Explaining Participation in the Conservation Reserve Program and its Effects on Farm Productivity and Efficiency

By

Richard N. Boisvert

and

Hung-Hao Chang[*]

Abstract

Using a three-stage sample selection model, we identify factors affecting the probability and level of participation in CRP. Statistical tests support hypotheses that off-farm work and participation in other farm programs are exogenous to the CRP decision. We compare the relative technical and scale efficiencies for CRP participants and non-participants.

May 15, 2005

---

[*] Richard Boisvert and Hung Hao Chang are, respectively, professor and graduate assistant in the Department of Applied Economics and Management at Cornell University. This research is sponsored in part by Cooperative Agreement No. 43-3AEL-2-80074 between the United States Department of Agriculture Economic Research Service Resource Economics Division and Cornell University, College of Agriculture and Life Sciences, Department of Applied Economics and Management. The results and their interpretation are those of the authors and are not those of ERS, USDA, or Cornell University. The authors accept responsibility for any errors or omissions.

This paper is to be presented at the selected paper sessions of the 2005 Annual Meetings of the American Agricultural Economics Association, Providence, Rhode Island, July 24-27, 2005.

Participation in the Conservation Reserve Program and its Effects on Farm Productivity and Efficiency

Richard N. Boisvert and Hung-Hao Chang

Introduction

Since 1985, the Conservation Reserve Program (CRP) has led to the retirement of 34 million acres of cropland. Under this voluntary program, the USDA contracts with farmers and landowners to retire highly erodible and environmentally sensitive cropland and pasture from agricultural production. Land in CRP is planted to grasses, trees, or other cover, thereby reducing soil erosion and water pollution, and providing other environmental benefits. Rental payments average $50/acre; landowners are reimbursed for about half the cost of establishing cover.

Over the past 20 years, the CRP has undergone important changes. Through legislative and regulatory initiatives that give added weight in ranking farmers' bids to environmental objectives other than soil erosion and program costs, USDA is now able to enroll more environmentally sensitive, but highly productive land. About 50% of current CRP contracts will expire by 2007; over 90% will expire by 2010. Some farmers will look to re-enroll cropland, while some land may be returned to crop production (Sullivan *et al*., 2004). If changes in CRP are to enhance its contribution to the environment, we must understand the factors affecting CRP participation and the productivity and well being of farm households participating in CRP.

This paper identifies those factors that affect both farmers' decisions to participate in the CRP and the level of participation. We also determine the effect of CRP participation on farm productivity. Our empirical analysis is based on data from the USDA's Agricultural Resource Management Survey (ARMS). We proceed with a specification of an agricultural household production model and interpret the first-order conditions and comparative statics. We continue with a discussion of the 3-stage econometric model. The first stage is a binary probit model for CRP participation. We perform statistical tests for the endogeneity of some regressors. In stage two, we estimate both a CRP per-acre payment equation and a CRP acreage enrollment equation, correcting for sample selection bias (Heckman, 1979). In stage three, we estimate group production functions and decompose the error into random and technical inefficiency components using two-stage method of moments (Kopp and Mullahy, 1990 and Huang *et al*., 2002). Technical and scale efficiencies are compared between groups, as are the differences in factor productivity. We conclude by highlighting the policy implications.

Theoretical Framework

We focus on a simple household production model to derive comparative static results. The farm operator is the only decision maker.[1] There are fixed endowments of operator time ($\overline{E}$) and farmland ($\overline{A}$). Time is allocated to leisure (l) and farm production (L). Total land is allocated between crop production (A) and enrollment in CRP (A_e). The household receives income from agricultural sales, CRP per acre payments (P_e), and decoupled payments (M). The utility of the farm household depends on the consumption (x) and leisure (l), as well as the improvement in environmental quality (e) generated by land committed to CRP. We assume that the commodity price, *P*, is random; $P = \overline{P} + \eta$, where $\overline{P}$ is the expected price and the random error follows an arbitrary distribution with mean zero and variance σ_η^2 (η~(0, σ_η^2)). Production is a well-behaved concave function

---

[1] While the presence of a spouse and children conditions the farmer's decisions, we abstract from complications associated with work on and off the farm by family members.

in land and labor: $F(L, A) = f(L, A) + g(L, A)\varepsilon + h(L, A)u$, where $\varepsilon \sim i.i.d(0, \sigma_{\varepsilon}^{2})$. Just and Pope (1979) note that an input is risk increasing (decreasing) if g' (.) is positive (negative). Production inefficiency is reflected in $h(L, A)u$; $u \sim i.i.d(\bar{u}, \sigma_{u}^{2})$ is the random noise in a stochastic frontier function.

Households maximize expected utility subject to income, time and land constraints:

$$(1)\quad \underset{x,l,A_e}{Max} = E\{U[x, l, e(A_e)]\}$$

s.t. (2) $x = (\bar{P} + \eta)F(L, A) + P_e A_e + M$; (3) $\bar{E} = L + l + L_e$; and (4) $\bar{A} = A_e + A$.

We eliminate variables l and x by substituting equations (2) through (4) into equation (1):

$$(5)\, \underset{A_e,L}{Max} = EU\{[(\bar{P} + \eta)(f(L, \bar{A} - A_e) + g(L, \bar{A} - A_e)\varepsilon - h(L, \bar{A} - A_e)u) + P_e A_e + M],$$

$$[\bar{E} - L - L_e], e(A_e)]\}.$$

The first-order necessary conditions for interior solutions are:[2]

$$(6)\, \frac{\partial EU}{\partial A_e} = -E\{U_x[(\bar{P} + \eta)(f_A + g_A\varepsilon - h_A u) + p_e]\} + E(U_e e_{A_e}) = 0$$

$$(7)\, \frac{\partial EU}{\partial L} = E\{U_x[(\bar{P} + \eta)(f_L + g_L\varepsilon - h_L u)]\} - E(U_l) = 0$$

where U_i is the first-order derivative of the utility function with respect to argument i. The optimal levels of A_e and L from the simultaneous solution of equations (6) and (7). To interpret the first-order conditions, we take the expectations of both equations (6) and (7) and derive some comparative static results. We assume that the random disturbances

---

[2] For tractability, we assume $U_{AeL} = U_{LAe} = 0$ (Fabella, 1989).

(η, ε, u) are independent and approximate the utility function with a second-order Taylor series expansion (Isik, 2002).[3] Equations (6) and (7) are:

$$(8) \quad \frac{1}{U_{\bar{x}}}\frac{\partial Eu(.)}{\partial A_e} = p_e - \bar{p}(f_a - h_a\bar{u}) + \phi[gg_a\sigma_\varepsilon^2(\bar{p}^2 + \sigma_\eta^2) + \sigma_\eta^2(ff_a + hh_a\sigma_u^2)] + \frac{U_e e_{Ae}}{U_{\bar{x}}} = 0$$

$$(9) \quad \frac{1}{U_{\bar{x}}}\frac{\partial Eu(.)}{\partial L} = \bar{p}(f_l - h_l\bar{u}) - \phi[gg_l\sigma_\varepsilon^2(\bar{p}^2 + \sigma_\eta^2) + \sigma_\eta^2(ff_l + hh_l\sigma_u^2)] - \frac{U_l}{U_{\bar{x}}} = 0$$

Under both price and production risk, and technical inefficiency, the optimal levels of land in CRP and labor for agricultural production depend on the expected market price and the production technology. Decisions depend on the nature of each source of risk, the risk characteristics of the inputs, the variance of each component of risk, technical inefficiency, and the expected marginal utility from leisure and the environment. To gain insights, we compare the optimal decisions of CRP acre enrollment to the situation with no risk or technical inefficiency. For the simpler model, the first-order condition corresponding to equation (8) is:

$$(8') \quad \frac{\partial Eu(.)}{\partial A_e} = p_e - \bar{p}f_a = 0.$$

According to equation (8'), the optimal decision is reached when the expected value of marginal agricultural production of land is equal to the CRP payment. According to equation (8) above, optimal CRP acres would be larger if land is a risk increasing input in agricultural production. If land in farming is risk decreasing, the effect of risk aversion on CRP may dominate the marginal revenue effect, leading to less land in CRP.

