Are Farmers' Decisions to Work off the Farm and Participate in the Conservation Reserve Program Independent, Joint or Sequential?

By

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Abstract

There is statistical evidence that decisions to participate in CRP and work off-farm are made simultaneously. Characteristics of households, farm operations other farm programs, and the local economies affect both decisions; some factors affect only one. Policy changes that affect one decision may affect another directly and/or indirectly.

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Background

It is now widely accepted that agricultural policy analysis must recognize the diverse nature of farms and the increasing interconnection between the farm business and farm household (Offutt, 2002). Labor has been released from agriculture through adoption of agricultural technology, and steady long-term economic growth has also pulled labor off farms. The dependence of households remaining in farming on income from non-farm sources has also increased steadily, narrowing, or actually reversing, the gap between the incomes of farm and non-farm households. The agricultural sector has also become more heterogeneous.

It is only recently, through the conservation compliance provisions of the 1985 farm bill, that environmental goals were elevated along side commodity policy objectives. The number of provisions offering farmers incentives to participate in environmentally related programs has increased, with overall spending to rise by 80% under the new farm legislation—to a 10-year total of $38.6 billion. The Conservation Reserve Program (CRP), the largest program targeting land use, pays farmers $2 billion / year to remove 34 million acres from agricultural production.

The potential contribution of both off-farm employment and government incentives to participate in environmentally related programs to farm household income and income stability may be increasingly significant as commodity-related sources of farm income support are reduced and farmers are exposed to greater market price risk. Decisions to participate in either of these activities lead to reductions in farm household resources committed to agricultural production. It is reasonable to hypothesize that these decisions are interrelated. If this is the case, policy implications derived from models that consider them as independent may be misleading.

This paper investigates the extent to which these two decisions by farm households are made independently, are simultaneous, or are determined sequentially. We are interested in how these decisions to work off the farm and participate in the CRP depend on the stock of human capital and risk attitudes of farm operators, as well as the composition of farm household income and wealth. It is also critical to identify how these decisions differ by region and how they are affected by land quality, farm size, and participation in other government programs.

To motivate the empirical model specification, we develop an agricultural household production model. Data for the empirical analysis come primarily from the 2001 annual Agricultural Research Management Survey (ARMS) conducted by the USDA.

We specify econometric models reflecting both the simultaneous and sequential decision hypotheses and develop a series of tests to choose among the models. The simultaneous decision hypothesis is reflected in multinomial logit and bivariate probit choice models. A nested multinomial logit model (NLM) is frequently used to model sequential choices, but it is not suitable in this application where characteristics of the farm households in the sample differ, but the characteristics of the choices available do not. For statistical identification, it is necessary to normalize on one of the choices, resulting in a loss of information. We take an alternative approach, which, to the best of our knowledge, has not been used to model sequential decisions such as those of interest here. We specify a model that combines the strengths of both an endogenous switching regression model and a bivariate probit model. It is similar to the sequential probit model proposed by Amemiya (1985) and applied by Tunali (1986). As with Tunali's models, our model allows for correlation between the two sequential choices. In addition, there are fully observed regimes in our model.

Theoretical Framework

To focus on the essence of this combined choice, we assume that all decisions are made by the farm operator.[1] There are fixed endowments of time ($\bar{E}$) and of farmland ($\bar{A}$). Time is allocated to leisure (l), farm production (L), and off-farm work (L_m). The household receives income from several sources: agricultural product sales, off-farm work at an off-farm wage (w), CRP per acre payments (P_e), and decoupled farm payments (M). Land is allocated between crop production (A), and CRP (A_e). Utility depends not only on farm household consumption (x) and leisure (l), but also the improvement in environmental quality (e) generated by land in CRP.

Agricultural output, y, depends on land and labor, where y = F (L, A) is a well-behaved concave production function. We assume that the commodity price, *P*, is random; $P = \bar{P} + \eta$, where $\bar{P}$ is the expected price and the random error follows an arbitrary distribution (η~(0, σ_η^2)). Production risk is reflected by: $F(L, A) = f(L, A) + g(L, A)\varepsilon$, $\varepsilon \sim i.i.d(0, \sigma_\varepsilon^2)$. According to Just and Pope (1979), an input is risk increasing (decreasing) if g' (.) is positive (negative).

The agricultural household maximizes expected utility, subject to a full income constraint, a time constraint, and an acreage constraint:

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

s.t.

(2) $x = (\bar{P} + \eta)F(L, A) + wL_m + P_e A_e + M$

(3) $\bar{E} = L + L_m + l$

(4) $\bar{A} = A_e + A$.

[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.

We rewrite the problem by eliminating l and x through substitution of equations (2 through 4) into equation (1). The choice variables are land in CRP (A_e), labor in off-farm work (L_m), and labor used for agricultural production (L):

$$(5)\ \underset{A_e, L_m, L}{Max} = EU\{[(\overline{P} + \eta)(f(L, \overline{A} - A_e) + g(L, \overline{A} - A_e)\varepsilon + wL_m + P_e A_e + M],\ [\overline{E} - L - L_m], e(A_e)]\}$$

The first-order necessary conditions for interior solutions are:

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

$$(7)\ \frac{\partial EU}{\partial L_m} = E\{U_x w - U_l\} = wE(U_x) - E(U_l) = 0$$

$$(8)\ \frac{\partial EU}{\partial L} = E\{U_x[(\overline{P} + \eta)(f_L + g_L\varepsilon)] - U_l\} = 0.$$

where U_i is the first-order derivative of the utility function with respect to argument i. The optimal levels of (A_e, L_m, L) for the agricultural household are given by the simultaneous solution of equations (6), (7), and (8). From equation (7), labor is allocated to off-farm work until the ratio of the expected marginal utility of leisure to the expected marginal utility of consumption is equal to the off-farm wage (w).

