid cap that is calculated in advance of enrollment. The bid cap is included to explain participation decisions because they influence the farmer's bidding strategies as shown in the theoretical analysis above. The probability is inelastic with respect to MAXBID. The elasticities of MAXBID for Model I and for Model II are 0.60 and 0.75, respectively.

An increase in the agricultural benefits from crop production is expected to decrease the probability of enrollment in the CRP because it increases the opportunity costs of participation in the program. In the estimated models, this corresponds to increases in the value of crop production (VALCROP) or decreases in the crop production costs (COST). The negative coefficients for VALCROP and the positive coefficient for COST are consistent with these interpretations. This indicates that increases in the value of crop production and/or decreases in the production costs reduce the probability of enrollment in the CRP. The estimated elasticities of VALCROP for Model I and Model II are -1.06 and -0.86, respectively. The estimated elasticities of the probability for COST in these models are 0.84 and 0.66, respectively.

The government payments (GOVPAY) are also included as a measure of the opportunity costs of enrollment in the CRP. The negative and statistically significant coefficient for GOVPAY indicates that government payments received by farmers have a negative impact on the participation decision. This result is expected because these payments increase the opportunity costs of crop production and therefore the opportunity costs of participation in the CRP. However, the enrollment probability is found to be inelastic with respect to the government payments (Table 2). The elasticity of probability with respect to this variable is found to be about -0.12 for all the estimated models.

We include the proportions of cropland allocated to corn and soybeans (CORNSOY), wheat, barley and oats (WHBR), and rice and cotton (RICOT) productions to take into account the impacts of regional differences in crop production patterns[5]. The coefficients on the variables for CORNSOY and RICOT are negative and statistically significant, while the coefficients of WHBR are positive for all the estimated models, but statistically significant only in Model I. These results indicate that the proportion of the cropland enrolled in the CRP are higher in the counties with higher wheat and barley productions as well as higher corn and soybean productions, and the enrollment probabilities are lower in the counties with higher rice and cotton productions. The elasticity of these variables is found to be about 0.10, indicating that the probability of enrollment is inelastic with respect to these variables. The coefficient on the proportion of the cropland irrigated (IRLAND) is negative and statistically significant. This indicates that irrigated land is less likely to be enrolled in the CRP than nonirrigated land.

As soil quality and environmental quality variables, the proportion of the land in LCCs I and II and the EBI are included in the estimations. LCCs I and II measure the land's suitability for crop production. The negative coefficient on LCCs indicates that the proportion of the land in LCCs I and II is negatively related to the enrollment in the CRP. The EBI in a county is included as an environmental quality indicator of that county. The proportion of the land enrolled in the CRP in a country could depend on the EBI rankings of that county. This is because the CRP contracts are selected by taking into account the EBI rankings of the cropland offered to the CRP. The coefficient on the EBI is positive and statistically significant at the 1% level for all the estimated models. The positive coefficient for the EBI shows that the probability of enrollment is positively related to the EBI. This result is consistent with the actual implementation of the

[5] We also estimated the models with dummy variables included for production regions. We do not present the results from these models because the results are similar to those reported in Table 2.

program in which contracts are accepted based on the EBI rankings relative to costs. The probability of enrollment in the CRP is found to be elastic with respect to the EBI for all the estimated models. The elasticity of probability is 1.15 for Model I and 1.45 for Model II.

We also examine the impacts of socioeconomic factors on the enrollment probabilities. Older farmers are expected to participate more in the CRP as a means of partial retirement. It is also reasonable to expect that counties with higher proportions of full-time landowners should have lower participation rates. These expectations are consistent with the estimated positive coefficient on the average age (AGE) and negative coefficient on the proportions of land operated by full-time owners (FULL). The probability of enrollment is elastic with respect to AGE and it is inelastic with respect to FULL. These results indicate that older farmers and higher proportions of land operated by part-time owners have higher enrollment probabilities. These results are consistent with the previous studies examining the factors affecting participation in the CRP and wetland reserve programs (McLean, Hui, and Joseph; Kalaitzandonakes and Monson; Parks and Kramer).