Comparative Static Results

---

[3] Our approach is in contrast to the one most commonly found in the literature that embody constant absolute risk aversion (e.g., Love and Buccola, 1991).

We gain further insights into the effects of risk, farm technology, and government policy on optimal input use by examining comparative statics with respect to risk preferences and decoupled farm payments. For simplicity, we isolate price risk.

For only price risk, input decisions (equations (8) and (9)) can be simplified as:

$$(10)\quad \frac{1}{U_{\bar{x}}}\frac{\partial Eu(.)}{\partial A_e} = p_e - \bar{p}f_a + \phi\sigma_\eta^2 ff_a + \frac{U_e e_{Ae}}{U_{\bar{x}}} = 0$$

$$(11)\quad \frac{1}{U_{\bar{x}}}\frac{\partial Eu(.)}{\partial L} = \bar{p}f_l - \phi\sigma_\eta^2 ff_l - \frac{U_l}{U_{\bar{x}}} = 0.$$

Land in CRP is determined by the CRP payment, the potential loss in average revenue from moving land out of production, the adjustment for price risk, and the utility the farm household derives from the contribution of CRP to environmental quality. Land in CRP increases with marginal changes in CRP payment, price risk aversion, and the utility of environmental quality. Land in CRP falls as the expected price of agricultural output increases, *ceteris paribus*. Similar logic suggests that labor allocated to agricultural production will rise with the expected price of agricultural output, but will fall with increases in price risk or in the marginal utility of leisure.

To identify effects of risk preferences, and CRP and decoupled payments payments, we derive comparative statics from total derivatives of equations (10 and 11):

$$(12)\quad \frac{\partial A_e}{\partial \phi} = \frac{f\sigma_\eta^2}{\underbrace{U_{\bar{x}}}_{(+)}}\left\{\underbrace{U_{\bar{x}}(\bar{p} - f\phi\sigma_\eta^2)(f_l f_{la} - f_a f_{ll})}_{(+)} + \underbrace{f_a(U_l\bar{p}\phi f_l - U_{ll})}_{(+)} \underbrace{- U_e e_{A_e}\phi\bar{p} f_l^{\,2}}_{(-)}\right\}$$

$$(13)\quad \frac{\partial L}{\partial \phi} = \frac{-f\sigma_\eta^2}{\underbrace{U_{\bar{x}}}_{(-)}}\left\{\begin{array}{l}\underbrace{U_{\bar{x}}(\bar{p} - f\phi\sigma_\eta^2)(f_a f_{la} - f_l f_{aa})}_{(+)} + \underbrace{U_l\phi f_a(p_e - \bar{p}f_a)}_{(-)} \\ \underbrace{- U_e f_l[e_{A_e^{\,2}} + e_{Ae}\phi(p_e - \bar{p}f_l^{\,2})]}_{(+)}\end{array}\right\}$$

$$(14)\quad \frac{\partial A_e}{\partial p_e} = \frac{1}{\underbrace{\bar{x}U_{\bar{x}}}_{(+)}} \left\{ \begin{array}{l} U_{\bar{x}}\{(\underbrace{\bar{p}-f\phi\sigma_\eta^2}_{(+)})[\underbrace{\lambda\phi\sigma_\eta^2 A_e f(f_a f_{ll} - f_l f_{la}) - \bar{x} f_{ll}}_{(?)}] + \underbrace{\phi\sigma_\eta^2 f_l{}^2 (x-\bar{p}f\lambda)}_{(+)}\} \\ + \underbrace{(\bar{x}-\lambda\phi\sigma_\eta^2 A_e f f_a)(\phi\bar{p} f_l U_l - U_{ll})}_{(+)} + \underbrace{U_e e_{A_e} \lambda\phi^2\sigma_\eta^2 A_e \bar{p} f f_l{}^2}_{(+)} \end{array} \right\}$$

$$(15)\quad \frac{\partial L}{\partial p_e} = \frac{-1}{\underbrace{\bar{x}U_{\bar{x}}}_{(-)}} \left\{ \begin{array}{l} U_{\bar{x}}\{(\underbrace{\bar{p}-f\phi\sigma_\eta^2}_{(+)})[\underbrace{\lambda\phi\sigma_\eta^2 A_e f(f_l f_{aa} - f_a f_{la}) + \bar{x} f_{la}}_{(?)}] \\ + \phi\sigma_\eta^2 f_l[\underbrace{\lambda f(\bar{p}f_a - p_e) - \bar{x}f_a}_{(?)}]\} + \phi U_l(\underbrace{p_e - \bar{p}f_a)(\bar{x} - \lambda\phi^2\sigma_\eta^2 A_e f f_a}_{(-)}) \\ \underbrace{+U_e\lambda\phi^2\sigma_\eta^2 A_e f f_l[e_{A_e{}^2} + e_{A_e}\phi(p_e - \bar{p}f_a)]}_{(-)} \end{array} \right\}$$

$$(16)\quad \frac{\partial A_e}{\partial M} = \frac{-\lambda f\phi\sigma_\eta^2}{\underbrace{\bar{x}U_{\bar{x}}}_{(-)}} \{\underbrace{U_{\bar{x}}(\bar{p}-f\phi\sigma_\eta^2)(f_l f_{la} - f_a f_{ll})}_{(+)} + \underbrace{f_a(U_l \bar{p}\phi f_l - U_{ll})}_{(+)} \underbrace{- U_e e_{A_e}\phi\bar{p} f_l{}^2}_{(-)}\}$$

$$(17)\quad \frac{\partial L}{\partial M} = \frac{\lambda\phi f\sigma_\eta^2}{\underbrace{\bar{x}U_{\bar{x}}}_{(+)}} \left\{ \begin{array}{l} \underbrace{U_{\bar{x}}(\bar{p}-f\phi\sigma_\eta^2)(f_a f_{la} - f_l f_{aa})}_{(+)} + \underbrace{U_l\phi f_a(p_e - \bar{p}f_a)}_{(-)} \\ \underbrace{-U_e f_l[e_{A_e{}^2} + e_{Ae}\phi(p_e - \bar{p}f_l{}^2)]}_{(+)} \end{array} \right\}.$$

$\lambda = -\frac{\partial\phi(\bar{x})}{\partial\bar{x}}\frac{\bar{x}}{\phi(\bar{x})}$, the elasticity of absolute risk aversion at expected post-risk consumption (Just and Zilberman, 1983), is positive for decreasing absolute risk aversion.

