The Impacts of Off-Farm Income on Farm Efficiency, Scale, and Profitability for Corn Farms

by

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Abstract

This paper estimates returns to scale and technical efficiency of corn farms following an input distance function approach and compares the relative performance of farm operator households with and without off-farm wages and salaries. We use 1995-2003 USDA data. The input distance function results suggest that off-farm outputs and inputs can be modeled in a multi-activity framework, which materially alter performance measures in the Corn Belt. We find that off-farm income boosts scale and technical efficiency of smaller operations. We also find that the number of hours worked off-farm by the spouse contributes to a higher technical efficiency.

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Introduction

Off-farm income by U.S. farmers and their spouses' has risen steadily over the past decades, becoming the most important component of farm household income (Mishra et al., 2002). Off-farm income also appears to smooth out income flows because off-farm wages are generally less variable than onfarm sources of income as described in Mishra and Sandretto (2002). Do off-farm sources of income also increase the overall efficiency of farm operator households and reduce costs as suggested in USDA (2001b).[1] Recently, Gardner (2005) argues that the recent integration of the farm and nonfarm labor markets means that many small farms are surviving and even flourishing to an extent not thought possible 20 or 30 years ago. Other authors such as Boisvert have stressed not only the growing links between farming activities and off-farm labor markets but the links between farm household activities and conservation payments and agricultural pollution. Given modeling and data challenges, the role of off-farm income has been largely neglected in empirical analyses of farm structure and economic performance. The purpose of this study is to explore and characterize on and off-farm labor uses in today's farm operator households and measure their economic performance in a multi-activity sense that includes assessing the economic impact of conservation reserve payments (CRP) and agricultural pollution, particularly manure odors and nitrogen and phosphorous buildups in ground and surface water.

To analyze this issue in more detail we set up a pseudo panel using 1995-2003 survey data and we follow an input distance function approach to estimate returns to scale and technical efficiency—and compare the relative performance of farm operator households with and without off-

1 . For purposes of our analysis farm operator household income includes income from farm activities and wages and salaries that the operator and all other household members received from off-farm sources. For our base farm operator household model we constrain all such off-farm income to zero.

farm income. We interpret off-farm income-generating activities as output along with livestock and crops, thus viewing the farm operator household as a multi-activity enterprise, an approach analogous to Avkiran's examination of the service and lending facets of a banking firm in a deregulated environment as a multi-activity enterprise (Avkiran 1999). We use detailed survey information of the farm operator household from USDA's Agricultural Resource Management Survey (ARMS). This annual survey includes information on operator and spouse hours worked on and off the farm, as well as on operator and spouse off-farm income. This allows inclusion both hours worked on and off the farm by both the operator and the spouse as factors influencing the efficiency of production in the multi-activity enterprise.

Off-farm income and nonfarm business opportunities have become increasingly important in many agricultural areas in recent years. As noted in USDA (2001b), most rural communities where small farms are prevalent are no longer "anchored" by farming. In fact nonfarm income sources have dominated net farm income in the U.S for many years.[2] In many cases, one family member focuses on the farm operation while spouse and children work off the farm. In other situations the farm operation is a side job. The Economic Research Service (ERS) developed a farm typology (Hoppe, Perry, and Banker, 1999) that groups farms based on the gross sales, occupation of operator, farm assets, and total household income (Table 1). Using these groupings, table 2 identifies off-farm income by typology group for the U.S. for 1993 and 1999. The table shows that for all family farms, the mean (per farm) and aggregate off-farm income grew dramatically in the short time between 1993 and 1999, almost twice as fast as the mean U.S. household income. While off-farm income is clearly concentrated in the residential farms, it is also important in smaller and intermediate commercial

2. Income from farming in the U.S., measured by net farm cash income, was $55.7 billion in 1999, as compared to $124 billion in 2002 (USDA 2001b).

farms. Among large and very large family farms off-farm income is less important relative to onfarm income, but, nonetheless, represents a sizeable income stream as shown by the 2000 data in table 2. Nationwide patterns in off-farm employment (the ratio of off-farm income/farm income) are shown in figure 1. These patterns reveal widely differing shares of off-farm income both within states and across regions.

The rapid structural change and increasing heterogeneity of agriculture involves several issues which influence household behavior and well being. We discuss the structural change, environmental, and government program participation issues below.

U.S. agricultural production patterns suggest that observed structural changes in U.S. agriculture, such as the expansion of contracting, are linked to scale and technical efficiencies, so that larger operations are increasingly more productive than small farms. Kumbhakar, Biswas, and Bailey (for dairy farms) and Sharma, Leung, and Zaleski (for hog farms) provide evidence that larger farms tend to be more technically efficient. Paul and Nehring, and Paul, Nehring, Banker, and Somwaru similarly link concentration in corn and livestock farming to scale and scope economies and efficiencies. These trends suggest that the survival of smaller households often depends on exploiting off-farm opportunities.

In some cases, however, increased efficiency may lead to environmental concerns. For example, as the share of output under contract increased from 22 percent to 63 percent between 1992 and 1998, the number of animals per harvested acre increased significantly in the U.S. hog industry, leading to increasing concerns about agricultural pollution. Hence, the manure disposal and odor problems often associated with such operations have, in some regions, stimulated growing interest in either reining in future growth or promoting economically and environmentally healthy growth. Livestock operations, particularly hog and dairy operations, are especially incompatible with urban-oriented neighbors due to negative externalities, including odors, insects, and water contaminants (Adelaja, Miller, and Taslim; Herriges, Secchi, and Babcock).

There is little in the literature on the effect of participation in conservation programs onfarm and farm household productivity. Historically less productive land was enrolled in the CRP (Conservation Reserve Program). In 2004 close to three and one-half million acres were enrolled in the program, of which acres enrolled in the Corn Belt states accounted for about 40 percent (see Figure 2). Recent changes in the CRP allow for more environmentally sensitive, but highly productive land, to be enrolled. This could have important implications on the impact of CRP participation on productivity.

Methodology

We use an input distance function approach to represent farms' technological structure in terms of minimum input use required to produce given output levels, because farmers typically have more short-term control over their input than output decisions. The resulting theoretical framework characterizes input contributions per acre, which is consistent with analysis of yields in traditional agricultural studies but stems theoretically from the homogeneity properties of the distance function.