We tested the potential endogeneity of some of the variables used in the estimations of the models presented in Table 2. To test the endogeneity of the variables, we use a two-step procedure described by Wooldridge (p. 474). This procedure determines whether some of the variables are endogenous and/or whether endogeneity has any effect on consistency of their estimate. To determine whether the variable x_2 is endogenous, we first run the ordinary least squares regression x_2 on other independent variables and save the residual (v). Second, we re-estimate (8) with the residual v included as an additional independent variable. We then test the null hypothesis that x_2 is exogenous in the estimated model by determining whether the coefficient on v is equal to zero. The results indicate that the null hypothesis of exogeneity can not be rejected for all the variables tested in the models presented in Table 2.

Determinants of Rental Payments

Table 3 presents the results of two alternative models (Model I and II) for the determinants of rental rates received. These models correspond to the determinants of enrollment probabilities presented in Table 2. As the estimation with maximum of likelihood improves the efficiency without changing the value of the estimated coefficients, we present the result of this estimation method in Table 3 for all factors and we just add the estimated coefficient β_γ obtained by the Heckman method. The estimated models fit the data quite well. The R^2 is 0.67 for Model I and 0.66 for Model II. The results also indicate that the null hypothesis of no sample selection bias (i.e., $\beta_\gamma = 0$ and $\rho = 0$ in ML estimation) is rejected for all the estimated models[6].

The climate variables and their variability are expected to impact the rental rates received. The estimated models show that the mean temperature (MTEM) has a positive impact and the mean precipitation (MPER) has a negative impact on the rental rates received (Model I). The variability of temperature (STEM) and precipitation (SPER) has negative impacts on the rental rates. These results are consistent with the analytical results obtained above. The variability of returns from agricultural production is positively related to the risk premium, reducing the threshold rental rates required to participate in the program. These results also hold with the Palmer Drought Index (MPAL) and its variability (SPAL) (Model II). Thus, the variability of return from agricultural production would likely reduce the certainty equivalent income and therefore the rental rates received.

The estimated coefficient for the maximum allowable bid (MAXBID) is positive and statistically significant at the 1% level for all the estimated models. The county-level bid cap influences farmers' participation decisions and the rental rates received because it influences

[6] We also tested the potential endogeneity of some of the variables used in the estimations of the models presented in Table 3. The results indicate that there is no evidence suggesting the endogeneity for the variables used in the estimations.

farmers' bidding strategies as shown in the theoretical model. The elasticities of MAXBID for Model I and Model II are 0.68 and 0.67, respectively. An increase in the agricultural benefits from crop production increases the rental rates received because it raises the opportunity costs of participation in the CRP. The estimated models indicate that increases in the value from crop production (VALCROP) and/or decreases in the production costs (COST) increase the rental rates. The positive and statistically significant coefficient for GOVPAY indicates that government payments have a positive impact on the rental rates received. This indicates that government payments raise the rental rates received through increasing the opportunity costs of participation in the CRP.

The coefficient on the EBI for all the estimated models is positive and statistically significant at the 1% level. This indicates that the EBI is positively related to the rental rates received. These results reveal that the lands with higher environmental benefits receive higher rental payments. The slope has a positive impact on the observed rental rates, indicating that the land with higher slope is likely to have higher rental rates. An increase in the proportion of the land in LCCs I and II categories is expected to increase the rental rates received. The positive coefficient for the proportion of LCCs I and II is consistent with this interpretation. The proportion of cropland irrigated will affect the rental rates received. The coefficient on IRLAND is positive and statistically significant, indicating that the proportion of land irrigated is positively related to the rental rates received.

We also consider socioeconomic factors as the determinants of rental rates received in the estimated models (Table 3). These variables would likely affect the rental rates through either affecting the opportunity costs of participation or farmers' perceptions about the CRP bidding process and rules. The coefficient on the age (AGE) is not statistically significant. On the other hand, the coefficients on the full-time owners (FULL) for all the estimated models are negative and statically significant, indicating that the rental rates received are negatively related to the proportion of the cropland operated by the full-time owners. These results could be because counties with the high full-time owners would likely participate less in the CRP and the lands they offer for the CRP are likely to have low opportunity costs of participation.

6. Conclusions

This paper examines the factors affecting farmers' participation strategies when deciding to enroll in the CRP under uncertainty. It develops a theoretical model of farmer decision-making to investigate the impacts of various factors on the optimal bidding strategies. A selectivity-based econometric model is then used to estimate the probability of enrollment in the CRP and determinants of rental payments. The results from the theoretical model show that the optimal bid increases with an increase in the farming income and environmental benefits of the land and with a decrease in the risk aversion and variability of returns. The econometric model determines the factors affecting the probability of enrollment and the determinants of the observed rental rates. The results show that increases in production costs and bid caps, and decreases in value of crop production have positive impacts on the participation decisions. Lands with higher environmental benefit index have a higher probability of enrollment and higher rental rates. The variability of climate variables positively impacts the enrollment probabilities and negatively impacts the rental rates received.