From equation (12), there are three terms determining land in CRP as Arrow's absolute risk aversion coefficient changes. The first term in {.} can be implicitly regarded as the contribution from consumption. This effect is positive since, based on the first-order Hessian, the term ($\bar{p} - f\phi\sigma_\eta^2$) is positive.[4] The second term in {.} is the contribution from the utility of leisure. The effect should be positive given the concave

---

[4] $|H_{11}| = \bar{p}f_{ll} - \phi\sigma_\eta^2(f_l{}^2 + ff_{ll}) + \frac{\bar{p}\phi\sigma_\eta^2\lambda ff_l{}^2}{\bar{x}} + \frac{U_{ll} - \phi\bar{p}f_l U_l}{U_{\bar{x}}} < 0$. The sufficiency condition for this is:
$\frac{\bar{x}}{f\lambda} > \bar{p} > f\phi\sigma_\eta^2$

nature of the utility function with respect to leisure. The third term in {.} is the contribution related to the effect of the environment**.** To sum up, the change in land in CRP as risk preferences change is ambiguous. However, more risk averse farm households likely enroll more land into CRP and use less labor in farming if the marginal utilities of leisure and the environment are constant or decline gradually. Similar arguments help understand the change in farm labor due to a change in risk preferences.

From equations (14) and (15) changes in CRP acreage and farm labor to changes in the CRP per acre payment also depend on the sizes of the terms related to risk preferences, and marginal utilities of consumption, leisure, and the environment. From equation (14), land in CRP may or may not increase with CRP payment. Under CARA (λ=0), it is easy to see that land in CRP does increase with the CRP payment.

Equations (16) and (17) are the comparative static results for changes in CRP land and farm labor due to a change in decoupled payments. The effects depend on (λ), and under CARA, λ=0, changing decoupled payments has no effect CRP land and farm labor.

Econometric Framework

The econometric specification consists of three stages: 1) the CRP participation equation; 2) per acre CRP payment and acreage equations; and 3) estimates of differences in technical efficiency and productivity between CRP participants and non-participants.

CRP Participation Decision

The CRP participation decision depends on the net benefit between (risk adjusted) reservation per acre return if the farmer leaves land in production and the potential government payment for enrolling land in the CRP. These equations are:

(18) $P^{r} = A_{r} X_{r} + e_{r}$ and

(19) $P^{g} = A_{g} X_{g} + e_{g}$,

where P^r and P^g represents the reservation per acre return, and the government per acre payment for CRP. The vectors X_r and X_g contain the exogenous variables that are assumed to determine the two separate equations; e_r and e_g are random disturbance terms. If the farmer participates in CRP, we assume the net benefit is positive. The unobservable latent choice variable (I^*) for the participation decision is:

(20) $I^* = P^{g} - P^{r} = H_{g}' X_{g} - H_{r}' X_{r} + (e_{g} - e_{r}) = H' X + e$;I=1 *iff* $I^*> 0$; I=0 *iff* $I^* < 0$.

The probability of participation can be specified as:

(21) $\Pr(I = 1) = \Pr(e > -H' X) = 1 - F(-H' X)$.

By assuming F (.) is a normal distribution function, a consistent estimator of H in equation (21) is found by Maximum Likelihood as (Maddala, 2001; Greene, 2002):

(22) $\log L = \sum_{i=1}^{n} I * \Phi(H' X) + (1 - I) * [1 - \Phi(H' X)]$.

Per Acre Payment and Acreage Response for CRP

Reduced forms for of the CRP payment and acreage enrollment equations are:

(23) $P = \alpha_{p}' X_{p} + e_{p}$ and

(24) $A = \alpha_{a}' X_{a} + e_{a}$,

where X_p and X_a are vectors of independent variables, and α_p and α_a are parameters.

The random errors (e, $e_{p,}$, e_a) follow a trivariate normal distribution,

$(e, e_{p}, e_{a}) \sim N(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{p} & \rho_{a} \\ \rho_{p} & \sigma_{p}^{2} & 0 \\ \rho_{a} & 0 & \sigma_{a}^{2} \end{bmatrix})$. Based on the application of Heckman’s (1979) sample selection correction, OLS provides consistent estimators of (α_a, α_p) in the conditional expected payment and CRP acres equations:

$$(25)\quad E(P \mid I=1) = \alpha_p' X_p + E(e_p \mid e > -H'X) = \alpha_p' X_p + \rho_p \sigma_p \frac{\phi(H'X)}{\Phi(H'X)}$$

$$(26)\quad E(A \mid I=1) = \alpha_a' X_a + E(e_a \mid e > -H'X) = \alpha_a' X_a + \rho_a \sigma_a \frac{\phi(H'X)}{\Phi(H'X)},$$

where $\frac{\phi(H'X)}{\Phi(H'X)}$ is the Inverse Mills Ratio (IMR).

Estimating the Production Functions

We estimate separate production functions for CRP participants and non-participants, *Y1* and *Y0*. Depending on the choice, the production function is:

$$(27)\quad Y_1 = \beta_1' X_1 + \varepsilon_1 \text{ or } Y_0 = \beta_0' X_0 + \varepsilon_0 ,$$

The conditional expected production, under joint normality for (e, ε_1) and (e, ε_0), are:

$$(28)\quad E(Y_1 \mid I=1) = \beta_1' X_1 + E(\varepsilon_1 \mid I=1) = \beta_1' X_1 + \rho_1 \sigma_1 \frac{\phi(H'X)}{\Phi(H'X)}$$

$$E(Y_0 \mid I=0) = \beta_0' X_0 + E(\varepsilon_0 \mid I=0) = \beta_0' X_0 - \rho_0 \sigma_0 \frac{\phi(H'X)}{1-\Phi(H'X)}\text{; and}$$

$$(29)\quad Y_1 = \beta_1' X_1 + \rho_1 \sigma_1 \frac{\phi(H'X)}{\Phi(H'X)} + \{\varepsilon_1 - \rho_1 \sigma_1 \frac{\phi(H'X)}{\Phi(H'X)}\} = \beta_1' X_1 + \rho_1 \sigma_1 \frac{\phi(H'X)}{\Phi(H'X)} + e_1^{ols}$$

$$Y_0 = \beta_0' X_0 - \rho_0 \sigma_0 \frac{\phi(H'X)}{1-\Phi(H'X)} + \{\varepsilon_0 + \rho_0 \sigma_0 \frac{\phi(H'X)}{1-\Phi(H'X)}\} = \beta_0' X_0 - \rho_0 \sigma_0 \frac{\phi(H'X)}{1-\Phi(H'X)} + e_0^{ols}$$

Since the expected values of the conditional random errors $(E(e_0^{ols} \mid I=1), E(e_1^{ols} \mid I=0))$ = 0; OLS gives consistent estimators for $(\beta_1, \beta_0, \rho_1\sigma_1, \rho_0\sigma_0)$.

Estimating the Technical Efficiency Index

Viewed from a stochastic frontier perspective, we can write:

(30) $Y_1 = \beta_1' X_1 + \varepsilon_1 = Y_1^F + v_1 - u_1$ and $Y_0 = \beta_0' X_0 + \varepsilon_0 = Y_0^F + v_0 - u_0$

where (Y_1^F, Y_0^F) are group frontier production functions. Following Aigner, *et al*. (1977), v_i, (i = 0,1) are two-sided error terms, *N*~(0, σ_{vi}^2); u_i's are one-sided non-negative technical inefficiency components with variances σ_{ui}^2. The components are assumed independent. The expected values of the one-sided error terms are not zero:

(31) $Y_1 = \beta_1' X_1 + \varepsilon_1 = Y_1^F - E(u_1) + [v_1 - u_1 + E(u_1)]$

$$Y_0 = \beta_0' X_0 + \varepsilon_0 = Y_0^F - E(u_0) + [v_0 - u_0 + E(u_0)]$$

From equation (31), two conditions must hold:

(32) $\beta_1' X_1 = Y_1^F - E(u_1)$ and $\varepsilon_1 = [v_1 - u_1 + E(u_1)] = e_{scf1} + E(u_1)$

$\beta_0' X_0 = Y_0^F - E(u_0)$ and $\varepsilon_0 = [v_0 - u_0 + E(u_0)] = e_{scf0} + E(u_0)$

The parameters ($\sigma_{v1}^2, \sigma_{v0}^2, \sigma_{u1}^2, \sigma_{u0}^2$) can be calculated using the information about ($\varepsilon_1, \varepsilon_0$), if combined with the information about E (u_1), and E (u_0). Although the predicted values of ($\hat{\varepsilon}_1, \hat{\varepsilon}_0$) can be informed from equation (27), we must specify the distribution of (u_1, u_0) to have the necessary information about (E (u_1), E (u_0)).