To interpret the other first-order conditions, we take the expectations of both equations (6) and (8). In doing so, the first term of equation (6) can be expanded into:

$$(9)\ \overline{P}[f_A E(U_x) + g_A E(U_x\varepsilon)] + [f_A E(U_x\eta) + g_A E(U_x\varepsilon\eta)] - P_e E(U_x)$$

By taking expectations and applying the appropriate approximation (Bohrnstedt and Goldberger 1969), then substituting these expressions for expected values and covariances into equations (6) and (8), the first-order necessary conditions are now:

$$(10)\ \frac{\partial EU}{\partial A_e} = -\overline{P}[(f_A)E(U_x) + g_A Cov(U_x, \varepsilon)]$$

$$-Cov(U_x,\eta) f_A - E(U_x)[g_A Cov(\eta\varepsilon)] + P_e E(U_x) + E(U_e) e_{A_e} = 0$$

(11) $$\frac{\partial EU}{\partial L} = \overline{P}[(f_L)E(U_x) + g_L Cov(U_x,\varepsilon)]$$

$$+ Cov(U_x,\eta) f_L + E(U_x)[g_L Cov(\eta\varepsilon)] - E(U_l) = 0$$

The optimality conditions for the levels of CRP area, equation (10), and labor for production, equation (11), are more complex, compared with standard farm-household production models, because optimal decisions depend on the covariance of the expected marginal utility with each source of risk, covariances of the random variables of different sources of risk sources, expected marginal utility, and risk characteristics of farm inputs.

From equation (10), land is allocated to CRP up to the point where the expected marginal utility of the CRP payment, plus the marginal utility of CRP land's contribution to the environment, is equal to the risk adjusted utility of the value of the marginal production forgone. The optimal CRP acreage is not necessary less than in the risk neutral case, and this result depends not only on the risk characteristics of land in production and the covariance between marginal utility and the two elements of risk, but also the covariance term between the two components of risk ($Cov(\eta\varepsilon)$). If land is risk increasing, land in CRP is still possibly lower than under risk neutrally if the covariance between the risk factors is high.[2]

From equation (11), labor is employed in agriculture up to where the marginal utility of the risk adjusted marginal product of labor is equal to the marginal utility of leisure. From equation (7), the marginal utility of leisure is equal to off-farm wages.

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[2] We have: $x = (\overline{P}+\eta)(f+g\varepsilon) + wL_m + P_e A_e = E(x) + \overline{P}(g\varepsilon) + \eta(f+g\varepsilon)$ .Assume $g\varepsilon > 0$ and $f + g\varepsilon >$ 0, then if $\eta > 0$ we know that $x > E(x)$. Under risk aversion, U'(x) < U'(E(x)), therefore, Cov (U_x', η) < 0. The same argument is applied to determine that Cov (U_x', ε) < 0 and Cov (U_x', u) > 0.

Econometric Framework

The primary objective of this study is to determine the decision making process that underlies the off-farm labor supply of farm households and participation in CRP. To avoid the misspecification of the econometric selection model, we propose several econometric strategies to characterize these decisions. We compare the performance of two econometric structures that embody a joint decision process against one that embodies a sequential decision process.

Joint Choice Structure

When decisions are considered joint, polychotomous choice models are commonly used in empirical analysis. These models fall into two classes. The first relies on multiple binary choice rules, defining each decision separately as a binary choice, but allowing for the correlation between these decisions. If the correlation proves significant, the decisions are truly jointly determined; otherwise they can be regarded more simply as separate choices. This forms the basis for testing whether the multiple choices should be regarded as independent or joint. If a joint normal distribution is assumed, a bivariate probit model is appropriate to consider the joint decisions between CRP participation and off-farm work.

The second class is the multinomial discrete choice model, based on a random utility framework (McFadden (1974); Dubin and McFadden (1984); Lee (1983)). Here, the decisions are considered to be joint, without the possibility that each choice could be made separately. If the error term is assumed to have a Type I extreme value distribution, we have the multinomial logit model by McFadden (1974).[3] Regarding model selection, in the case of participation in CRP and/or off-farm work, there are four distinct regimes—participate in: CRP only, off-farm work only, both CRP and off-farm work, and neither.

[3] Theil (1969) originally studied the choice of transportation mode; Barham *et al*. (2002) studied the adoption of rBST on U.S. dairy farms.

Bivariate Probit Choice

According to this choice model, the CRP participation decision is determined by the reservation per acre return (perhaps risk adjusted) to the farmer of retaining the land in production with the government's payment for land in the conservation reserve program (CRP). The off-farm job decision is determined by comparing the potential off-farm market wage with the shadow value (perhaps also risk adjusted) of the farmer's time in farm production.

The specifications for these two equations are:

(12) $P^r = A_r X_r + e_r$ and $P^g = A_g X_g + e_g$

(13) $W^r = B_r S_r + u_r$ and $W^g = B_g S_g + u_g$,

where P^r and P^g represent the reservation per acre payment, and the potential government per acre CRP payment; W^r and W^g represent the shadow value of the farming time and the market off-farm wage. The vectors X_r, X_g, S_r, and S_g are the exogenous variables, and e_r, e_g, u_r, and u_g are the random disturbance terms. The latent binary choice variables (I_1*, I_2*) for the participation decisions of each farmer can be defined as:[4]

(14) $I_1* = P^g - P^r = H_{g1}' X_{g1} - H_{r1}' X_{r1} + (e_g - e_r) = H_1' X_1 + e_1$

$$I_2* = W^g - W^r = H_{g2}' X_{g2} - H_{r2}' X_{r2} + (u_r - u_g) = H_2' X_2 + e_2 .$$

The joint distribution of (e_1, e_2) follows a bivariate normal distribution, $N(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix})$, where the correlation coefficient (ρ) captures the joint nature of these two decisions. Only the actual decisions, I_i are observed. The observation rules for these two latent variables are: $I_i = 1$ (the farmer participates in activity i) iff $I_i* > 0$; and $I_i = 0$ (the farmer does not participate in activity i) iff $I_i* < 0$, i=1,2. The probabilities for the four regimes are (Greene 2002):

[4] For simplicity, subscript 1 refers to the CRP decision, and subscript 2 refers to the off-farm job of the operator.