The majority of econometric studies that have modeled a multiple-output technology have used a dual cost function (e.g., Ferrier and Lovell, 1990). The cost function approach requires that output and input prices be observable and requires the assumption of cost-minimizing behavior. The input distance function, on the other hand, permits a multi-input, multi-output technology without requiring observations on output and input prices as described by Coelli and Perelman (1996, 2000). The input distance vector considers how much the inputs may be proportionally contracted with outputs held fixed. In this sense it implies cost minimization. The appropriate functional form is ideally flexible, easy to calculate, and permits the imposition of homogeneity.

This primal representation allows us to measure production structure indicators such as marginal input/output contributions and scale economies, and has advantages over dual measures representing economic optimizing behavior not only because we do not have data on prices across observations, but also because one might not wish to assume full price responsiveness, due to input fixities and time lags in farmers' observation of output prices.

The Model

Empirical analysis of economic performance requires representing the underlying multi-dimensional (-input and -output) production technology. A general form for such a technology may be characterized by an input set, L(***Y,R***), summarizing the production frontier in terms of the set of all input vectors ***X*** that can produce the output vector ***Y***, given the vector of shift and environmental variables ***R*** (the nonfarm assets, animal units, age, education, CRP indicators, and time dummies). From this production set we can specify an input distance function (denoted by superscript I) that identifies the minimum possible input levels for producing a given output vector:

(1) $D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R}) = \max\{\rho: (\boldsymbol{X}/\rho) \in L(\boldsymbol{Y},\boldsymbol{R})\}$.

$D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})$ is therefore essentially a multi-input input-requirement function, representing the production technology while allowing deviations from the frontier.

We estimate this function using stochastic production frontier (SPF) techniques, assuming technical efficiency is imputed as a radial contraction of inputs to the frontier (constant input composition). The econometric model includes two error terms, a random error term, v_{it}, assumed to be normally distributed, and a one-sided error term, u_{it}, assumed to be distributed as a half normal, to represent the distance from the frontier.

Estimating $D^I(\boldsymbol{X}, \boldsymbol{Y}, \boldsymbol{R})$ requires imposing linear homogeneity in input levels (Färe and Primont), which is accomplished through normalization (Lovell, Richardson, Travers, and Wood); $D^I(\boldsymbol{X}, \boldsymbol{Y}, \boldsymbol{R})/X_1 = D^I(\boldsymbol{X}/X_1, \boldsymbol{Y}, \boldsymbol{R}) = D^I(\boldsymbol{X^*}, \boldsymbol{Y}, \boldsymbol{R})$.[3] Approximating this function by a translog functional form to limit *a priori* restrictions on the relationships among its arguments results in:

$$\text{(2a)}\quad \ln D^I_{it}/X_{1,it} = \alpha_0 + \Sigma_m \alpha_m \ln X^*_{mit} + .5\, \Sigma_m \Sigma_n \alpha_{mn} \ln X^*_{mit} \ln X^*_{nit} + \Sigma_k \beta_k \ln Y_{kit}$$

$$+ .5\, \Sigma_k \Sigma_l \beta_{kl} \ln Y_{kit} \ln Y_{lit} + \Sigma_q \phi_q R_{qit} + .5\, \Sigma_q \Sigma_r \phi_{qr} R_{qit} R_{rit} + \Sigma_k \Sigma_m \gamma_{km} \ln Y_{kit} \ln X^*_{mit}$$

$$+ \Sigma_q \Sigma_m \gamma_{qm} \ln R_{qit} \ln X^*_{mit} + \Sigma_k \Sigma_q \gamma_{kq} \ln Y_{kit} \ln R_{qit} + v_{it} = TL(\boldsymbol{X^*}, \boldsymbol{Y}, \boldsymbol{R}) + v_{it}\ , \text{ or}$$

$$\text{(2b)}\quad -\ln X_{1,it} = TL(\boldsymbol{X^*}, \boldsymbol{Y}, \boldsymbol{R}) + v_{it} - \ln D^I_{it} = TL(\boldsymbol{X^*}, \boldsymbol{Y}, \boldsymbol{R}) + v_{it} - u_{it}\ ,$$

where i denotes farm, t the time period, k,l, the outputs, m,n, the inputs, and q, r the ***R*** variables. We specify X_1 as land, so the function is specified on a per-acre basis, consistent with much of the literature onfarm production in terms of yields.

In addition, the distance from the frontier, $-\ln D^I_{it}$ is explicitly characterized as the technical inefficiency error $-u_{it}$. As in Battese and Coelli,[4] we use maximum likelihood (ML) methods to estimate (2b) as an error components model, assuming $-u_{it}$ is a nonnegative random variable independently distributed as a truncation at zero of the $N(m_{it},\sigma_u^2)$ distribution, where $m_{it}=\boldsymbol{R}_{it}\delta$, $\boldsymbol{R}_{it}$ is a vector of farm efficiency determinants (assumed here to be the factors in the ***R*** vector), and δ is a vector of estimable parameters. The random error component v_{it} is assumed to be independently and identically distributed, $N(0,\sigma_v^2)$. We estimate both a household model and a farm model (which omits the off-farm income output and the farm efficiency determinants ***R***).

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3. By definition, linear homogeneity implies that $D^I(\omega\boldsymbol{X}, \boldsymbol{Y}, \boldsymbol{R}) = \omega D^I(\boldsymbol{X}, \boldsymbol{Y}, \boldsymbol{R})$ for any $\omega>0$; so if ω is set arbitrarily at $1/X_1$, $D^I(\boldsymbol{X}, \boldsymbol{Y}, \boldsymbol{R})/X_1 = D^I(\boldsymbol{X}/X_1, \boldsymbol{Y}, \boldsymbol{R})$.

4.We used Tim Coelli's FRONTIER package for the SPF estimation, and computed the measures and t-statistics for measures using PC-TSP.

The productivity impacts (marginal productive contributions, MPC) of outputs or inputs can be estimated from this model by the first order elasticities $MPC_m = -\varepsilon_{DI,Ym} = -\partial \ln D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})/\partial \ln Y_m = \varepsilon_{X1,Ym}$ and $MPC_k = -\varepsilon_{DI,X^*m} = -\partial \ln D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})/\partial \ln X^*_k = \varepsilon_{X1,X^*k}$. MPC_m indicates the increase in overall input use when output expands (and so should be positive, like a marginal cost or output elasticity measure), and MPC_k indicates the shadow value (Färe and Primont) of the k^{th} input relative to X_1 (and so should be negative, like the slope of an isoquant). Similarly, the marginal productive contributions of structural factors (NASSET, ANUNIT, AGE, ED, CRP, and the time shifters) can be measured through the elasticities $MPC_{Rq} = -\varepsilon_{DI,Rq} = -\partial \ln D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})/\partial R_q = \varepsilon_{X1,Rq}$ (if $\varepsilon_{X1,Rq} < 0$, increased R_q implies that less input is required to produce a given output, which implies enhanced productivity, and vice versa).[5]

Scale economies (SE) are calculated as the combined contribution of the M outputs Y_m, or the scale elasticity $SE = -\varepsilon_{DI,Y} = -\Sigma_m \partial \ln D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})/\partial \ln Y_m = \varepsilon_{X1,Y}$. That is, the sum of the input elasticities, $\Sigma_m \partial \ln X_1/\partial \ln Y_m$, indicates the overall input-output relationship and thus returns to scale. The extent of scale economies is thus implied by the short-fall of SE from 1; if $SE<1$ inputs do not increase proportionately with output levels, implying increasing returns to scale.