Once the distributions of u_1 and u_0 are specified, we estimate ($\sigma_{v1}^2, \sigma_{v0}^2, \sigma_{u1}^2, \sigma_{u0}^2$) by applying the two-stage method of moments (Olson, *et al*. 1980; Huang *et al*., 2002), utilizing the fact that since E (u_1) are E (u_0) are constant, the second and third central moments of ($\hat{\varepsilon}_1, \hat{\varepsilon}_0$) are equal to these corresponding moments of (v_1-u_1) and (v_0-u_0).

Under the half-normal distribution, the first three moment conditions of *u* are:

(33) $E(u_i) = \sqrt{\frac{2}{\pi}}\sigma_{u_i}$ $V(u_i) = \frac{\pi - 2}{\pi}\sigma_{u_i}^2$ and $E(u_i{}^3) = -\sqrt{\frac{2}{\pi}}(1 - \frac{4}{\pi})\sigma_{u_i}^3$.

To solve for the parameters ($\sigma^2_{v_i}, \sigma^2_{u_i}$), we must recall the definitions of moments:

(34) $m_2 = \sigma^2_{v_i} + V(u_i) = \sigma^2_{v_i} + \frac{\pi - 2}{\pi}\sigma^2_{u_i}$ and $m_3 = E(u_i{}^3) = -\sqrt{\frac{2}{\pi}}(1 - \frac{4}{\pi})\sigma^3_{u_i}$.

The consistent estimators of ($\sigma^2_{v_i}, \sigma^2_{u_i}$) are then:

(35) $\hat{\sigma}^2_{u_i} = (\frac{m_3}{\sqrt{2/\pi}(1 - 4/\pi)})^{2/3}$ and $\hat{\sigma}^2_{v_i} = m_2 - (1 - \frac{2}{\pi})\hat{\sigma}^2_{u_i}$.

Given the estimators of ($\sigma^2_{v_i}, \sigma^2_{u_i}$), the two error components can be estimated as:

(36) $\hat{e}_{scf\ i} = \hat{\varepsilon}_i - \sqrt{\frac{2}{\pi}}\hat{\sigma}_{u\,i}$.

The calculation of the technical efficiency index requires point estimates for the random variable *u* for each farmer. Following Jondrow *et al.* (1982), the expected value of *u* given the composite error (*v*-*u*) under the assumption of a half-normal distribution is:

(37) $E(\hat{u}_i \mid \hat{e}_{scfi}) = \frac{\sigma\lambda}{(1+\lambda^2)}[\frac{\phi(\frac{\hat{e}_{scfi}\lambda}{\sigma})}{1 - \Phi(\frac{\hat{e}_{scfi}\lambda}{\sigma})} - \frac{\hat{e}_{scfi}\lambda}{\sigma}]$, where $\sigma = (\hat{\sigma}^2_{u_i} + \hat{\sigma}^2_{v_i})^{1/2}$ and $\lambda = \frac{\hat{\sigma}_{u_i}}{\hat{\sigma}_{v_i}}$.

The technical efficiency index of each farmer is (Kumbhaker and Lovell, 2000):

(38) $TE = e^{-E(\hat{u}|\hat{e}_{scf}i)}$

Estimating Productivity Differences Between Groups

We cannot directly compare the technical efficiency indices from the estimation above because the production environment is assumed to differ by group. The above results do provide information on differences in technical efficiency for farms within each group. Using this information, we can estimate the Total Factor Productivity (TFP) index (Malmquist, 1953) to see the between-group productivity differences[5]and identify the sources of these differences by decomposing TFP.[6] Although data envelope analysis is normally used, TFP can also be defined for stochastic frontiers (Coelli, *et al.*, 1998). The generalized relative TFP index is (Fare *et al.*,1994; Coelli and Love, 2003):

$$(39)\ \ M(y_1,x_1,y_0,x_0)=\frac{TE^{V1}(y_1,x_1)}{TE^{V0}(y_0,x_0)}*\left[\frac{TE^{V0}(y_0,x_0)}{TE^{V1}(y_1,x_1)}\frac{TE^{C1}(y_1,x_1)}{TE^{C0}(y_0,x_0)}\right].$$

$$*\left[\frac{TE^{C0}(y_1,x_1)}{TE^{C1}(y_1,x_1)}*\frac{TE^{C0}(y_0,x_0)}{TE^{C1}(y_0,x_0)}\right]^{1/2},$$

where M(.) represents the relative TFP index of group 1 (CRP participants) relative to group 0 (non-participants). V and C superscripts refer to the variable returns to scale (VRS) and constant returns to scale (CRS), respectively. The term TE^{kj} (y_i,x_i) represents technical efficiency for group j using the level of inputs for group *i*. Total factor productivity is decomposed into three sources. The ratio outside the square brackets measures the relative difference in technical efficiency between groups 1 and 0--the relative distance between actual production and the frontier function between groups for the VRS technology. The first term in brackets measures the ratio of scale efficiencies between groups. The second term in brackets measures the relative difference in technology--a comparison of the production frontiers between groups.

The Data

The primary farm household data used in this paper are from the 2001 Agricultural Resource Management Survey (ARMS), conducted by the National

---

[5] Although the TFP index is usually applied to time series data to measure productivity changes through time, this concept can also be applied to the cross section data. (Fare *et al*., 1994; Thirtle *et al*., 1995).

[6] To implement this generalized TFP formula, it was necessary to estimate two standard production functions (equation 27) for each group. One production function was restricted to be CRS; the other was not restricted. For each function, the error was decomposed according to the two-stage method of moments.

Agricultural Statistics Service of the United States Department of Agriculture (USDA). We limit our attention to the sample of crop farm households because of our interest in examining the effect of CRP participation on farm productivity. The final sample count is 2,248. About 23% of the sample participated in CRP and or CREP and about 56% of the farm operators worked off the farm (Table 1).

We also rely on some data from additional sources. The economic characteristics of local areas, for example, are merged into our ARMS data set. These are county-level data from the BEA income and employment files in 2000, the BLS, and the 1990 Census of Population. For these characteristics to be pre-determined, the data are lagged one year.

Three county-level land quality variables are defined as the product of a variable reflecting the length of the growing season and the land capability class (Darwin and Ingram, 2004). The land capability classes are those used in the Natural Resources Conservation Survey (NRCS) and elsewhere to classify land based primarily on physical soil characteristics. This index is calculated based on quantifiable factors in the universal soil loss equation.[7]

Another factor affecting CRP participation is the Environmental Benefits Index (EBI) calculated by Farm Service Agency. The EBI score in part determines the maximum price that can be paid for land offered into the CRP.[8] It would have been ideal to have an EBI index available for each farm household in the ARMS data, but this was not the case. As an alternative, we use the EBI data from Jaroszewski, *et al*. (2000) and

---

[7] We owe special thanks to Roger Claassen for making the data available. The variables are defined as: LQH96 = "high" land quality = GS*(LCC1+LCC2); LQM96 = "medium" land quality = GS*(LCC3+LCC4); and LQL96 = "low land quality = GS*(LCC5+LCC6+LCC7+LCC8), where LCCi = % of land in soil capability class i, and GS = ratio of mean rain-fed season to mean irrigated season.