The results from this study have policy implications for the design and implementation of conservation programs promoting shifts in behavior, farm programs that cope with various sources of uncertainty, and development of estimates of environmental program performance. Environmental policies are increasingly relying on the use of land retirement and conversion programs to reduce adverse impacts of agricultural production practices. Incorporating uncertainty in analyzing conservation programs is important not only to design appropriate incentive payments but also to examine costs and benefits of such programs. Success of land retirement and conservation programs depends on appropriate design of land rental payments and environmental benefit instruments. The results also emphasize the implications of farm programs and policies that reduce various sources of uncertainty for farmer participation in land retirement programs. Such policies would include price support programs, crop insurance, or future markets. Thus, these policies could have impacts on encouraging production on erodible land and reduce CRP participation. Additionally, the results underscore the importance of incorporating uncertainty and risk preferences in cost-benefit analysis of conservation programs, targeting farmers with high environmental benefits, and improving the environmental benefit instruments to better target those farmers.

This paper focused on the impact of uncertainty on farmers' participation strategies when deciding to enroll in the CRP. Future work should focus on extending the theoretical analysis to incorporate other decisions such as input use and land allocations into this model. This paper also used the weather variability as a proxy for the variability of agricultural returns. Developing alternative measures of uncertainty for agricultural returns and analyzing how different sources of uncertainty affect farmer participation as well as incorporating multiple outputs in the theoretical model are important future research topics in this area. Since the model developed in this paper is a single period model and CRP contracts involve multi year commitments, future research should incorporate the impacts of intertemporal nature of participation decision.

Table 1. Descriptive Statistics of the Data Used in the Estimations

Variable	Description	Mean	Std. Dev
ADOPT	Percentage of Cropland in the CRP	0.034	0.238
RENT	Rental Rates Received ($/Acre)	54.875	23.336
MAXBID	Maximum Allowable Bid ($/Acre)	60.627	24.589
EBI	Environmental Benefit Index	192.120	26.681
SLOPE	Average Slope (%)	1.188	0.985
LCCs	Proportion of Land in LCCs I and II	0.350	0.164
IRLAND	Proportion of Irrigated Land	0.079	0.163
VALCROP	Value of Crop Production ($/Acre)	552.390	1309.100
COST	Cost of Production ($/Acre)	418.610	735.680
GOVPAY	Government Payments ($/Acre)	16.310	7.788
AGE	Average Age of Farmers (Years)	54.103	2.160
FULL	Percentage of Full-time Farmers	56.494	12.937
CORNSOY	Percentage of Land in Corn and Soybeans	53.373	33.780
WHBR	Percentage of Land in Wheat, Barley, and Oats	26.492	22.386
RICOT	Percentage of Land in Rice and Cotton	6.030	15.075
MTEM	Average Temperature (Fahrenheit)	53.621	7.708
MPER	Average Precipitation (Inches)	3.084	0.988
STEM	Standard Deviation of Temperature	2.611	0.713
SPER	Standard Deviation of Precipitation	0.633	0.233
MPAL	Palmer Drought Index	0.099	0.273
SPAL	Standard Deviation of Palmer Drought Index	1.784	0.360

Note: Number of observations is 1,729.