The second order effects of the $\boldsymbol{R}$ factors on output and input contributions and overall scale economies can in turn be measured as $\varepsilon_{MPCm,Rq} = -\partial \ln \varepsilon_{DIYm}/\partial R_q = -\partial^2 \ln D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})/\partial \ln Y_m \partial R_q$, $\varepsilon_{MPCk,Rq} = -\partial \ln \varepsilon_{DIX^*k}/\partial R_q = -\partial^2 \ln D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})/\partial \ln X^*_k \partial R_q$, and $\varepsilon_{SE,Rq} = \partial \ln SE/\partial R_q$. These measures therefore indicate whether, for example, more contracting increases or reduces the input use associated with production of Y_m.

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5 Note that a standard "productivity" or "technical change" measure, usually defined as the elasticity with respect to time, or the time trend of the input-output relationship, is not targeted here. Elasticities with respect to the time dummies provide indications of production frontier shifts for each time period, but for short time series other external factors such as weather often confound estimation of a real technical change trend.

Finally, technical efficiency (TE) "scores" are estimated as TE = exp($-u_{it}$.). The impact of changes in R_q on technical efficiency can also be measured by the corresponding δ coefficient in the inefficiency specification for $-u_{it}$.

The Data

While we have farm-level annual data from USDA, different farms are sampled each year. Analysis of the economic performance of farm households and their determinants cannot, however, be conducted on these data directly. In the absence of genuine panel data we construct a pseudo-panel data set using repeated cross-sections across farm typologies and other characteristics. The pseudo panel is created by grouping the individual observations into a number of homogeneous cohorts, demarcated on the basis of their common observable time-invariant characteristics, such as geographic location, farm typology (retirement and residential, family, and corporate farms), and size (sales) (table 3). The resulting pseudo panel data includes the weighted mean values of the variables to be analyzed, by cohort, state, and year. The subsequent economic analysis uses the cohort means rather than the individual farm-level observations.

Thus, we have a balanced panel of 780 annual observations (130 per time period, for our 10-state sample). For presentation of our results, we group these cohorts into residential farms (RES), small family farms (SM), larger family farms (LG), and very large family and non-family farms (VLG). To assure a large number of observations per cohort for regional analysis we aggregated the annual data to two-year cells for selected years (1995/96, 1999/2000 and 2001/2002 while using annual data for 1997, 1998, and 2003), thus summarizing the activities of 3,097 farms in 1995/96, 2,599 farms in 1997, 4,731 farms in 1998, 6,784 farms in 1999/00, 6,307 farms in 2000/2001, and 5,201 farms in 2003. The summary statistics for 1995/96 presented in Table 4, document the sharp variation across farm size in the value/level of off-farm assets, animal units, age, education, off-farm income, and operator and spouse off-farm hours worked**.**

The farm level data used to construct the pseudo panel data set for the 1995-2003 period were obtained from the Agricultural Resources Management Study (ARMS) surveys. The ARMS is an annual survey designed by the National Agricultural Statistics Service (NASS) and the Economic Research Service (ERS) both from USDA. Our data cover ten primary corn-producing states in the Heartland and selected livestock states and agricultural statistics districts: Illinois, Indiana, Iowa, Kansas, Missouri, Ohio, Nebraska, Michigan, Minnesota and Wisconsin.

These data include information on the value of nonfarm assets (NASSET), on animal units per cultivated acre, (ANUNIT), age of operator (AGE), education of operator (ED), and, the CRP payments (CRP). Additional outputs and inputs distinguished for our analysis include five specific outputs: Y_{CRN}=corn, Y_S=soybean, Y_{COT}=cotton, Y_C=other crops, Y_A=livestock and Y_{OFF}=off-farm earned income,; and ten inputs, X_{LD}=land, X_L=labor, X_K=capital, X_E=energy (fuel), X_F=fertilizer, X_P=pesticides, X_{FD}=feed, X_{SD}=seed, X_C=other crop-specific materials, X_A=other animal specific materials, and X_O=all other operating expenses. Time dummies, t_{1997}-t_{200}, are also included as fixed effects. In the household model labor is augmented in the off-farm model by adding a wage bill for operator and spouse hours worked off-farm, valued at the hired wage rate to approximate the use of farm and off-farm labor in a multi-activity enterprise.

Agricultural outputs are computed as the sum of the value of sales for each type of farm product, in dollars per farm. The variable inputs are annual per-farm expenditures on each input category. Capital machinery and land are measured as the annualized flows of capital services from assets and land. All these variables are deflated by the estimated increase or decrease in agricultural production prices in 1997-2003 compared to 1995/96.[6]

We estimate our model by stochastic production frontier (SPF) methods, using data from several annual U.S. Department of Agriculture (USDA) surveys of farms, where fattened cattle, hogs, and dairy are major components of agricultural output. The farm-level data are used to construct a pseudo-panel data set in terms of cohorts, to deal with the problem of linking annual cross-section data over time. We distinguish crop (corn, soy, cotton, "other"), livestock, and off-farm outputs, and land, labor, capital, fuel, chemicals (fertilizer, pesticides), materials (feed, seed and "other"), and specific crop and animal inputs. The SPF methods used allow us to estimate both technical efficiency as a one-sided error term, and its determinants through the stochastic specification.