[8] The components of EBI are: wildlife habitat, water quality benefit, reduction in wind erosion, long-term benefit from cover, air quality benefit, conservation propriety areas, and a cost factor.

estimate an EBI for major ERS agricultural regions based on the percentage of land in conservation practices currently in CRP. By using the data, we assume that when CRP commitments were made, land was likely to be in these land uses in similar proportions.

Empirical Results

We distinguish several sets of results: the CRP choice model and the specification tests; the estimated CRP payment and acreage equations; and the estimated production functions and the related measures of technical efficiency and productivity. Throughout the discussion of these results, the effects of variables on CRP participation, CRP payments, and CRP acreages are obvious from the signs on particular variables.

The CRP Participation Equation

As is seen in Table 2, the likelihood of participation in CRP increases with farm size.[9] When compared to cash grain farms, however, the likelihood of participation is lower for farms engaged in vegetable, fruit or nursery production. This reflects the high-value nature of production and higher opportunity cost to those farmers for enrolling land in CRP.

In addition to the negative effect of the opportunity cost of land on participation, one could also hypothesize that the likelihood of participation would rise with the level of CRP payments. It is impossible to include such a variable in the participation equation because of the sample selection problem. Park and Schorr (1997) argued that the maximum bid price ought to be one of the factors affecting CRP participation. We have no information on actual bids or bids accepted, but we do find that farm households that are located in areas where the EBI scores for land currently enrolled are high are more

---

[9] The result differs from the county-level analysis by Kazim and Osborn (1990) who found a negative correlation between farm operating acreage and CRP participation; but is consistent with the positive relationship found by McLean, Hui, and Joseph (1994) based on a survey of 113 farmers in Louisiana.

likely to participate in CRP, *ceteris paribus*. Farmers might well expect to have higher bids accepted in areas where the EBI scores are high.

Participation in CRP rises as the proportion of land in the surrounding county is classified as high quality, but not as low quality. This might suggests that CRP participation may be higher in areas where land is well suited for agriculture, but, unfortunately, unless one had information about land quality by farm, it is impossible to tell anything about the quality of land that is enrolled in CRP, or how the land quality on the farm affects a farmer's decision to participate. Our results are consistent with county-level analyses reporting negative relationships between a soil erosion index and CRP participation (Goodwin, *et al*., 2004; Kazim and Osborn, 1990).

It is also true that the likelihood of CRP participation falls if the farm is enrolled in a voluntary agricultural district, is subject to a farmland preservation easement, or is located in an agricultural protection zone or zoned exclusively for agricultural use. Farmers participating in these farmland retention programs are concerned with the economic viability of farming, especially in rapidly growing areas where there is serious competition for land for non-agricultural purposes. The fact that CRP participation falls with an increase in proportion of urban population reinforces the results.[10]

Based on our comparative static results, it is no surprise that the receipt of decoupled payments decreases the likelihood of participation in CRP. These payments are not tied to production of a specific crop, but farmers receiving them are required to maintain a certain amount of land in production. Furthermore, when compared to CRP payments, decoupled payments provide an alternative source of income stability that could offset the greater price and production yield risk from leaving more land in

---

[10] Duke (2004) also found that the likelihood of participation in CRP is lower in highly urbanized areas.

agricultural production.[11] Since CRP payments are less variable than are returns to farming, there is additional support for these conclusions by the fact that the probability of CRP participation falls as preference for risk increases.

In previous literature, the empirical evidence of the effects of human capital and stage in the life cycle (age, experience, and education) on CRP participation is mixed.[12] Based on our analysis, the likelihood of CRP participation increases both with the age and the level of education of the farm operator. In terms of the life cycle, older farmers may commit some land to CRP as a way of reducing operator labor requirements or holding onto farmland assets until they are needed for retirement, or they can be passed on through an estate. The fact that farm operators working off the farm are more likely to participate in CRP may reflect a desire on the part of those working off the farm to reduce farm labor requirements. A similar result is found in the case of a spouse working off the farm, although this effect is not statistically significant.

Econometric Tests Related to the Probit Choice Model

We test to see whether or not binary choices other than participation in CRP are exogenous to reinforce the validity of policy conclusions involving these variables. The assumption of normality of the probit model is also tested.

Tests for Exogenous Decisions

The variables for which this is a concern are: off-farm work by the operator or spouse, participation in EQIP, participation in agricultural districts, etc. and the receipt of

---

[11] These finding are also consistent with those reported in other studies examining the effect of government payment on CRP participation (Isik and Yang, 2004). However, participating in other environmental programs (EQIP) of the farm household increases the likelihood of CRP participation although it is not statistically significant. Participation in both EQIP and CRP could reflect a farmer's stewardship for the environment by removing particularly venerable land from production, while using more environmentally friendly practices on land still in production.

[12] Kazim and Osborn (1994) and Kalaitzandonakes and Monson (1994) found a negative relationship between age and the CRP participation, but McLean, Hui, and Joseph (1994) found the reverse.

decoupled payments. We test the null hypothesis that binary decisions associated with the four discrete binary variables are exogenous to CRP participation using a method by Vella (1993). For decoupled payments, the test follows Smith and Blundell (1986).

These tests involve several steps. For each discrete variable, we specify a separate participation equation including the variables from both the original CRP participation equation and new variables that are believed to determine the variable being tested.[13] For each test, we estimate a two-equation simultaneous probit model (Vella, 1993)[14] that that includes the original CRP equation and the new equation for the variable being tested. We calculate the general inverse mills ratios for the new participation equation and re-estimate the original binary CRP equation with the general inverse mills ratios as an explanatory variable. We fail to reject the hypothesis that these binary choices are exogenous if the t-ratios on the coefficients associated with the general inverse mills ratios is statistically insignificant.[15] Once the new equation is specified for decoupled payments,[16] we follow the two-stage method by Smith and Blundell (1986) to test the null hypothesis that decoupled payment are exogenous. Predicted residuals are added to the original choice model; if the coefficient on this variable is statistically insignificant, we fail to reject the null hypothesis.

---

[13] The specification of these extra variables is based on the goodness of fit from several possible trials.

[14] Empirically, the additional variables used in testing the operator's decision to work off the farm are: if the operator is raised on the farm and indices relating to the local economic importance of manufacturing, services, agriculture, and trade. The additional variables in testing the spouse's decision to work off the farm include several human capital variables, the family characteristics and the local economic indices by sector. The age of the operator and farming experience represent human capital, and the number of the household members and the numbers of children represent the family characteristics. We add nothing for testing if the decisions to participate in EQIP and agricultural districts are endogenous to CRP choice, since these three programs are all related to environmental considerations. As such, the factors determining these three decisions are likely the same.

[15] We adjust standard errors based on asymptotic theory proposed by Murphy and Topel (1985).

[16] The additional variables in testing the decision to receive decoupled payments decision are the local economic indices for manufacturing, agriculture, services, and trade.

Except for the decision to participate in EQIP, we fail to reject the hypothesis that the corresponding decision is exogenous to the CRP participation decision (Table 3). The test for EQIP may not be valid; the model prediction for the EQIP equation is only 2.6%.