Table 2. Estimated Grouped Probit Models of Enrollment Probabilities

	Model I			Model II		
Variable	**Estimate**	**Std. Error**	**Elast.**	**Estimate**	**Std. Error**	**Elast.**
MAXBID	0.006***	0.001	0.60	0.007***	0.001	0.75
EBI	2.221***	0.160	1.15	2.646***	0.141	1.45
SLOPE	-0.339***	0.031	-0.46	-0.424***	0.033	-0.65
LCCs	-1.095***	0.172	-0.28	-1.296***	0.173	-0.36
IRLAND	-0.336*	0.190	-0.07	-0.731***	0.186	-0.15
VALCROP	-0.001***	0.0002	-1.06	-0.001***	0.0002	-0.86
COST	0.001***	0.0003	0.84	0.001***	0.0003	0.66
GOVPAY	-0.003	0.002	-0.12	0.004**	-0.002	-0.13
AGE	0.071***	0.012	2.39	0.073***	0.012	1.75
FULL	-0.011***	0.003	-0.36	-0.007***	0.003	-0.53
CORNSOY	-0.003***	0.001	-0.08	-0.002**	0.001	-0.01
WHBR	0.009***	0.002	0.09	0.003	0.002	0.04
RICOT	-0.009***	0.002	-0.11	-0.009***	0.002	-0.11
MTEM	-0.014**	0.007	-0.98	-	-	-
MPER	0.446***	0.060	1.33	-	-	-
STEM	0.108**	0.053	0.93	-	-	-
SPER	0.586***	0.176	0.28	-	-	-
MPAL	-	-	-	0.654***	0.105	0.12
SPAL	-	-	-	0.741***	0.112	0.14
CONSTANT	-3.903***	0.657	-	-1.846**	0.833	-
R^2	0.61			0.59		
Log of Likelihood	-187.572			-184.847		

Note: ***, **, and * indicates that the parameter is significant at 1%, 5%, and 10% level, respectively.

Table 3. Selectivity-Corrected Determinants of Rental Rates

	Model I			Model II		
Variable	**Estimate**	**Std. Error**	**Elast.**	**Estimate**	**Std. Error**	**Elast.**
MAXBID	0.616***	0.019	0.68	0.608***	0.018	0.67
EBI	0.291***	0.014	1.02	0.298***	0.014	1.04
SLOPE	0.893**	0.426	0.02	0.885**	0.424	0.12
LCCs	-9.300***	2.922	-0.14	-8.729***	2.911	-0.14
IRLAND	5.635**	2.467	0.11	4.376*	2.495	0.11
VALCROP	0.003***	0.001	0.13	0.004***	0.001	0.14
COST	-0.007***	0.002	-0.15	-0.008***	0.002	-0.16
GOVPAY	0.317***	0.042	0.09	0.316***	0.043	0.09
AGE	-0.007	0.245	-0.01	0.158	0.214	0.16
FULL	-0.153***	0.042	-0.16	-0.199***	0.040	-0.20
CORNSOY	0.019	0.012	0.02	0.008	0.010	0.01
WHBR	0.070***	0.023	0.02	0.082***	0.022	0.02
RICOT	0.074***	0.025	0.01	0.066**	0.026	0.01
MTEM	0.237**	0.102	0.23	-	-	-
MPER	-3.712***	0.750	-0.21	-	-	-
STEM	-1.173**	0.671	-0.06	-	-	-
SPER	-1.791	2.279	-0.02	-	-	-
MPAL	-	-	-	2.659	2.032	0.17
SPAL	-	-	-	-1.708	1.542	-0.16
ρ	-0.634***	0.243	-	-0.669***	0.257	-
σ	0.931***	0.345	-	0.964***	0.357	-
$\boldsymbol{\beta}_{\gamma}$	-0.591***	0.235	-	-0.646***	0.240	-
CONSTANT	-33.100***	11.751	-	-44.086***	12.50	-
$\mathbf{R^2}$	0.67			0.66		

Note: ***, **, and * indicates that the parameter is significant at 1%, 5%, and 10% level, respectively.
As the estimation with maximum of likelihood improves the efficiency without changing the value of the estimated coefficients, we give the result of this estimation method for all factors and we just add the estimated coefficient of $\boldsymbol{\beta}_{\gamma}$ obtained by the Heckman method.

References

Classen, R., L. Hansen, M. Peters, and V. Breneman, M. Weinberg, A. Cattaneo, P. Feather, D. Gadsby, D. Hellerstein, J. Hopkins, P. Johnston, M. Morehart, and M. Smith. "Agri-Environmental Policy at the Crossroads: Guideposts on a Changing Landscape." Agricultural Economic Report 794, ERS, USDA, 2001.

Cooper, J.C., and C.T. Osborn. "The Effect of Rental Rates on the Extension of Conservation Reserve Program Contracts." *American Journal of Agricultural Economics* 80(1998): 184-94.

Davidson, R. and J. G. MacKinnon. *Estimation and Inference in Econometrics*. New York: Oxford University Press, 1993.

Détang-Dessendre, C., C. Drapier, and H. Jayet. "The Impact of Migration on Wages: Empirical Evidence from French Youth." *Journal of Regional Science* 44(4)(2004): 661-691.