(15) $P_{11} = \Pr(I_1 = 1, I_2 = 1) = \Pr(e_1 > -H_1' X_1, e_2 > -H_2' X_2) = \int_{-H_1'X_1}^{\infty} \int_{-H_2'X_2}^{\infty} \phi(I_1, I_2, \rho) dI_1 dI_2$

$= \Phi(H_1' X_1, H_2' X_2, \rho)$

$P_{10} = \Pr(I_1 = 1, I_2 = 0) = \Pr(e_1 > -H_1' X_1, e_2 < -H_2' X_2) = \int_{-H_1'X_1}^{\infty} \int_{-\infty}^{-H_2'X_2} \phi(I_1, I_2, \rho) dI_1 dI_2$

$= \Phi(H_1' X_1) - P_{11}$

$P_{01} = \Pr(I_1 = 0, I_2 = 1) = \Pr(e_1 < -H_1' X_1, e_2 > -H_2' X_2) = \Phi(H_2' X_2) - P_{11}$

$P_{00} = 1 - P_{11} - P_{10} - P_{01}$,

where $\phi(I_1, I_2, \rho) = \frac{\exp(-1/2 * \frac{(I_1^2 + I_2^2 - 2\rho I_1 I_2)}{1-\rho^2})}{2\pi(1-\rho^2)^{1/2}}$, the joint bivariate normal distribution of

(I_1,I_2). The model is estimated by FIML using the log likelihood function (Greene 2002):

(16) $\log L = \sum_{i=1}^{N_1} \log \Phi\{[(2I_1 - 1)(H_1' X_1)], [(2I_2 - 1)(H_2' X_2)], [((2I_1 - 1))(2I_2 - 1)\rho]\}$

Multinomial Logit Model

The Random Utility Model (RUM) is consistent with the maximization of utility by the household (McFadden 1974). Suppose utility is discrete, and each farmer (*i*) has j alternatives available.[5] The indirect utility of each alternative is:

(17) $U_{ij} = V_{ij} + \varepsilon_{ij}$ i= 1..N ; j= 1.. M

If alternative *s* is chosen, we assume that the indirect utility of alternative *s* provides farmer *i* with the highest utility, when compared to the other alternatives:

(18) $U_{is} = V_{is} + \varepsilon_{is} > V_{ij} + \varepsilon_{ij} = U_{ij}$, or (18') $V_{is} - V_{ij} + \varepsilon_{is} > \varepsilon_{ij} \quad \forall j \neq s$

[5] In our case, there are four: participate in neither CRP nor off-farm work; participate in CRP only; participate in off-farm work only; or participate in both.

The probability that farmer *i* chooses alternative *s* is:

$$(19) \quad \Pr(U_{is} = 1) = \int_{-\infty}^{\infty} \prod_{j \neq s} F(\varepsilon_{ij} < V_{is} - V_{ij} + \varepsilon_{is}) f(\varepsilon_{ij}) d\varepsilon_{ij}$$

$$= \int_{-\infty}^{\infty} \prod_{j \neq s} F(\varepsilon_{ij} < V_{is} - V_{ij} + \varepsilon_{is}) dF(\varepsilon_{ij}) d\varepsilon_{ij}$$

Assuming a Type I extreme value error distribution (McFadden 1974), the probability of farmer *i* choosing alternative *s* for the multinomial logit model is:

$$(19') \quad \Pr(U_{is} = 1) = \frac{\exp(r_{ij}' w_{ij})}{\sum_{j=1}^{M} \exp(r'_{ij} w_{ij})}$$

The structural model can be estimated using (FIML). The log likelihood function is:

$$(20) \quad LogL = \sum_{i=1}^{n} \sum_{j=1}^{J} d_{ij} \log \Pr(U_{ij} = 1)$$

where d is the binary indicator for each choice; it equals one if alternative s is chosen.

Sequential Decision Choice Structure

Rather than being determined simultaneously, it is possible that these two decisions are made sequentially. The farm household might consider one of the decisions first and makes the other decision sequentially depending on the first choice. Maddala (1983) suggests that it is important to distinguish joint and sequential decisions. Lee and Maddala (1994) have noted with no prior information about the decision making process, it is best to model both as a sequential process. We must also examine both orderings of the CRP and off-farm labor choices.

We categorize the sequential choice models into two families: multiple and the multivariate choice structures. The nested logit model fits into the first category, but it is not appropriate here because the characteristics of the farm households differ, but the characteristics of the choices available do not differ. For statistical identification, one would normalize on one of the choices, resulting in a loss of information. Instead, we adapt a bivariate probit framework to accommodate the sequential decision process.

Sequential Choice Based on the Bivariate Probit Framework

Amemiya (1985) was the pioneer in adapting the probit model to sequential choices. He regards the sequential decision process simply as two uncorrelated binary probit choices. Abowd and Farber (1982), Poirier (1980), and Tunali (1986) have proposed similar models that allow for correlation between sequential decisions.

To allow for a correlation between a farmer's decision to work off the farm and to participate in CRP, we propose a variation on the sequential bivariate probit model by Tunali (1986). We illustrate for the case where the farmer makes the off-farm job decision prior to the CRP choice. The CRP decision, given that the farmer has already chosen to work off the farm, should be regarded differently than the decision to participate in CRP, given that the farmer has decided not to work off the farm. The unique feature of this formulation is that it actually involves three choices. Each of them can be specified as a binary probit model, but they are all correlated. The full model is:

(21) $D_1^* = z_1' r_1 + \varepsilon_1 \qquad D_1 = 1 \text{ iff } D_1^* > 0$

$D_2^* = z_2' r_2 + \varepsilon_2 \qquad D_2 = 1 \text{ iff } D_2^* > 0$, conditional on $D_1 > 0$

$D_3^* = z_3' r_3 + \varepsilon_3 \qquad D_3 = 1 \text{ iff } D_3^* > 0$, conditional on $D_1 < 0$,

where D_1^* is the latent variable for the off-farm labor decision; D_2^* is the latent variable for the CRP decision, given the operator works off the farm; D_3^* is the latent variable for the CRP decision, given the operator does not work off the farm. We assume the error terms $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$

follow the trivariate normal distribution: $N[(0,0,0);\begin{bmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{12} & 1 & 0 \\ \rho_{13} & 0 & 1 \end{bmatrix}]$; z contains the parameters of interest for each choice equation, and r is an individual covariate.[6] The four regimes are:

D_1=1 and D_2=1; operator participates in CRP, given the choice not to work off farm;

D_1=1 and D_2=0; operator does not participate in CRP, given a choice not to work off farm;

D_1=0 and D_3=1; operator participates in CRP, given a choice to work off farm; and

D_1=0 and D_3=0; operator does not participate in CRP, given a choice not to work off farm.