The Empirical Results

The parameter estimates for the household model are reported in Appendix table1. Although most of the parameter estimates are not directly interpretable due to the flexible functional form (the elasticity measures are combinations of various parameters and data), some estimates are directly interpretable. In particular, the statistically significant productive impact of CRP ($\gamma_{YOFF,CRP}$ = -0.0005) means that the increased conservation payments increase the productive contribution of (decrease the inputs required for) off-farm output (income). This is consistent with the second order productivity elasticity representing the effects of *CRP* on Y_{OFF} in Table 7. The exact nature of the productive impact of CRP interacting with off-farm income given our data set is most directly interpretable as it potentially relates to less own labor use when households are enrolled in the CRP program. In the household model own labor includes onfarm labor use estimated from the survey and an estimate of

6. These deflators are computed using the indexes of prices received and paid (1995-96=100), Ag Statistics.

off-farm labor use based on the proportion of off-farm hours worked relative to total hours as described in the data section. Table 7 also shows that the second order productivity elasticity for animal units indicates a productive impact as animal units increase (indicating that higher concentrations of livestock decrease the inputs required overall consistent with results in Paul et al AJAE) and a decline in productivity as age increases (indicating that an increase in age increases the inputs required overall). We also find that hours worked by the spouse off-farm generate a "productive" technical efficiency contribution through its δ coefficient as shown in Appendix table 1. And we find that increases in animal units and acres are consistent with higher technical efficiency.

The parameter estimates for the farm model are reported in Appendix table 2. As in the household model we find that hours worked by the spouse off-farm provide "productive" technical efficiency contribution as does an increase in animal units. In contrast we find that an increase in total government payments is consistent with a decrease in technical efficiency.

Table 5 reports the levels of our overall performance indicators (scale economy, SE, and technical efficiency, TE), and the productive contributions (MPCs) of contracts and waste, for the whole sample, and for different size farms. The elasticity measures are evaluated at the data averages for the particular sample under consideration, to allow estimation of standard errors through the delta method The TE measures are averages of the estimated efficiency scores across all the observations in the sample.

As shown in table 6 the measures show strong scale economies, which are greatest for smaller farms, indicating scale inefficiency for these farms (lower unit costs associated with growth, due to increasing returns to scale). Technical efficiency also increases with farm size, with RES farms on average only reaching about 80 percent of full "best practice" efficiency, whereas VLG farms exhibit more than 90 percent efficiency. Comparing household and farm model results for SE we see that off-farm income relatively boosts scale efficiency for residential and small farms compared to large and very large farms. We see no major difference in TE across size classes in either model.

Table 8 presents the average MPCs across all observations for each output and input, as well as the time shifts (from the 1995-96 base), to further evaluate the estimated production patterns. The MPCs for the outputs represent the proportional "marginal cost" or input-use share of the output. By far the largest input share is devoted to animal or livestock outputs (Y_A) – about 25 percent on average (and increasing from 19 to 37 percent as one moves from smaller to larger farm sizes).

The MPCs for the inputs indicate the contribution of that input to overall input use (substitutability). The largest (in absolute value) MPC is for own labor, followed by hired labor, feed, pesticides, and seed. The positive estimated shadow value for the crop-specific input may be due to the heavier reliance on livestock production of the farms in our sample. This estimate is, however, small, with a large standard error; the difference of MPC_{CROP} from zero is insignificant.

Summary and Concluding Remarks

Off-farm work by farm operators and their spouses' has risen steadily over the past decades, made possible by alternative employment opportunities and facilitated by labor-saving technological progress, such as mechanization, and has become the most important component of farm household income. As reported by USDA, total net income earned by farm households from farming grew from about $15 billion in 1969 to nearly $50 billion in 1999. However, off-farm earned income, which began at a roughly comparable figure in 1969 ($15 billion), soared to about $120 billion in 1999. In addition, as womens' wages have risen, married women have become more likely to work in the paid labor market and household tasks are now shared between spouses. Moreover, as U.S.

farms continue to grow markedly in size, issues related to the interaction of off-farm income, farm size, and economic performance in general are among the leading concerns affecting U.S. agriculture. Because of growing interest in the efficacy of off-farm employment, agricultural economists have been looked to for objective information on, among other things, estimation of factors influencing off-farm employment, the interaction of government program participation and off-farm work, and measures of economic performance including off-farm work.

Despite its considerable importance, and perhaps due to modeling and data challenges, issues related to the impact of off-farm income have been largely neglected (with a few notable exceptions) in studies of farm structure and economic performance in U.S. agriculture. To comprehensively gauge the economic health of farm operator households we interpret off-farm income as an output along with corn, soybeans, other crops, and livestock. We follow an input distance function approach to estimate returns to scale and technical efficiency--and compare the relative performance of farm operator households with and without off-farm wages and salaries. We use 1995-2003 ARMS data. The input distance function results suggest that, for this time period, off-farm outputs and inputs can be modeled in a multi-activity framework and materially alter performance measures in the Corn Belt.

We find that off-farm income boosts the scale and technical efficiency of smaller operations. We also find that the number of hours worked off-farm by the operator's spouse contribute to a higher technical efficiency, both in off-farm and farm models. These results suggest a competitive advantage of smaller operations with off-farm sources of income over those smaller operations focusing only on farming activities, but that the primary impact arises from scale effects.

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Figure 1: The Importance of Off-farm Income by ASD*: 2001
(Off-farm Income/Total Income)