Tests for Normality

We test the normality assumption of the error using a general non-parametric test by comparing predicted probabilities between the probit model and a non-parametric regression (Horowitz, 1993). The quadratic density is selected as the kernel density, with bandwidth of 0.15.[17] By inspection of Figure 1, the probit model performs similarly to the non-parametric alternative, particularly for probabilities less than 0.50. The two predictions are less consistent for probabilities greater than 0.5, but they still lie within the non-parametric confidence band. Normality is not rejected.

CRP Payment and Acreage Equations

In developing a complete understanding of factors affecting CRP enrollment, we must also estimate an equation for the number of acres enrolled for the CRP participants. Since it is expected that the level of payment may well influence land enrolled, we estimate a CRP payment equation as well. The inverse mills ratio is included in both equations to control for any sample selection bias, and it is statistically significant in both. Consistent with a tradition in labor economics, the performance of the payment equation was improved through a semi-logarithmic specification.

On balance, the factors that affect the size of CRP payments make sense (Table 4). CRP payments are directly related to the proportion of cropland in the area that is of high quality, and they differ by region. All else equal, they tend to be higher in the Heartland, but lower in the Eastern Uplands, the Southern Seaboard, and the Fruitful Rim than in the

---

[17] The same conclusions are evident for different choices in bandwidth.

rest of the regions.[18] Payments increase with the percentage of local employment in manufacturing which is likely related to the strength of the regional economy.

The CRP payment also decreases as the proportion of land on the farm that is planted to cash grain increases. The fact that payments are lower for farms classified as cash grain could well reflect the fact that these farm operators may tend to enroll somewhat poorer quality land in CRP, particularly in situations where the most productive land is retained in crop production.

The effect of human capital on payment is represented by years of farming experience and its squared term. The farmer with more farming experience is likely to receive higher payments, but the payment increases at a decreasing rate. This experience may contribute to effectiveness at bidding and selecting appropriate land and management practice for CRP land.

To control for endogenously, we use the predicted per acre payment as the instrument in the acreage equation. From a policy standpoint, the factors that affect the acreage enrolled in CRP are quite interesting (Table 5). An immediate noteworthy result is that the number of acres enrolled in CRP increases as the CRP payment per acre increases. However, the negative coefficient on an interaction term for payment and low land quality (PLQL) indicates that this effect decreases in size in areas with higher proportions of low quality land.

One would certainly expect acreage enrolled to respond to this direct payment incentive.[19] It is perhaps one of the most significant findings in our analysis because it is

---

[18] While these results would seem reasonable, it would be helpful to know how these differences square with differences in agricultural land prices or rental rates across these regions. If this were true, there would be evidence that CRP payments differ relative to the opportunity cost of land in production by region.

inconsistent with much of the previous literature, particularly studies based on county-level analysis, where the acres enrolled fall as payments rise.[20] The fact that the positive price effect decreases in areas with high proportions of low quality land is consistent with the belief held by some that the maximum payment is often set too high in areas attempting to enroll higher quality land. It is also consistent with a belief that some farmers trying to enroll poorer quality land bid relatively low to ensure acceptance.

Acreage in CRP is lower in the Heartland and Mississippi Portal, but higher in the Northern Great Plains, Eastern Uplands, the Southern Seaboard, and the Fruitful Rim. These results reinforce the fact that acres enrolled for CRP participants decline as the proportion of land that is of high quality in a locality increases. This is somewhat at odds with the results from the CRP participation equation (Table 2), where the likelihood of participation in CRP is increased as the proportion of land that is of high quality in a locality increases. Our result might be interpreted as a problem in adverse selection: farmers may be unlikely to enroll high or medium quality land into CRP; they retain it in crop production. It is difficult to know if this finding is consistent with one of the primary goals of CRP, the reduction of soil erosion and other environmental residuals. There is consistency only if poorer quality land is more subject to erosion and environmentally venerable.

---

[19] Suter (2004) found that annual incentive payments affect CREP enrollment in buffer strips, measured as a proportion of eligible farmland. His study is based on data aggregated at the county level, but the positive relationship between land enrolled and level of payment was only apparent when he used a refined estimate of eligible farmland derived from GIS data on the amount of agricultural land along streams in the target watersheds.

[20] For example, both Fleming (2004) and Goodwin *et al*. (2004), who study the CRP acreage response based on the county-level data, found a negative relationship between CRP acreage enrollment and the annual payment. This would make sense only if farmers try to lower their bids in order to increase the chance of their bids being accepted.

In the participation equation above, we developed an argument for why farmers receiving higher decoupled payments are less likely to participate in CRP. A similar rationale would explain why the acreage in CRP for those participants with higher decoupled payments would enroll fewer acres. CRP acreage is also determined by local economic indices. Local areas with a higher proportion employed in manufacturing have less land enrolled in CRP, which might reflect the opportunity cost of land in non-agricultural uses and work against large acreages being committed to programs such as CRP. We also see that farmers participating in EQIP are likely to decrease the acreage enrolled of CRP. This result might seem at odds with our finding from the CRP participation equation above. Since both EQIP and CRP are environmental friendly programs, these results could reflect competition for land in programs that contribute in different ways to a farmer's stewardship of the land.

There are also characteristics of the farming operation and household that affect the acreage enrollment. Acreage increases with farm and family size, and for those farms classified as cash grain farms, although the effect of the latter is not statistically significant in the acreage equation. Acreage decreases with the farming experience of the operator, but increases with the farm operator's education; this reinforces the effect from the participation equation, but the effect of education is not statistically significant. As in the participation equation, CRP acreage increases with the aversion to risk.

Production Efficiency and CRP Participation

To identify the effects of CRP participation on farm productivity, we first specify variable returns to scale Cobb-Douglas production functions for CRP participants and for non-participants. Gross cash sales, including crop and livestock sales, are used as the measure of production.[21] Total acres operated is the land input. We aggregate the expenditures for fertilizer, seeds, plants, fuel, and utilities as a measure of production cost. The hired labor cost includes regular hired and contact labor. Capital is measured by the fixed value of farm machinery and equipment, breeding stock, and farm buildings. Although the production functions for both groups exhibit increasing return to scale (Table 6), farmers participating in CRP enjoy the higher returns to scale (1.26 vs. 1.063). The production elasticities for the inputs differ between groups as well.

After decomposing the two error components, we see from Table 7 that the average technical efficiency is slightly lower for the CRP participants (0.354 vs. 0.368). Although not shown in the table, the estimates of technical efficiency for CRP participants are also more disperse than those for the non-CRP participants.

Based on the generalized Malmquist TFP Index, the TFP of participants is slightly below that of the non-participant group (ratio of 0.938), at the means of the data (Table 7). This is partially explained by the fact that CRP participants are less technically efficient (ratio of 0.962), and they are on a lower production frontier (ratio of 0.765). CRP participants generally have larger farms; our results suggest that they can indeed exploit greater returns to scale. Without this opportunity, as measured by the ratio of scale efficiency, 1.276, the TFP of CRP farms would probably be even lower.

Concluding Remarks

Using the 2001 ARMS data, we estimate a binary probit model for CRP participation and test for exogeneity of some other policy choice variables and normality. We estimate both a CRP per-acre payment equation and a CRP acreage enrollment

---

[21] The output variable used here is the same as used by Goodwin and Mishara (2004) to study the efficiency of farm households working off the farm.

equation, correcting for sample selection bias. In the third stage, we estimate differences in technical and scale efficiency and factor productivity between CRP participants and non-participants. Statistical tests confirm the need to control for sample selection, and support the hypothesis that off-farm work decisions and participation in other farm programs are not determined endogenously with CRP participation.