Under the trivariate normality assumption, the probabilities of each regime are:

(22) $\Pr(D_1 = 1, D_2 = 1) = \Pr(\varepsilon_1 > -z_1' r_1, \varepsilon_2 > -z_2' r_2) = \Phi(z_1' r_1, z_2' r_2, \rho_{12})$;

$\Pr(D_1 = 1, D_2 = 0) = \Pr(\varepsilon_1 > -z_1' r_1, \varepsilon_2 < -z_2' r_2) = \Phi(z_1' r_1, -z_2' r_2, -\rho_{12})$;

$\Pr(D_1 = 0, D_3 = 1) = \Pr(\varepsilon_1 < -z_1' r_1, \varepsilon_3 > -z_3' r_3) = \Phi(-z_1' r_1, z_3' r_3, -\rho_{13})$; and

$\Pr(D_1 = 0, D_3 = 0) = \Pr(\varepsilon_1 < -z_1' r_1, \varepsilon_2 < -z_3' r_3) = \Phi(-z_1' r_1, -z_3' r_3, \rho_{13})$.

This model can be estimated by FIML using the likelihood function:

$$(23)\quad L = \prod_{D_1=1,D_2=1} \Phi(z_1' r_1, z_2' r_2, \rho_{12}). \prod_{D_1=1,D_2=0} \Phi(z_1' r_1, -z_2' r_2, -\rho_{12}). \prod_{D_1=0,D_3=1} \Phi(-z_1' r_1, z_3' r_3, -\rho_{13})$$

$$. \prod_{D_1=0,D_3=0} \Phi(-z_1' r_1, -z_3' r_3, \rho_{13})$$

$\Phi(.)$ is the cumulative distribution of the standard bivariate normal random variable.[7]

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[6] Our model differs from the one proposed by Tunali (1986) in that we define two different choice structures for the second stage, due to the sequential nature of the choice. More specifically, the correlation between D_2^* and D_3^* is zero, since these two outcomes are mutually exclusive. Moreover, Tunali (1986) defined the case with incomplete classification of the observed outcomes. He studies the sequential choice of migration/re-migration process. That is: if people choose to stay, then there is no re-migration decision observable. The same model has been applied to the labor market by Henneberger and Sousa-Poza (1998). People report their wage only when they choose to work. Khanna (2001) applied this model to the field of agricultural economics. She studied the nitrogen productivity under the sequential choice for the adoption of two site-specific technologies. Our model also differs from the endogenous switching regression model (Lee 1978) since the second-stage equation in our model is the latent dependent variable, instead of the continuous one. This difference requires maximum likelihood estimation.

Testing the Choice Structures and Model Selection Criteria

To choose between the bivariate probit and multinomial logit decision structures, we use a non-nested test proposed by Vuong (1989) that is based on the likelihood ratio test. To test the nested tree structure for the sequential bivariate probit model, we use a (LDC) Likelihood Dominance Criterion (Pollak and Wales, 1991). See Appendix A. The independence of the IIA assumption in the multinomial logit model is tested using a Hausman-Wu test (Maddala, 2001).

The Data and Empirical Specification

The farm household data used in this paper are from the 2001 Agricultural Resource Management Survey (ARMS). By including much data on the farm household (e.g. non-farm assets, sources of non-farm income, household demographics, etc.), the ARMS database differs markedly from the earlier farm costs and return survey. It now provides the basis for assessing changes in the well being of farm households nationwide. For purposes of this study, the ARMS data related to off-farm income and participation in the variety of traditional farm programs and programs related to the environment such as CRP, CREP, and EQIP are particularly important.

Since the objective of this paper is to understand participation in CRP and off-farm work by farm households, we limit our attention to the sample of farm households, and we exclude some large corporate operations, etc. We limit our attention to farms classified as crop farms because other aspects of the larger study of which this paper is a part, are designed to study the effects of CRP participation on farm productivity. Given the diversity of crop farming

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[7] Since equation (23) is highly non-linear, the selection of the initial values might be crucial for estimation. Therefore, the initial values of the parameters for equation (23) are determined by estimating a Heckman-Type two-stage model. In the first stage, the standard binary probit choice model for off-farm work is estimated using maximum likelihood methods. Given the consistent estimators of the first stage, the second stage CRP participation is the conditional choice, based on the first stage off-farm decision. Two second-stage models, using the standard Heckman's error correction, provide estimates of CRP participation, conditional on the first-stage decision.

(24) $E(D_2^*) = z_2'r_2 + E(\varepsilon_2 \mid \varepsilon_1 > -z_1'r_1) = z_2'r_2 + \frac{\phi(z_1'r_1)}{\Phi(z_1'r_1)}$ $\quad E(D_3^*) = z_3'r_3 + E(\varepsilon_3 \mid \varepsilon_1 < -z_1'r_1) = z_3'r_3 - \frac{\phi(z_1'r_1)}{1-\Phi(z_1'r_1)}$.

nationwide, it is already a considerable stretch to argue that there is a single production function for each group. The inclusion of livestock farms would compound the difficulties.