Farm Service Agency. USDA *Conservation Reserve Programs*. http://www.fsa.usda.gov/dafp/cepd/crp.htm, 2003.

Feather, P., D. Hellerstein, and L. Hansen. "Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP." Agricultural Economic Report 778, ERS, USDA, 1999.

General Accounting Office. "Agricultural Conservation, State Advisory Committees' Views on How USDA Programs Could Better Address Environmental Concerns." Report to the Committee on Agriculture, Nutrition, and Forestry, U.S. Senate, GAO-02-295, 2002.

Greene, W.H. "Sample Selection Bias as a Specification Error: Comment." *Econometrica* 49(1981): 795-798.

Greene, W.H. *Econometric Analysis*, 3rd Edition, Upper Saddle River, NJ: Prentice-Hall, 1997.

Goodwin, B.K. and V.H. Smith. "An Ex Post Evaluation of the Conservation Reserve Program, Federal Crop Insurance, and Other Government Programs: Program Participation and Soil Erosion." *Journal of Agricultural and Resource Economics* 28(2003): 201-216.

Heckman, J.J. "Sample Selection Bias as a Specification Error." *Econometrica* 47(1979): 153-161.

Isik, M. "Resource Management under Production and Output Price Uncertainty: Implications for Environmental Policy." *American Journal of Agricultural Economics* 84(August 2002): 557-571.

Johnson, J., and Dinardo, J. *Econometric Methods*. MacGraw-Hill, 1997.

Kalaitzandonakes, N.G., and M. Monson. "An Analysis of Potential Conservation Effort of CRP Participants in the State of Missouri: A Latent Variable Approach." *Journal of Agricultural and Applied Economics* 26(1994): 200-208.

Khanna, M., Yang, W., Farnsworth, R. and Onal, H. "Cost Effective Targeting of CREP to Improve Water Quality with Endogenous Sediment Deposition Coefficients." *American Journal of Agricultural Economics* 85(3)(2003): 538-553

Konyar, K., and C.T. Osborn. "A National-Level Economic Analysis of Conservation Reserve Program Participation: A Discrete Choice Approach." *Journal of Agricultural Economics Research* 42(1990): 5-12.

Maddala, G.S. *Limited Dependent and Qualitative Variables in Econometrics*. Econometrics Society Monographs No.3, Cambridge University Press, New York, NY, 1987.

McLean, M.P., J. Hui, and R. Joseph. "An Empirical Analysis of Louisiana Small Farmers'

Involvement in the Conservation Reserve Program." *Journal of Agricultural and Applied Economics* 26(1994): 379-85.

Latacz-Lohmann, U., and C. Van der Hamsvoort. "Auctioning Conservation Contracts: A Theoretical Analysis and Application." *American Journal of Agricultural Economics* 79 (1997): 407-418.

Parks, P.J., and R. Kramer. "A Policy Simulation of the Wetlands Reserve Program." *Journal of Environmental Economics and Management* 28(1995): 223-240.

Ribaudo, M. "Water Quality Benefits from the Conservation Reserve Program." Agricultural Economic Report 627, ERS, USDA, 1990.

Reichelderfer, K., and W.G. Boggess. "Government Decision-Making and Program Performance: The Case of Conservation Reserve Program." *American Journal of Agricultural Economics* 19(1988): 143-159.

Rothschild, M., and J. Stiglitz. "Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information." *Quarterly Journal of Economics* (November 1976): 629-49.

Shoemaker, R. "Agricultural Land Values and Rents under the Conservation Reserve Program." *Land Economics* 65(1989):131-37.

Skaggs, R. K., R.E. Kirksey, and W.M. Harper. "Determinants and Implications of Post-CRP Land Use Decisions." *Journal of Agricultural and Resource Economics* 19(1994): 299-312.

Smith, M. "Land Retirement." In Agricultural Resources and Environmental Indicators, No AH722, Economic Research Service, USDA, 2000.

The National Climatic Data Center (NCDC), 2004, NCDC Webpage, http://lwf.ncdc.noaa.gov/oa/ncdc.html.

Yang, W. and Isik, M. "Integrating Farmers' Decision Making to Target Land Retirement Programs." *Agricultural and Resource Economics Review* 33(2)(2004): 186-197.

Wooldridge, J.M. *Econometric Analysis of Cross Section and Panel Data*. The MIT Press, Cambridge, Massachusetts, 2002.