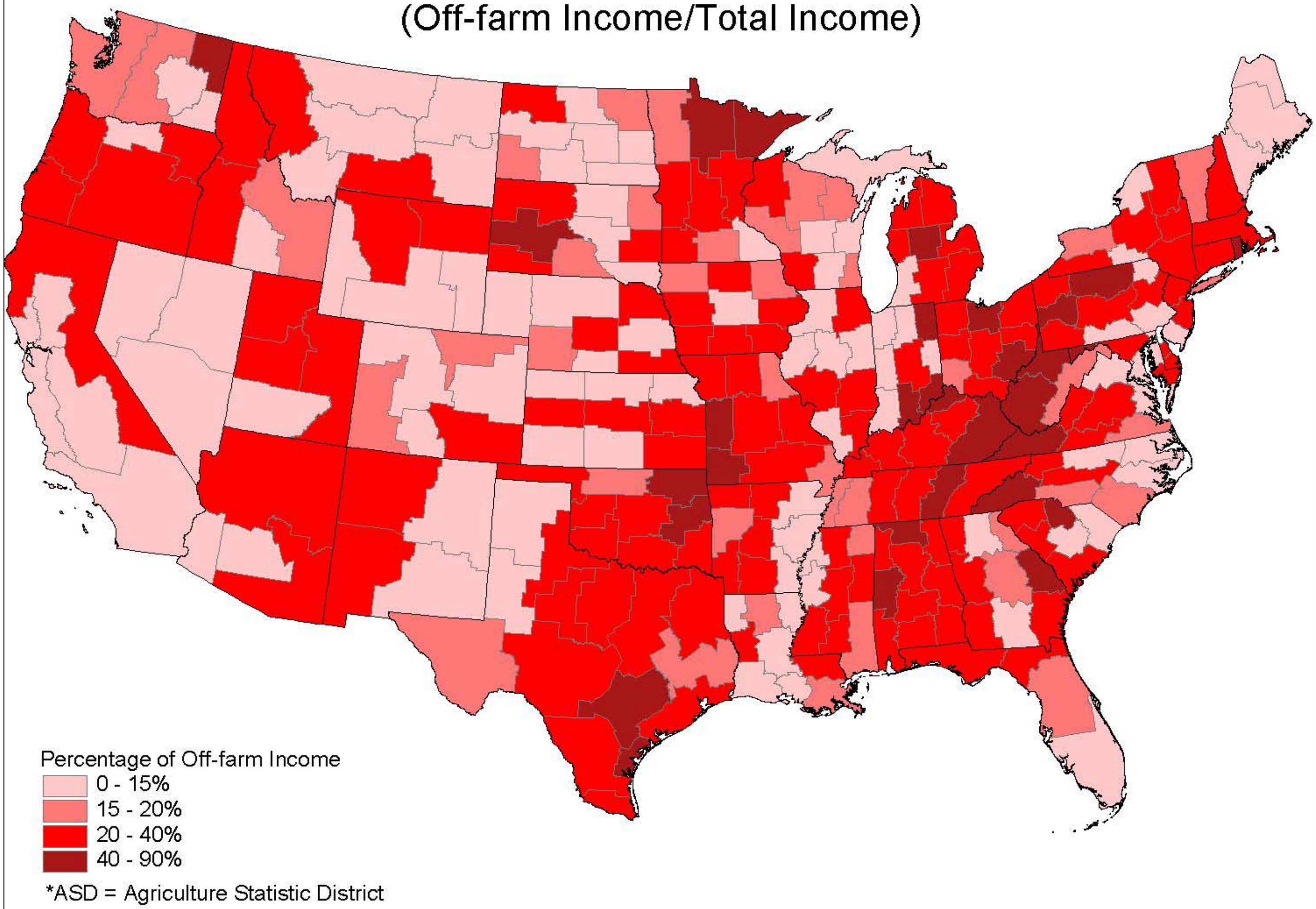

Figure 2 Current Conservation Reserve ProgramAcreage

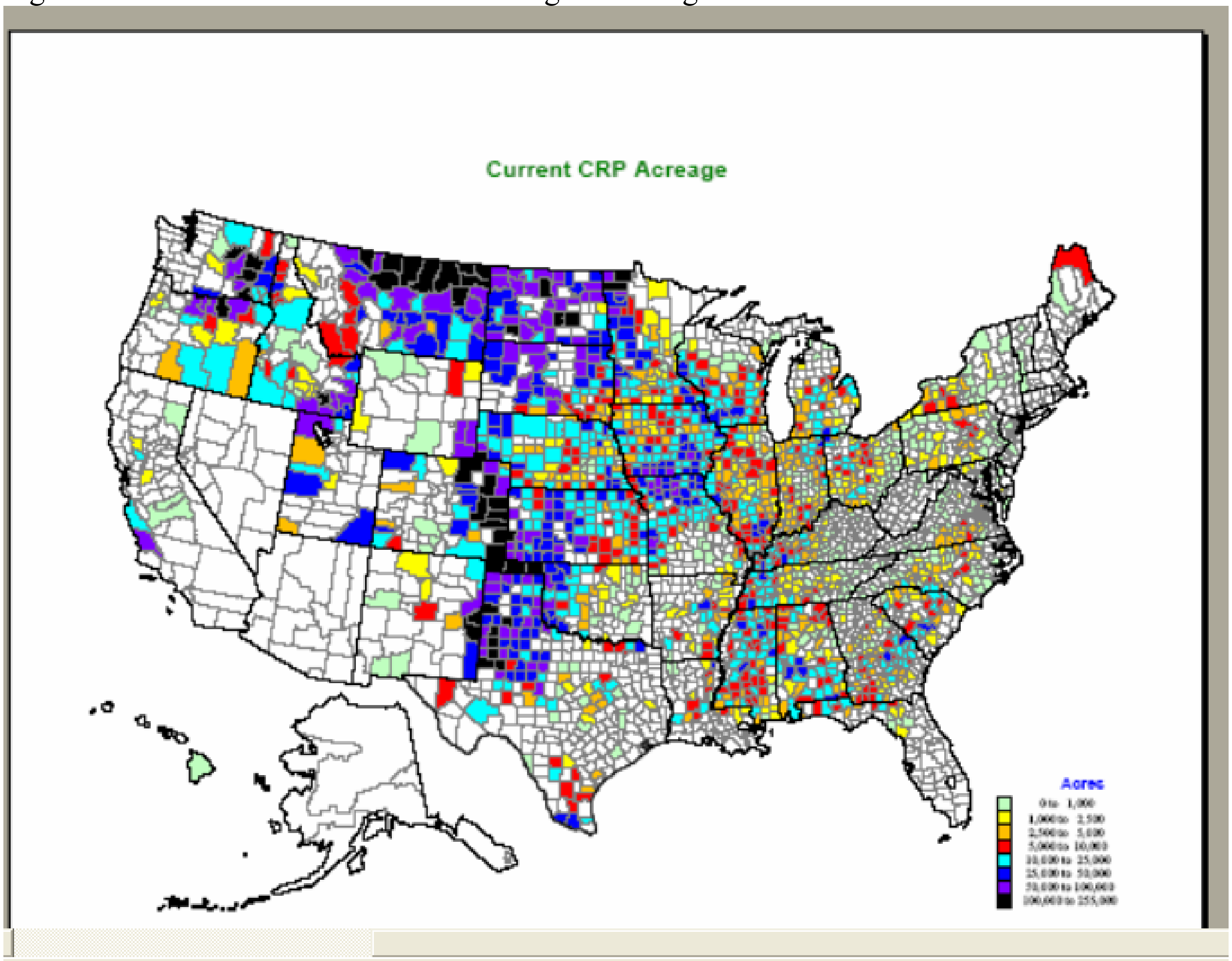

Table 1. Farm Typology Groupings

Small Family Farms (sales less than $250,000)

1. Limited-resource. Any small farm with: gross sales less than $100,000, total farm assets less $150,000, and total operator household income less than $20,000. Limited-resource farmers may report farming, a nonfarm occupation, or retirement as their major occupation

2. Retirement. Small farms whose operators report they are retired (excludes limited-resource farms operated by retired farmers).

3. Residential/lifestyle. Small farms whose operators report a major occupation other than farming (excludes limited-resource farms with operators reporting a nonfarm major occupation).