The final sample count is 2,223, and Table 1 contains information summarizing the variables used in the empirical models. The frequencies of CRP participation and off-farm work are summarized in Table 2. About 22% of the farm households participate in CRP, and in about 56% of them, the operator works off the farm. However, only 282 (13%) participate in both; 211 (10%) participate only in CRP, while 960 (43%) participate only in the off-farm labor market.

We do rely on data from additional sources. The economic characteristics of local area, for example, are merged into our ARMS data set. These are county-level data from the Bureau of Economic Analysis (BEA) income and employment files for 2000, the Bureau of Labor Statistics, and the 1990 Census of Population, STF-3 file. Three variables representing land quality at the county level in which the farm is located are used. Land quality is determined as the product of a variable reflecting the length of the growing season and the land capability class. The data on the length of the growing season are those used in a global economic model developed to evaluate long-run agricultural and environmental sustainability (Darwin and Ingram, 2004). The growing season variable is an estimate of the length of the rain-fed growing season. The land capability classes are those used by the Natural Resources Conservation Survey (NRCS) and elsewhere to classify land based on physical soil characteristics. The index is calculated from factors in the universal soil loss equation.[8]

Another critical factor affecting CRP participation is the Environmental Benefits Index (EBI) that is calculated by Farm Service Agency (FSA) and NRCS. The EBI score in part

[8] We owe a 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 = percentage of land in the county that is in soil capability class i, and GS = the ratio of the mean rain-fed season to the mean irrigated season.

determines the maximum price that can be paid for land offered into the CRP. It is assigned in each environmental category for each offered parcel as prescribed by the handbook that lists specific details on how points are to be assigned for each conservation practice and land characteristics.[9] 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 estimate an EBI for major ERS agricultural regions based on the percentage of land in the various conservation practices currently enrolled in CRP. By using these data, it is explicitly assumed that when CRP participation commitments were made, land was likely to be committed to these land uses in similar proportions.

In specifying the empirical models, we are guided by the theoretical results from above, as well as from previous literature. As suggested by Lass, Findeis, and Hallberg (1991), it is convenient to think about the factors affecting participation in off-farm work in the four groups including: operator's individual characteristics; farm family characteristics; farm production and financial characteristics; and location factors. We also draw on the work by Goodwin and Mishra (2004) and El-Osta *et al*. (2004). Some of the factors affecting CRP participation are similar to those affecting the off-farm work decision. In specifying these models, we are guided generally by other work, such as that by Duke (2004), Suter (2004), and Park and Schorr (1997).

Empirical Results

Our first set of empirical results is for the statistical tests used in choosing the decision structure. The second is a discussion of the estimated model for preferred decision structure.

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

Testing the Independent, Joint, and Sequential Decision Structures

We summarize our test results about the joint and the sequential decisions in Tables 3 and 4. Based on Vuong's test in part A of Table 3, there is no clear preference between the bivariate probit model or the multinomial logit model. Although these results are inconclusive, we do reject the hypothesis of IIA (the independence of irrelevant alternatives) in the multinomial logit model according to the Hausman-Wu tests for four of the nine deleted group combinations involved in the test (Table 4). On this basis, there is some reason to believe that the bivariate probit model captures the joint nature of decisions to participate in CRP and work off the farm.

To test the appropriateness of the sequential bivariate probit model, we begin with the test for the order in which the two decisions are made. The results of the LDC test suggest that the decision to work off the farm is made prior to the decision to participate in CRP (Part B, of Table 3).[10] In turn, part C of Table 3 contains the LDC test that determines the appropriateness of the joint decision structure against the sequential decision structure. Since the LDC test from above suggests that the decision to work off the farm is made prior to the decision to participate in CRP, it is that version of the sequential bivariate probit model that is used in this test. Our result of this test supports the selection of the bivariate probit model. This reinforces our conclusion above that the joint decision model is better able to capture the process associated with decisions to participate in CRP and work off the farm working.

This conclusion is confirmed once again by a test of this joint decision structure hypothesis against a null hypothesis that the two decisions are independent binary choices. This test involves testing the null hypothesis that the correlation coefficient between the decisions in the bivariate probit model is zero. The results of this test are in part D of Table 3. Based on the

[10] LDC has been used as the model selection criterion for testing sequential structures based on a nested multinomial logit model framework (Kling and Thomson, 1996; Hauber and Parsons, 2000).

Likelihood Ratio test, we reject the hypothesis that this correlation between these two decisions is zero at the 95% confidence level.

Estimated Empirical Models

Based on the statistical evidence that decisions to participate in CRP and work off the farm are determined jointly, rather than sequentially or independently, we now turn to a discussion of the estimated bivariate probit model.

Determinants of CRP Participation

Participating in CRP depends generally on some characteristics of the farm, the farm operator, land quality, and the circumstances in the local economy (Table 5). There are also some differences in participation by major ERS production region. It is clear that the probability of participation in CRP increases with farm size. The probability of participation is lower if the farm is primarily engaged in vegetable or nursery production, rather than cash grain production. This reflects a higher opportunity cost of land on the vegetable or nursery farms.

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 the annual CRP payments. Unfortunately, it is impossible to include such a variable in participation equations such as this because of the sample selection problem. However, Park and Schorr (1997) argued that the maximum bid price ought to be one of factors affecting CRP participation. We have no information on actual bids or bids accepted for our sample farms, but we do find that farm households that are located in areas where the EBI scores for land currently enrolled are high are more likely to participate in CRP, *ceteris paribus*. It is likely that in areas where the EBI scores were high, farmers might well expect to have higher bids accepted.

Based on the measures of soil quality related to the general quality of the soil resource in the region described above, participation in CRP rises as the proportion of land in the surrounding county is classified as high or as low quality. This result suggests that CRP participation may be higher in areas where most of the land is well suited for agriculture, and lower in the areas where there is less land suitable for crop production.