We find that the farms with smaller payments from other farm programs are more likely to participate in CRP, as are farmers that work off the farm and are in areas where land quality is relatively high. In contrast, although farmers in areas where soil quality is high are more likely to participate in CRP, the level of participation (as measured by acreage enrolled) is higher in areas where land quality is relatively low. Since the coefficient on the predicted per-acre payments is positive and statistically significant in this acreage equation, the level of participation does increase with the payment level. Farmers' risk attitudes affect participation. More risk-averse farmers are more likely to participate in CRP, and they also tend to enroll more acres. We also find that farmers attempting to protect the future viability of their farming operations by participating in state or local agricultural district programs, are located in an agricultural protection zone, etc. are less likely remove cropland from agricultural production by participating in CRP. Finally, CRP farms are somewhat larger than non-participants, and they are able to exploit larger economies of scale. Despite this fact, they are both slightly less technically efficient, and they have a slightly lower production frontier.

References

Aigner, D., C. Lovell, and P. Schmidt (1977). “Formulation and Estimation of Stochastic Frontier Production Function Models.” *Journal of Econometrics* 6(1):21-37.

Coelli, T., D. Prasada Rao., and G. Battese (1998). *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

Coelli, T., A. Estache, S. Perelman, and L. Trujillo (2003). A Primer on Efficiency Measurement for Utilities and Transport Regulators. Washington D.C.: The World Bank.

Darwin, R., and K. Ingram (2004). “A Global Land and Water Resource Database for Economic Models.” *Economic Research Service Technical Bulletin.* Economic Research Service, USDA, Washington, D.C.

Duke, J. (2004). “Participation in Agricultural Land Preservation Programs: Parcel Quality and a Complex Policy Environment.” *Agricultural and Resource Economics Review* 33(1): 34-49.

Fabella, R. (1989). “Separability and Risk in the Static Household Production Model.” *Southern Economic Journal* 55(4): 954-61.

Fare, R. *et al*. (1994). “Productivity Developments in Swedish Hospitals: A Malmquist Output Index Approach.” In Dordrecht (ed.) *Data Envelopment Analysis: Theory, Methodology, and Application*. Boston and London: Kluwer Academic Press. (pp. 257-72)

Fleming, R. (2004). “An Econometric Analysis of the Environmental Benefits Provided by the Conservation Reserve Program.” *Journal of Agricultural and Applied Economics* 36(2): 399-413.

Green, W. (2002). *Econometric Analysis*. Englewood Cliffs, NJ: Prentice Hall, Inc.

Goodwin, B., M. Vandeveer, and J. Deal (2004). “An Empirical Analysis of Acreage Effects of Participation in the Federal Crop Insurance Program.” *American Journal of Agricultural Economics* 86(4): 1058-77.

Goodwin, B. and A. Mishra (2004). “Farming Efficiency and the Determinants of Multiple Job Holding by Farm Operators.” *American Journal of Agricultural Economics* 86(3): 722-9.

Heckman, J. (1979). “Sample Selection Bias as a Specification Error.” *Econometrica* 47(1): 153-61.

Horowitz, J. (1993). “Semiparametric Estimation of a Work-Trip Mode Choice Model.” *Journal of Econometrics* 58 (1/2): 49-70.

Huang, M., C. Huang., and T. Fu (2002). “Cultivation Arrangement and the Cost Efficiency of Rice Farming in Taiwan.” *Journal of Productivity Analysis* 18(3): 223-39.

Isik, M. (2002). “Resource Management Under Production and Output Price Uncertainty: Implication for Environmental Policy.” *American Journal of Agricultural Economics* 84(3): 557-71.

Isik, M., and W.Yang (2004). “An Analysis of the Effects of Uncertainty and Irreversibility on Farmer Participation in the Conservation Reserve program.” *Journal of Agricultural and Resource Economics* 29(2): 242-59.

Jaroszewski, L., G. Poe, and R. Boisvert (2000). “Allocating Land to New York’s Conservation Reserve Enhancement Program to Maximum Environmental Benefit”, Paper Presented in the *Annual Meeting of American Agricultural Economic Association*. Tampa. Florida. U.S.A

Jondrow, J., C. Lovell., I. Materov., and P. Schmidt (1982). “On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model.” *Journal of Econometrics* 19 (2/3): 233-8.

Just, R. and R. Pope (1979). “Production Function Estimation and Related Risk Consideration.” *American Journal of Agricultural Economics* 61(2): 276-84.

Just, R. and D. Zilberman (1983). “Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture.” *Oxford Economic Paper* 35(2): 307-28.

Kalaitzandonakes, N. and M. Monson (1994). “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(1): 200-8.

Kazim, K. and C. Osborn (1990). “A National-Level Economic Analysis of Conservation Reserve Program Participation: A Discrete Choice Approach.” *The Journal of Agricultural Economics Research* 42(2): 5-12.

Kopp, R. and J. Mullahy (1990). “Moment-Based Estimation and Testing of Stochastic Frontier Models.” *Journal of Econometrics* 46(1/2): 165-83.

Kumbhakar, S. and C. Lovell (2000). *Stochastic Frontier Analysis.* Cambridge: Cambridge University Press.

Love, H. and S. Buccola (1991).“Joint Risk Preference-Technology Estimation with a Primal System.” A*merican Journal of Agricultural Economics* 73(3):765-74.

McLean-Meyinsse, P., J. Hui., and R. Joseph. (1994). "An Empirical Analysis of Louisiana Small Farmers' Involvement in the Conservation Reserve Program." *Journal of Agricultural and Applied Economics* 26(2):379-85.

Maddala, G. (2001). *Introduction to Econometrics*. New York: John Wiley & Sons, Inc.

Malmquist, S. (1953). "Index Numbers and Indifference Surfaces." *Trabajos de Estadistica* 4: 209-42.

Murphy, K. and R. Topel (1985). "Estimation and Inference in Two-Step Econometric Models." *Journal of Business and Economic Statistics* 3(4): 370-9.

Olson, J., P. Schmidt, and D. Waldman (1980). "A Monte Carlo Study of Estimators of Stochastic Frontier Models." *Journal of Productivity Analysis* 10(1):103-17.

Park, P. and J. Schorr (1997). "Sustaining Open Space Benefits in the Northeast: An Evaluation of the Conservation Reserve Program." *Journal of Environmental Economics and Management* 32(1): 85-94.

Smith, R. and R. Blundell (1986). "An Exogeneity Test for a Simultaneous Equation Tobit Model with an Application to Labor Supply." *Econometrica* 54(3):679-85.

Sullivan. P., *et al*. (2004). "The Conservation Reserve Program: Economic Implications for Rural America." *Agricultural Economic Report* No. 834, Economic Research Serve (ERS), United States Department of Agriculture (USDA), Washington, DC.

Suter, J. (2004). "Incentives and Enrollment in the Conservation Reserve Enhancement Program: An Approach Using Actual Enrollment and Geographic Information Systems (GIS)." Unpublished Master Thesis, Department of Applied Economics and Management, Cornell University, Ithaca, New York.

Thirtle, C., *et al*. (1995). "Accounting for Productivity Differences in European Agriculture: Cointegration, Multilateral TFPs and R&D Spillovers." In *Agricultural Competitiveness: Market Forces and Policy Choice: Proceeding of the Twenty-Second International Conference of Agricultural Economists*: 652-69.

Vella, F. (1993). "A Simple Estimation for Simultaneous Model with Censored Endogenous Regressors." *International Economic Review* 34(2): 441-57.