4. Farming occupation/lower-sales. Small farms with sales less than $100,000 whose operators report farming as their major occupation (excludes limited-resource farms whose operators report farming as their major occupation).

5. Farming occupation/higher-sales. Small farms with sales between $100,000 and $249,999 whose operators report farming as their major occupation.

Other Farms

6. Large family farms. Sales between $250,000 and $499,999.

7. Very large family farms. Sales of $500,000 or more

8. Nonfamily farms. Farms organized as nonfamily corporations or cooperatives, as well as farms operated by hired managers

Source: U.S. Department of Agriculture, Economic Research Service

Table 2. Off-Farm Income, By Year, and Farm Typology

Typology Class	Aggregate Off-farm Income (billion dollars)		Share of Aggregate Off-Farm Income (percent)		Mean Off-Farm Income (billion dollars)		Share of Income from Off-Farm Sources
	1993	1999	1993	1999	1993	1999	2000
Limited Resource	3.657	1.664	4.9	1.3	12,398	13,114	127.1
Retirement	8.078	12.495	11.2	10.0	34,273	41,991	103.8
Residential	40.792	81.787	56.6	65.7	59,216	87,796	107.6
Farming/low sales	12.950	19.166	13.9	15.4	25,489	39,892	105.8
Farming/high sales	3.597	4.669	5.0	3.7	17,286	26,621	69.3
Large family farms	1.738	2.675	2.4	2.1	25,487	34,598	47.2
Very Lrg family farms	1.358	2.078	1.9	1.7	32,840	35,572	21.7
All op. households	72.080	124.534	100.0	100.0	35,408	57,988	95.5

Source: ERS estimates and USDA (2001a).

Table 3: Final Cohort Definitions

Small farms			***Large farms***		
Cohort	***Typology***	***GV Sales***	***Cohort***	***Typology***	***GV Sales***
COH1	1-3	<2,499	COH9	- 6	250,000-330,000
COH2	1-3	2,500-29,999	COH10	6	330,000-410,000
COH3	1-3	>30,000	COH11	6	>410,000
COH4	4	<10,000	COH12	7	<1,000,000
COH5	4	10,000-29,999	COH13	7	>1,000,000
COH6	4	>30,000			
COH7	5	100,000-174,999			
COH8	5	175,000-249,999			

Table 4. Summary Statistics for Corn Farms by Typology, 1995/96

		All Farms	Residential	Small	Large	Very Large
Farms in sample (no.)		4,031	908	872	1,182	1,339
% of weighted farms		100	51.13	25.98	15.76	7.13
% of weighted acres		100	19.75	24.78	30.29	25.18
% of weighted output		100	9.69	12.27	33.69	44.35
Revenues				(Dollars/farm)		
Corn		20,017	3.353	9,542	48,679	114,505
Soybean		15,429	4,083	7,996	35,483	79,650
other crop		13,292	2,098	7,377	25,418	88,460
Animal		43,490	6,487	16,738	85,144	313,207
Off-farm		26,604	35,486	17,014	19,565	13,470
Expenditures				(Dollars/farm)		
Own Labor		18,081	8,624	20,546	33,870	41,992
Hire Labor		4,826	479	1,113	7,253	43,505
Fuel		3,500	819	2,479	7,571	17,451
Fertilizer		6,183	1,056	3,554	15,733	31,495
Seed		3,792	761	2,086	8,368	21,650
Feed		10,109	2,132	3,354	19,840	70,157
Animal inputs		7,875	1,478	2,549	8,215	72,346
Crop inputs		1,844	660	1,280	3,497	8,738
Pesticides		4,635	1,021	2,407	10,201	26,366
Machinery		28,053	8,689	18,036	60,065	132,343
Land		39,740	13,688	27,641	94,077	150,962
Other variables						
Operator off-farm work	Hours	785	1059	542	527	271
Spouse off-farm	Hours	489	491	439	592	425
Age	Level	56.88	54.27	59.74	60.12	57.98
Education	Level	2.53	2.37	2.29	3.17	3.29
Manure nitrogen	Lbs/Acre	16.61	1.54	3.05	4.91	46.55
Animal Units	Unit/Acre	0.44	0.05	0.11	0.17	1.17
Off-farm wage	$/hr	25.64	34.23	16.50	16.53	17.50
Crop payments	Dollars	653	793	748	180	346
Off-farm assets	Dollars	68,315	71,706	61,611	64,689	76,616
Size	Acres	362.94	140.27	346.38	694.27	1281.42

Table 5. Scale Efficiency (SE), Total Efficiency (TE), and Marginal Productive Contributions (MPC) - Summary for all Household Model Corn Farms, 1995/96 to 2003

	ALL	t-value
SE	**0.663**	62.05
TE	**0.868**	
$MPC_{NONFARM\ ASSETS}$	**-0.0022**	-0.51
$MPC_{ANIMAL\ UNITS}$	**-0.1691**	-1.81
MPC_{AGE}	**0.0012**	1.66
$MPC_{EDUCATION}$	**0.0135**	1.30
MPC_{CRP}	**-0.0022**	-5.07

Table 6. Scale Efficiency (SE), Total Efficiency (TE) By Typology , Corn Farms 1995/96 to 2003

	Residential Farms		Small Farms		Large Farms		Very Large Farms	
Household	Efficiency	t-value	Efficiency	t-value	Efficiency	t-value	Efficiency	t-value
SE	**0.539**	38.47	**0.565**	39.36	**0.736**	68.05	**0.810**	60.69
TE	**0.786**		**0.837**		**0.914**		**0.920**	
Farm								
SE	***0.477***	*39.18*	***0.502***	*40.47*	***0.651***	*58.79*	***0.717***	*54.18*
TE	***0.773***		***0.849***		***0.913***		***0.906***	

Table 7. Second Order Impacts, Household Model Corn Farms 1995/96 to 2003

	Elasticity	t-value
$\varepsilon_{SE,\ NONFARM\ ASSETS}$	-0.00004	-0.03
$\varepsilon_{SE,\ ANIMAL\ UNITS}$	-0.0174	-1.81
$\varepsilon_{SE,\ AGE}$	0.0001	1.67
$\varepsilon_{SE,\ EDUCATION}$	0.0013	1.29
$\varepsilon_{SE,\ CRP}$	0.0048	-5.07

Table 8. Marginal Productive Contributions (MPC) for Outputs, Inputs, and Time Shifts, Full Sample for Corn Farms for the Household Model, 1995/96 to 2003