There are two variables that suggest participation in CRP has something to do with the life cycle of the farm operator. The likelihood of CRP participation increases with age. Thus, as farmers get older, committing some land to CRP may be one way of reducing operator labor requirements. This may also be a way of holding onto farmland assets until they are needed for the retirement years, or so that they can be passed on through an estate. The fact that there is a positive correlation between the probability of farmers working off the farm and the probability of participation in CRP (as measured by ρ) may also be a way of reducing operator labor requirements. Finally, the probability of CRP participation increases as a farmer's education level increases; this is perhaps an indication that investments in human capital investment might lead to increases in CRP. To the extent that the investments lead to greater appreciation of the environmental benefits from CRP, these effects square with the theoretical model above.

In the theory discussed above, there are also several ways in which risk can affect the participation in CRP. As aversion to risk increases, the likelihood of participation in a program where payments are certain, such as CRP, will increase. This conclusion is supported by the negative sign on the variable "RISK" in Table 5 (e.g. high values for "RISK" are associated with farmers who prefer more risk). Furthermore, by allowing for decreasing absolute risk aversion (DARA), our theory is also consistent with the fact that decoupled payments, "AMTA_A", reduce the likelihood of CRP participation.[11] With DARA, farmers are likely to be less concerned about diversifying into risk-free income opportunities as wealth increases through decoupled payments.[12] Finally, since commodity program related loan deficiency payments (LDP) reduce farm income variability, these payments also reduce risk averse farmers' concerns for allocating farm resources to programs such as CRP.[13]

Participation in other programs also affects the likelihood for CRP participation. For example, if the farmer is enrolled in a voluntary agricultural district, subject to a farmland preservation easement, is located in an agricultural protection zone or an area zoned exclusively for agricultural use (the variable AGDIST), the farmer is less likely to participate in CRP. Many farmers participate in these types of programs (most of which are state or local programs) out of concern for maintaining their land in agricultural production in rapidly growing areas where there is competition for land for non-agricultural purposes. Therefore, it is hardly surprising that, *ceteris paribus*, these farmers would be less likely to enroll land in a program such as CRP that essentially takes land out of production. The fact that the likelihood of CRP participation falls as the proportion of population that is urban rises would seem to reinforce this explanation.[14] In contrast, farmers who participate in EQIP are also more likely to participate in CRP. Participation in both EQIP and CRP could reflect a farmer's stewardship for the environment

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[11] We know that if one assumes a negative exponential utility that embodies the assumption of constant absolute risk aversion (CARA), a change in farm household wealth is independent of the farm household's production decisions. Limits on the length of this paper prevent us from developing our theoretical results regarding risk in detail. However, elsewhere we develop a more general risk formulation where we assume instead that the utility function can be approximated by a second-order Taylor series expansion about the mean (Kumbhakar, 2002 and Isik, 2002). Accordingly, we make no specific assumptions about the utility function, or about the distribution of the random variable. We develop comparative static results showing that CRP participation is affected by a change in wealth associated with decoupled payments under decreasing absolute risk aversion (Chang and Boisvert, 2005).

[12] By assuming non-constant absolute risk aversion, Hennessey's (1998) framework is also consistent with our results in the sense that he shows that under these conditions, decoupled payments can affect crop production alternatives.

[13] In a simpler model of just the CRP choice, the null hypotheses that decoupled payments, loan deficiency payments, participation in EQIP and in local agricultural districts, etc. are exogenous to the decision to participate in CRP could not be rejected.

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

(reflected in our theoretical model) by removing venerable land from production, while also using more environmentally friendly practices on land still in production.

Determinants of the Off-Farm Work Decision

As expected, the decision of the farm operator to engage in off-farm work also depends on characteristics of the farm, the farm operator, and the circumstances in the local economy. As in much of the existing literature (e.g. Sumner 1982; Benjamin and Guyomard 1994; Abdulai and Delgado 1999), our results continue to confirm the fact that older farmers are more likely to work off the farm.[15] However, the effect is nonlinear, with the likelihood of participation increasing with the operator's age up to about age 44, but declining thereafter. Although the operator's education has a positive effect on the probability of participation in off-farm work, the years of experience on the farm has a negative effect that increases at an increasing rate. Farm operators raised on farms are also less likely to work off the farm. Since returns to off-farm labor are likely to be less variable than farm returns, the indication that the likelihood of off-farm participation is lower for farm operators willing to accept more risk (a negative coefficient on "RISK" in Table 3, a variable that increases as a farmer is willing to accept more risk) is consistent with the theory of risk averse behavior, but the effect is not statistically significant.

The likelihood of working off the farm decreases with family size, but increases if the spouse is primarily a homemaker. This latter result may not square with the fact that the operator's likelihood of working off the farm increases with the spouse working off the farm. To disentangle these results, we might well have to specify the characteristics of household size in greater detail and deal with the fact that the decision of the spouse to work off the farm may be endogenous. Attempts will be made to disentangle these effects in subsequent analyses.

[15] Our result is not consistent with Whittaker and Ahearn (1991), who found that young operators were more likely than older operators to work off the farm.

The likelihood of participation in off-farm work declines with farm size and farm tenancy, as measured by the proportion of land owned, and it is lower for vegetable or nursery operations. The negative effects on the likelihood of participation of both net worth and participation in government programs other than CRP may reflect wealth or scale effects on off-farm labor supply (Goodwin and Mishra, 2004). The negative effect of tenancy on the likelihood for off-farm job participation reflects a greater commitment to agricultural production (*ceteris paribus*) from operators that own their own land. Finally, there is some indication that the strength of the local economy, as measured by the proportion of jobs that are manufacturing, increases the likelihood of participation in off-farm work. The extent to which the local economy depends on jobs in the trade sectors reduces the likelihood of participation in off-farm work.

Concluding Remarks

This paper investigates the extent to which decisions by farm households to participate in CRP and to off-farm work are made independently, are simultaneous, or are determined sequentially. We compare two major econometric approaches that are consistent with a simultaneous decision hypothesis, the multinomial logit and bivariate probit models, with an appropriate variation in a sequential bivariate probit model. In so doing, we eliminate the need to normalize on one of the choices as would be the case if we were to use a nested logit model for the sequential choice.