Table 1: Summary Statistics for the full sample of Farms in the ARMS Data, 2001

Variable Names	Variable Definitions	Mean	Std.
OP	Operator works off farm (=1)	0.56	0.50
SP	Spouse is work off farm (=1)	0.53	0.50
CRP_CREP	Household in CRP or CREP (=1)	0.23	0.42
EQIP	Participate in EQIP (=1)	0.0029	0.0539
URBAN	% labor market area's population in urban areas	56.06	22.17
MANUF	LMA's employment in manufacturing (%), lagged one year	13.84	6.90
LQH_96	Index of high quality land, 1996	0.33	0.25
LQM_96	Index of medium quality land,1996	0.29	0.15
LQL_96	Index of low quality land, 1996	0.23	0.19
AGDIST	Ooperator participates in local agricultural preservation program (=1)	0.05	0.22
REGN1	ERS region 1(Heartland) (=1)	0.28	0.45
REGN3	ERS region 3 (Northern Great Plains) (=1)	0.08	0.27
REGN567	ERS region 5 (Eastern Uplands), 6 (Southern Seaboard), 7 (Fruitful Rim) (=1)	0.29	0.45
REGN9	ERS region 9 (Mississippi Portal) (=1)	0.05	0.22
H_SIZE	Number of household members	2.74	1.26
OP_ED_C	Education level of the operator (years)	13.08	2.45
OP_EDSQ	Square terms of education level of the operator (year)	177.04	65.48
CROP17	Cash grain farm, (=1)	0.71	0.46
CROP456	Vegetable, fruit, or nursery farm, (=1)	0.21	0.41
AMTA_A	Per acre AMTA payment	5.42	12.57
LDP_A	Per acre LDP payment	8.25	18.63
OP_AGE	Age of the operator	54.57	13.71
LP_CRP_C	Logarithm of the per acre CRP payment	3.99	0.71
OP_EXP	Years operator worked on farm job	25.50	63.00
OP_EXPSQ	Square of years that the operator worked on farm	4618	123835
RISK	Risk preference of operator; =0 if risk averse, 10 if risk loving	4.43	2.46
RAISE_OP	Operator raised on the farm (=1)	0.78	0.41
CROPSIZ1	Operaed acreage divided by 1,000	0.32	0.68
A_CRP_C	Acre enrollment in CRP or CREP	140.78	293.23
EBI	Environmental benefit index	61.67	3.85
LGOUT	Logarithm of the crop and livestock sales divided by 1,000	2.63	2.05
LGLC_C	Logarithm of the livestock, crop, energy expenses	9.29	1.95
LGLAND	Logarithm of operated acreage	4.70	1.87
LGCA	Logarithm value of mach.and equip. breeding stock, building ($1,000)	5.43	1.35
LGLABOR	Logarithm of hired labor cost	5.43	3.91

* Note: all variables are weighted by the full sampl weights

Table 2: CRP Participation Equation (Probit Model)

Variable	Coefficient	Standard Error	Coef./St.Err.
Constant	-5.4548	1.4610	-3.7335
OP_AGE	0.0333	0.0036	9.3062
OP_ED_C	0.0731	0.0151	4.8455
LQH_96	0.5025	0.2127	2.3619
LQL_96	-1.1808	0.3188	-3.7033
EQIP	1.1404	0.6637	1.7181
AGDIST	-1.1552	0.2767	-4.1754
EBI	0.0499	0.0220	2.2696
AMTA_A	-0.0301	0.0047	-6.3696
LDP_A	-0.0137	0.0028	-4.9278
RISK	-0.0661	0.0168	-3.9395
CROP456	-1.8804	0.2894	-6.4980
CROPSIZ1	0.2791	0.0516	5.4145
REGN1	0.1325	0.1009	1.3122
REGN567	-0.3654	0.1455	-2.5118
REGN9	1.2075	0.2548	4.7393
URBAN	-0.0145	0.0017	-8.3349
SP	0.1043	0.0806	1.2943
OP	0.1786	0.0878	2.0340
Sample	2248		
Log-likelihood	-801.12		
Correct prediction	0.79		

Table 3: Tests for Exogenous Variables in CRP Participation Equation

Variable Tested	T_value	P_value
	*Binary Exogenous Variable**	
OP	-1.613	0.107
SP	0.426	0.670
EQIP	2.198	0.028
AGDIST	0.731	0.465
	Continous Exogenous Variable	
AMTA_A	-0.667	0.505

** Standard error is adjusted by Murphy and Topel's method.*

Table 4: CRP Payment Equation

Variable	Coef.	St. Error	b/St.Err.
Constant	2.803	0.775	3.616
OP_EXP	0.040	0.006	6.963
OP_EXPSQ	-0.001	0.000	-7.054
LQH_96	0.796	0.156	5.107
LQM_96	0.954	0.229	4.161
EBI	0.001	0.012	0.049
CROPSIZ1	-0.020	0.031	-0.626
H_SIZE	-0.045	0.025	-1.800
REGN1	0.551	0.072	7.694
REGN567	-0.495	0.129	-3.846
CROP17	-0.327	0.171	-1.916
MANUF	0.014	0.004	3.299
IMR	0.193	0.066	2.929

Table 5: CRP Acreage Equation

Variable	Coef.	St. Error	b/St.Er.
Constant	632.99	288.84	2.19
OP_EXP	-20.81	5.77	-3.61
OP_EXPSQ	0.36	0.09	3.82
OP_ED_C	8.95	42.53	0.21
OP_EDSQ	-0.59	1.57	-0.38
RISK	-4.65	5.86	-0.79
LQH_96	-818.42	116.15	-7.05
LQM_96	-749.06	139.73	-5.36
REGN1	-227.22	90.36	-2.51
REGN3	70.03	42.95	1.63
REGN567	74.64	62.62	1.19
REGN9	-108.12	64.24	-1.68
CROPSIZ1	134.98	15.78	8.56
AMTA_A	-3.69	2.38	-1.55
H_SIZE	17.97	12.30	1.46
MANUF	-4.71	3.19	-1.48
SERV	2.48	3.19	0.78
EQIP	-442.07	155.71	-2.84
PLQL	-7.53	3.37	-2.24
P_HAT	7.95	2.51	3.17
IMR	-76.45	44.68	-1.71

Table 6: Traditional Production Functions

Variable	Coefficient	Standard Error	b/St.Er.
	For CRP Participants		
Constant	-6.009	0.537	-11.191
LGLAND	0.462	0.091	5.074
LGLC_C	0.308	0.093	3.297
LGLABOR	0.092	0.019	4.894
LGCA	0.398	0.085	4.683
IMR	0.403	0.086	4.667
RTS	1.260		
R^2	0.717		
Adjust R^2	0.712		
Sample	308		
	For CRP Non-Participants		
Constant	-4.765	0.270	-17.631
LGLAND	0.259	0.034	7.597
LGLC_C	0.493	0.049	10.005
LGLABOR	0.113	0.009	12.413
LGCA	0.198	0.033	5.958
IMR	0.234	0.104	2.245
RTS	1.063		
R^2	0.718		
Adjust R^2	0.717		
Sample	1740		

Table 7: Technical Efficiency and Productivity Comparisons

Technical Efficiency, CRP participants (VRS)	0.354
Technical Efficiency,non-participants (VRS)	0.368
Technical Efficiency Index Ratio	0.962
Production Frontier Index Ratio	0.765
Economic Scale Index Ratio	1.276
Total Factor Productivity Ratio	0.939

** Note: Ratios are calculated based on non-participant group.*

Figure 1: Nonparametric Test for Normality