Output	MCP	t-value	Input	MCP	t-value	Year	MCP	t-value
Corn	**0.131**	19.11	Fertilizer	**-0.117**	-7.61	1993	**-0.029**	-0.71
Soybeans	**0.147**	20.71	Own labor	**-0.192**	-12.11	1995	**-0.390**	-0.68
Other crops	**0.098**	24.27	Energy	**-0.013**	-1.16	1997	**0.193**	3.05
Livestock	**0.264**	37.07	Seeds	**-0.101**	-7.39	1999	**0.076**	1.27
Off-farm earned income	**0.022**	2.65	Feed	**-0.121**	-16.16	2001	**0.071**	1.10
			Animal specific materials	**-0.036**	-9.40			
			Crop-specific materials	**0.003**	0.61			
			Hired labor	**-0.153**	-14.66			
			Capital	**-0.024**	-1.43			
			Pesticides	**-0.139**	-8.25			

Appendix Table 1. Input Distance Function Parameter Estimates: Household Model

Variable	Parameter (t-value)	Variable	Parameter (t-value)	Variable	Parameter (t-value)
α_0	5.953 (6.43)	$\gamma_{YOFF,AGE}$	0.001 (0.95)	$\alpha_{XS,XCROP}$	0.001 (4.11)
α_{XF}	0.156 (1.75)	$\gamma_{YOFF,ED}$	0.001 (0.71)	$\alpha_{XS,XOTH}$	-0.037 (-2.79)
α_{XL}	-0.243 (-2.59)	$\gamma_{YOFF,CRP}$	-0.0005 (-3.16)	$\alpha_{XS,K}$	0.051 (1.34)
α_{XE}	-0.012 (-0.24)	$\gamma_{YOFF,AN\ UNITS}$	-0.0003 (-1.11)	$\alpha_{XFEED,XLIVE}$	-0.019 (-6.92)
α_{XS}	-0.076 (-2.42)	$\gamma_{YOFF,ASSETS}$	-0.0002 (-0.32)	$\alpha_{XFEED,XP}$	-0.035 (-1.83)
α_{XFEED}	-0.068 (-1.60)	$\alpha_{XF,XF}$	0.005 (0.22)	$\alpha_{XFEED,XCROP}$	-0.001 (-0.39)
α_{XLIVE}	-0.126 (-4.34)	$\alpha_{XF,XL}$	-0.155 (-3.37)	$\alpha_{XFEED,XOTH}$	0.030 (4.14)
α_{XPEST}	-0.292 (-3.25)	$\alpha_{XF,XE}$	0.053 (1.47)	$\alpha_{XFEED,XK}$	-0.043 (-1.97)
α_{XCROP}	0.079 (3.10)	$\alpha_{XF,XS}$	0.009 (0.43)	$\alpha_{XLIVE,XCROP}$	-0.001 (-0.26)
α_{XOTH}	-0.122 (-2.79)	$\alpha_{XF,XFEED}$	0.032 (1.60)	$\alpha_{XLIVE,XP}$	-0.013 (-0.93)
α_{XK}	-0.0.28 (-0.33)	$\alpha_{XF,XLIVE}$	0.018 (1.36)	$\alpha_{XLIVE,XOTH}$	0.002 (0.44)
β_{YCRN}	0.120 (2.67)	$\alpha_{XF,XP}$	0.047 (1.57)	$\alpha_{XOTH,XP}$	-0.083 (-3.50)
β_{YSOY}	-0.028 (-0.56)	$\alpha_{XF,XCROP}$	-0.038 (-2.69)	$\alpha_{XLIVE,XK}$	0.034 (2.09)
$\beta_{YOTHCRP}$	-0.071 (-1.40)	$\alpha_{XF,XOTH}$	0.139 (6.02)	$\alpha_{XCROP,XOTH}$	0.003 (0.44)
$\beta_{YANIMALS}$	0.018 (0.20)	$\alpha_{XF,XK}$	-0.047 (-1.03)	$\alpha_{XCROP,XP}$	0.022 (1.65)
$\beta_{YOff\text{-}Farm}$	0.027 (0.30)	$\alpha_{XL,XE}$	-0.043 (-1.47)	$\alpha_{XCROP,XK}$	-0.006 (-0.42)
$\beta_{YCRN,YCRN}$	0.011 (9.87)	$\alpha_{XL,XS}$	0.071 (2.02)	$\alpha_{XOTH,XK}$	-0.027 (-1.51)
$\beta_{YSOY,YSOYY}$	0.010 (7.22)	$\alpha_{XL,XFEED}$	0.013 (0.83)	$\alpha_{XP,XK}$	0.018 (0.51)
$\beta_{YOTH,YOTH}$	0.010 (9.79)	$\alpha_{XL,XLIVE}$	0.011 (0.92)	ϕ_{1996}	-0.172 (-3.35)
$\beta_{YA,YA}$	0.023 (10.83)	$\alpha_{XL,XP}$	0.049 (1.21)	ϕ_{1997}	0.057 (1.85)
$\beta_{YOFF,YOFF}$	0.001 (0.67)	$\alpha_{XL,XCROP}$	-0.001 (-0.01)	ϕ_{1998}	-0.109 (-3.36)
$\beta_{YCRN,YSOY}$	0.003 (1.92)	$\alpha_{XL,XOTH}$	-0.031 (-2.36)	ϕ_{2000}	0.028 (0.85)
$\beta_{YCRN,YOT}$	-0.005 (-3.01)	$\alpha_{XL,XK}$	0.031 (0.86)	ϕ_{2003}	-0.021 (-0.59)
$\beta_{YCRN,YA}$	-0.010 (-3.94)	$\alpha_{XE,XS}$	-0.025 (-0.81)	δ_0	1.050 (4.94)
$\beta_{YCRN,YOFF}$	-0.008 (-2.32)	$\alpha_{XE,XFEED}$	0.041 (3.13)	δ_{GOVT}	0.017 (0.90)
$\beta_{YSOY,YOT}$	-0.008 (-3.62)	$\alpha_{XE,XLIVE}$	-0.017 (-2.67)	$\delta_{OFF\text{-}FARM\ ASSETS}$	0.027 (0.55)
$\beta_{YSOY,YA}$	-0.001 (-0.38)	$\alpha_{XE,XP}$	-0.018 (-0.42)	$\delta_{TOT\ ANIMAL\ UNITS}$	-0.037 (-3.27)
$\beta_{YSOY,YOFF}$	0.006 (1.39)	$\alpha_{XE,XCROP}$	0.002 (0.42)	δ_{ACRES}	-0.216 (-6.02)
$\beta_{YOT,YA}$	-0.002 (-0.80)	$\alpha_{XE,XOTH}$	0.015 (0.92)	$\delta_{OP\ HOURS\ OFF\text{-}FARM}$	-0.002 (-0.20)
$\beta_{YOT,YOFF}$	0.012 (2.66)	$\alpha_{XE,XK}$	-0.028 (-0.92)	$\delta_{GSP\ HOURS\ OFF\text{-}FARM}$	-0.034 (-2.59)
$\beta_{YA,YOFF}$	-0.012 (-1.65)	$\alpha_{XS,XFEED}$	0.007 (0.38)	δ^2	0.050 (12.41)
		$\alpha_{XS,XLIVE}$	-0.013 (-1.48)	γ	0.747 (13.22)
		$\alpha_{XS,XP}$	-0.067 (-4.01)		