Based on estimated models for sequential choice and the two simultaneous choice specifications, the empirical results suggest that the decisions to work off the farm are not made independently from decisions to participate in CRP. If we focus on the sequential choice model, we find that households seem to make off-farm work decisions prior to decisions to participate in CRP. However, in terms of the simultaneous choice models, results also show that the bivariate probit model performs better than the multinomial logit model, particularly since we reject the IIA hypothesis embodied in the multinomial logit. Since the correlation coefficient between these two decisions is 12% and is statistical significant, there is evidence that these two decisions are made simultaneously. Support is also found for the simultaneous decision specification from the results of the LDC tests applied to the bivariate and sequential probit models.

These results all seem to support a joint decision structure, but since the analysis is based on cross sectional data, it is difficult to know how the results might have changed had we had access to panel data containing information about the actual timing of these two decisions. What is perhaps clear from the analysis is that these two decisions are not made independently, a finding that should have important policy significance.

Focusing on the preferred bivariate probit specification, there are common factors that affect both decisions. Older farm operators with more education are more likely to work off the farm and participate in CRP, as are farmers who are more risk averse. Furthermore, operators of larger farms are less likely to participate in an off-farm job, but more likely to be in CRP. Not surprisingly, households participating in other environmentally related programs are more likely to participate in CRP. However, those farmers enrolled in state or local agricultural districts or participate in other local farmland retention programs are less likely to participate in CRP. Factors that affect only the likelihood of off-farm employment include tenancy, working status of the spouse, household size, and farming experience.

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Appendix A
Testing the Choice Structures and Model Selection Criteria

Model Selection Criterion between Two Joint (non-sequential) Decision Models

To choose between the bivariate probit and multinomial logit decision structures, we use a non-nested test proposed by Vuong (1989) that is based on the likelihood ratio test. Given likelihood functions $f(y_i \mid r_i, \alpha)$ and $g(y_i \mid z_i, \theta)$ corresponding to bivariate probit and multinomial logit models, respectively, we estimate the variance of the difference between the two likelihood functions, defined as:

$$w_n^2 = \frac{1}{n}\sum_{i=1}^{n}[\log\frac{f(y_i \mid r_i, \alpha)}{g(y_i \mid z_i, \theta)}]^2 - [\frac{1}{n}\sum_{i=1}^{n}\log\frac{f(y_i \mid r_i, \alpha)}{g(y_i \mid z_i, \theta)}]^2$$

If $E[\log\frac{f(y_i \mid r_i, \alpha)}{g(y_i \mid z_i, \theta)}] = 0$, then there is no basis on which to prefer one model to the other. Under this null hypothesis that there is no difference, Vuong derived the test statistics as:

$Z = \frac{LR_n(\alpha, \theta)}{n^{0.5} w_n} \sim N(0,1)$. If this test statistic exceeds the critical value, and

$E[\log\frac{f(y_i \mid r_i, \alpha)}{g(y_i \mid z_i, \theta)}] > 0$, then the bivariate probit model, is preferred to the multinomial logit model. If this test statistic exceeds the critical value, and $E[\log\frac{f(y_i \mid r_i, \alpha)}{g(y_i \mid z_i, \theta)}] < 0$, then the multinomial logit model is preferred to the bivariate probit model.

Although the multinomial logit model is used commonly by empirical economists in studying individual choices among different alternatives, the model implicitly has the property of the independence of irrelevant alternatives (IIA). Under IIA, the introduction of an alternative will not change the log odds-ratio between any pair of the existing choices. This assumption is thought to be a weakness of the model; therefore, we test the IIA property of the multinomial logit model using a standard Hausman-Wu test (e.g. Maddala, 2001). If the IIA property is rejected, this model specification might not appropriate for our choice situation.

Test of the Nested Tree Structure for the Sequential Bivariate Probit Model

To test the nested tree structure for the sequential bivariate probit model, we utilize the "Likelihood Dominance Criterion" (LDC) proposed by Pollak and Wales (1991). After using maximum likelihood methods to estimate models under each of the two assumptions about which choice is made first, the comparison is based on the log likelihood values and the number of the parameters in each model (e.g. Kling and Thomson, 1996). With no prior information, we must test the hypothesis:

H_0: CRP participation decision is made prior to the decision to work off the farm.

H_1: Off-farm working decision is made first before the CRP decision.

The model selection criterion under the LDC test is (Pollak and Wales, 1991, p. 236):

(i) LDC prefers H_0 to H_1 if $L_1 - L_0 < [X(n_1+1) - X(n_0+1)]/2$

(ii) LDC is indecisive if $[X(n_1 - n_0+1) - X(1)]/2 > L_1 - L_0 > [X(n_1+1) - X(n_0+1)]/2$

(iii) LDC prefers H_1 to H_0 if $L_1 - L_0 > [X(n_1 - n_0 + 1) - X(1)]/2$

where L_1, L_0 are the log likelihood values, and n_1, n_0 are the numbers of the parameters in the two models, respectively. X (k) is the chi-square critical value with the degree of freedom of k for a 95% confidence interval.

Table 1: Summary Statistics Crop Farms in the ARMS Data, 2001, Sample of 2223

Variable Names	Variable Definitions	Mean	Std.
OP	Operator working off farm (=1)	0.56	0.50
CRP_CREP	Enrolled in CRP or CREP (=1)	0.22	0.42
HOUR_OP	Operators annual hours off farm	1980	842
URBAN	Percentage of labor market area's population living in urban areas	56.45	21.78
MANUF	LMA's employment in manufacturing (%)	13.94	6.87
TRADE	LMA's employment in wholesale and retail trade (%)	20.32	2.35
LQH_96	Proportion of high quality land of 1996	0.33	0.25
LQL_96	Proportion of low quality land of 1996	0.23	0.19
EQIP	Participate in EQIP (=1)	0.0030	0.0543
SP	Spouse working off farm (=1)	0.53	0.50
AGDIST	Participates in local agricultural preservation program (=1)	0.05	0.22
REGN1	ERS region 1(Heartland) (=1)	0.29	0.45
REGN3	ERS region 3 (Northern Great Plains) (=1)	0.07	0.26
REGN567	ERS region 5 (Eastern Uplands), 6 (Southern Seaboard), 7 (Fruitful Rim) (=1)	0.29	0.46
REGN9	ERS region 9 (Mississippi Portal) (=1)	0.05	0.22
H_SIZE	Number of household members	2.75	1.27
OP_ED_C	Education level of the operator (year)	13.04	2.43
CROP17	Cash grain farm, (=1)	0.70	0.46
CROP456	Vegetable, fruit, or nursery farm, (=1)	0.21	0.41
NETWORT1	Household networth value divided by 100,000	4.61	15.70
SP_HMAK	Spouse is a home maker (=1)	0.25	0.43
TENANCY	Owned acreage divided by total acreage	0.95	2.08
AMTA_A	Per acre AMTA payment	5.50	12.65
LDP_A	Per acre LDP payment	8.35	18.72
OP_AGE	Age of the operator	54.59	13.78
LP_CRP_C	Logrithm of the per acre CRP payment	3.99	0.71
LGWAGEOP	Logrithm of the opearator's off-farm job wage	2.83	0.74
OP_EXP	Years of the operator working on farm job	25.50	63.00
RISK	Risk preference operator; 0 if risk averse, 10 if risk loving	4.48	2.43
RAISE_OP	Operator was raised on the farm (=1)	0.79	0.41
CROPSIZ1	Operated acreage divided by 1,000	0.32	0.68
A_CRP_C	Acre enrollment in CRP and CREP	150.32	305.22
EBI	Environmental benefits index	61.64	3.87

** Note: All variables are weighted by the full sample weights; the sample size is 2,223*

Table 2: Distribution of the Joint Choice

	CRP		
OP	0	1	Total
0	770	211	981
%	*34.64*	*9.49*	*44.13*
1	960	282	1242
%	*43.18*	*12.69*	*55.87*
Total	1730	493	2223
%	*77.82*	*22.18*	

Weighted with full sample weights.

Table 3: Model Selection Criterion Between Models

	Difference in Log Likelihood	**Difference in Para #**	**Test Value**	**Critical Value**	**Model Selection**
A. Joint Decision Models					
BVP vs MNL*	--	--	-1.6309	-1.69	**No Preference**
B. Sequential Decision Models					
Sequential BVP**					
OP vs CRP	8.51	3	--	2.83	**OP**
C. Joint vs Sequential Choices					
Sequential BVP vs BVP**	-19	18	--	10.53	**BVP**
D. Joint vs Independent Choices*					
BVP vs (CRP&OP)			7.126	3.84	**BVP**

*Note: *: Vuong Test; **: LDC Test; ***: LR Test OP (CRP) is where off-farm (CRP) decision is made first.*

Table 4: IIA Test for the M L Model

Deleted Group	(x^2)
group 3 only	4
group 1 only	3
group 0 only	162
group 2 and 3	9
group 1 and 2	18
group 1 and 3	3
group 3 and 0	129
group 2 and 0	93
group 1 and 0	130

*Critical value is 41.33; * is rejected at 95% level*
group 0: nonparticipants; group 1: CRP=1 only
group 2: OP=1 only; group3: CRP=OP=1

Table 5: Bivariate Probit Model Estimation

Variable	Coefficient	Std	b/Std	P Value
		Estimation for CRP Equation		
Constant	-4.948	1.414	-3.499	0.001
OP_AGE	0.029	0.003	9.405	0.000
OP_ED_C	0.073	0.016	4.621	0.000
LQH_96	0.544	0.212	2.568	0.010
LQL_96	-1.072	0.327	-3.283	0.001
EQIP	1.130	0.409	2.762	0.006
AGDIST	-1.163	0.266	-4.375	0.000
EBI	0.047	0.021	2.184	0.029
AMTA_A	-0.030	0.005	-6.331	0.000
LDP_A	-0.014	0.003	-5.057	0.000
RISK	-0.057	0.018	-3.195	0.001
CROP456	-1.921	0.265	-7.236	0.000
CROPSIZ1	0.232	0.040	5.732	0.000
REGN1	0.164	0.105	1.562	0.118
REGN567	-0.386	0.144	-2.679	0.007
REGN9	1.247	0.266	4.688	0.000
URBAN	-0.014	0.002	-7.905	0.000
		Estimation for OP Equation		
Constant	-0.928	0.585	-1.586	0.113
OP_AGE	0.139	0.017	8.401	0.000
OP_AGESQ	-1.633	0.147	-11.088	0.000
OP_ED_C	0.060	0.014	4.269	0.000
OP_EXP	-0.018	0.004	-4.983	0.000
OP_EXPSQ	0.000	0.000	4.899	0.000
H_SIZE	-0.087	0.030	-2.925	0.003
CROPSIZ1	-0.597	0.032	-18.682	0.000
RAISE_OP	-0.452	0.097	-4.645	0.000
MANUF	0.020	0.006	3.614	0.000
TRADE	-0.041	0.015	-2.840	0.005
AMTA_A	-0.007	0.002	-3.035	0.002
LDP_A	-0.003	0.001	-1.908	0.056
RISK	-0.017	0.014	-1.185	0.236
NETWORT1	-0.003	0.004	-0.879	0.380
SP_HMAK	0.250	0.073	3.415	0.001
CROP456	-0.878	0.094	-9.356	0.000
REGN3	0.287	0.132	2.170	0.030
REGN567	-0.214	0.076	-2.795	0.005
TENANCY	-0.043	0.023	-1.886	0.059
		Correlation Coefficient		
RHO	0.121	0.053	2.292	0.022
Log-likelihood	-1872	LR test*	7.126	

** The null hypothesis for LR test is: RHO=0, critical value of x^2 (0.95,1) is 3.84*