Log-likelihood 325.989

Appendix Table 2. Input Distance Function Parameter Estimates: Farm Model

Variable	Parameter (t-value)	Variable	Parameter (t-value)	Variable	Parameter (t-value)
α_{0}	5.923 (20.58)	$\alpha_{XF,XF}$	0.00001 (0.003)	$\alpha_{XS,XCROP}$	0.035 (3.88)
α_{XF}	-0.020 (-0.22)	$\alpha_{XF,XL}$	0.006 (0.15)	$\alpha_{XS,XOTH}$	0.002 (0.75)
α_{XL}	-0.173 (-2.09)	$\alpha_{XF,XE}$	-0.012 (-1.00)	$\alpha_{XS,K}$	0.019 (0.50)
α_{XE}	-0.041 (-0.83)	$\alpha_{XF,XS}$	0.012 (0.51)	$\alpha_{XFEED,XLIVE}$	-0.016 (-6.62)
α_{XS}	-0.120 (-1.83)	$\alpha_{XF,XFEED}$	-0.021 (-1.32)	$\alpha_{XFEED,XP}$	-0.009 (-0.44)
α_{XFEED}	-0.038 (-0.89)	$\alpha_{XF,XLIVE}$	0.049 (3.69)	$\alpha_{XFEED,XCROP}$	0.001 (0.35)
α_{XLIVE}	-0.156 (-5.38)	$\alpha_{XF,XP}$	0.053 (1.72)	$\alpha_{XFEED,XOTH}$	0.004 (2.26)
α_{XPEST}	-0.142 (-171)	$\alpha_{XF,XCROP}$	-0.024 (-1.73)	$\alpha_{XFEED,XK}$	-0.031 (-1.35)
α_{XCROP}	0.052 (2.28)	$\alpha_{XF,XOTH}$	-0.003 (-0.49)	$\alpha_{XLIVE,XCROP}$	-0.001 (-0.45)
α_{XOTH}	-0.289 (-10.46)	$\alpha_{XF,XK}$	0.007 (0.15)	$\alpha_{XLIVE,XP}$	-0.023 (-1.66)
α_{XK}	0.099 (1.23)	$\alpha_{XL,XE}$	-0.017 (-0.70)	$\alpha_{XLIVE,XOTH}$	0.002 (1.18)
β_{YCRN}	0.069 (3.39)	$\alpha_{XL,XS}$	0.049 (1.43)	$\alpha_{XOTH,XP}$	0.032 (0.62)
β_{YSOY}	0.019 (1.08)	$\alpha_{XL,XFEED}$	0.013 (0.85)	$\alpha_{XLIVE,XK}$	0.040 (2.32)
$\beta_{YOTHCRP}$	-0.017 (-0.91)	$\alpha_{XL,XLIVE}$	0.009 (0.72)	$\alpha_{XCROP,XOTH}$	0.0004 (0.25)
$\beta_{YANIMALS}$	0.053 (1.64)	$\alpha_{XL,XP}$	-0.058 (-1.66)	$\alpha_{XCROP,XP}$	-0.003 (-0.29)
$\beta_{YCRN,YCRN}$	0.014 (11.16)	$\alpha_{XL,XCROP}$	-0.010 (-0.89)	$\alpha_{XCROP,XK}$	0.006 (0.42)
$\beta_{YSOY,YSOY}$	0.009 (6.92)	$\alpha_{XL,XOTH}$	-0.013 (-3.60)	$\alpha_{XOTH,XK}$	0.006 (1.26)
$\beta_{YOTH,YOTH}$	0.012 (10.17)	$\alpha_{XL,XK}$	-0.004 (-0.12)	$\alpha_{XP,XK}$	0.011 (0.29)
$\beta_{YA,YA}$	0.020 (10.85)	$\alpha_{XE,XS}$	0.112 (3.37)	ϕ_{1996}	-4.065 (-11.03)
$\beta_{YCRN,YSOY}$	0.0004 (0.28)	$\alpha_{XE,XFEED}$	-0.031 (-1.00)	ϕ_{1998}	0.084 (2.78)
$\beta_{YCRN,YOT}$	-0.009 (-5.86)	$\alpha_{XE,XLIVE}$	-0.017 (-2.56)	ϕ_{2000}	-0.090 (-3.02)
$\beta_{YCRN,YA}$	-0.010 (-4.51)	$\alpha_{XE,XP}$	0.054 (1.29)	ϕ_{2002}	0.201 (5.73)
$\beta_{YSOY,YOT}$	0.0002 (1.09)	$\alpha_{XE,XCROP}$	0.001 (0.12)	ϕ_{2003}	0.151 (3.76)
$\beta_{YSOY,YA}$	-0.007 (-3.21)	$\alpha_{XE,XOTH}$	0.008 (1.68)	δ_{0}	1.333 (4.73)
$\beta_{YOT,YA}$	-0.006 (-2.14)	$\alpha_{XE,XK}$	-0.031 (-0.98)	δ_{GOVT}	0.086 (2.94)
		$\alpha_{XS,XFEED}$	0.048 (2.59)	$\delta_{OFF\text{-}FARM\ ASSETS}$	0.019 (1.55)
		$\alpha_{XS,XLIVE}$	-0.033 (-3.67)	$\delta_{TOT\ ANIMAL\ UNITS}$	-0.101 (-4.74)
		$\alpha_{XS,XP}$	-0.060 (-3.09)	δ_{ACRES}	-0.050 (-5.00)
				$\delta_{OP\ HOURS\ OFF\text{-}FARM}$	0.017 (1.28)
				$\delta_{SP\ HOURS\ OFF\text{-}FARM}$	-0.056 (-3.04)
				δ^{2}	0.135 (4.55)
				γ	0.902 (26.34)
				Log-likelihood	276.117