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Impact of Earned and Unearned Off-Farm Income on Adoption of New Technologies

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Abstract

Sustainable agriculture requires farmers' adoption of new technologies and practices that sustain the environmental quality, while providing the agricultural output. Off-farm income has been analyzed in technology adoption studies, due to its increasing share in agricultural household income. The objective of current study is to analyze the impact of earned and unearned off-farm income of both the farm operator and spouse on adoption of new technologies. The results of the current study shows that earned off-farm income positively impact adoption of capital intensive and risk technologies. However, unearned off-farm income negatively impacts adoption of new technologies.

Key Words: Off-Farm Income, Technology Adoption, Sustainable Agriculture

Sustainable agriculture requires farmers' adoption of new technologies and practices that sustain the environmental quality, while providing the agricultural output. Farmers are expected to adopt various technologies and practices, such as energy crops, genetically modified (GM) crops, and conservation practices. Off-farm income has been analyzed in technology adoption studies, due to its increasing share in agricultural household income (Gedikoglu et al., 2011; Gedikoglu and McCann, 2007). As of 2011, almost 90% of the farm household income came from off-farm income (US Department of Agriculture, 2013). For the off-farm income, around 32% came from earned off-farm income of the farm operator, 22% came from earned off-farm income of the spouse, 19% came from unearned off-farm income, and the rest from other off-farm sources (US Department of Agriculture, 2013). Hence, earned off-farm income is an important source for agricultural households.

The Energy Independence and Security Act of 2007 set a renewable fuel standard of 36 billion gallons of biofuel production by 2022, of which 16 billion gallons are to come from cellulosic biofuels. Cellulose fiber is a major component in plant cell walls, which allows ethanol to be produced from plant sources that do not compete with food prices. Switchgrass is one of the major energy crops that have been analyzed as source of cellulosic biomass. The studies show that switchgrass has high yield potential, which varies between 6 ton / ha and 8 ton / ha (Khanna et al., 2008). We classify switchgrass as the capital intensive and risk technology. For labor saving technology, we analyze the adoption of Roundup Ready® corn, which is a GM crop. Roundup Ready® corn allows farmers to apply only one herbicide instead of multiple herbicides. Hence, Roundup Ready® corn helps farmers to use less labor on the farm. For labor intensive practices, following (Gedikoglu et al., 2011; Gedikoglu and McCann, 2007), we analyze adoption of record keeping. Agricultural production is a significant sources of water pollution in the U.S (Aillery et al., 2005). Farmers' adoption of nutrient management practices, such as record keeping can prevent the water pollution and enhance the environmental quality. The objective of current study is to analyze the impact of earned and unearned off-farm income of both the farm operator and spouse on adoption of labor saving, labor intensive, and capital intensive and risky technologies.

Theoretical Framework

To represent the adoption decision, we use and agricultural household model with distinguishing the choice variables between the farm operator and the spouse. Hence, the current model has decision variables both for the farm operator and the spouse. The current model is extension of the agricultural household models by Huffman (1980), Cornejo, *et al*. (2005), and Gedikoglu and McCann (2007). The household problem can be represented as;

$$(1) \quad \max_{\boldsymbol{C},\boldsymbol{L}_e,\boldsymbol{L}_a,\boldsymbol{K}_a} U\left(\boldsymbol{C},\boldsymbol{L}_e,E(\boldsymbol{L}_a,\boldsymbol{K}_a)\right)$$

$$s.t.$$

$$(2) \quad P_c.\boldsymbol{C}+r.\boldsymbol{K}+r.\boldsymbol{K}_a+W.\boldsymbol{L}_{on} \le P_q.Q+W.\boldsymbol{L}_{of}$$

$$(3) \quad L_{on}+L_{of}+L_a+L_e \le 24$$

$$(4) \quad Q \le F(K,L_{on})$$

where, U (.) is the utility function of the household, **C** is the vector consumption, $\boldsymbol{L}_e$ is leisure vector for the operator and spouse, E(.) is the level of environmental quality for both operator and the spouse, which is an increasing function of amount of labor, L_a, and amount of capital, K_a, reserved for adoption of technologies by both the operator and spouse.

The budget constraint is represented in equation (2). P_c is the price for the consumption good, P_q is the price for the farm output, Q is the farm output and W is the wage rate for the off-farm work. r is the market interest rate and K is the capital for production activities. The time constraint is represented in equation (3). The total amount of time available for the household is 24 hours. L_{on} is the amount of time provided for on-farm activities, L_{of} is the time devoted to off-farm work. The technology constraint is reflected in equation (4). Where, $F(.)$ is the neo-classical production, which is an increasing function of amount of capital K, and amount of on-farm labor, L_{on}. To maximize consumption, farmers will always produce at the level available by the technology; hence the technology constraint is always binding $Q = F(.)$.

To find the solution to the household problem, the structured Langrangian becomes;

$$L: \max_{C, L_e, L_a, K_a} U\left(C, L_e, E(L_a, K_a)\right) + \lambda\left(P_q.F(K, L_{on}) + W.L_{of} - P_c.C - r.K - r.K_a - W.L_{on}\right) \\ + \mu\left(24 - L_{on} - L_{of} - L_a - L_e\right)$$

the first order conditions become;

$$(5) \quad \frac{\partial L}{\partial C} : U_1' - P\lambda \le 0 \qquad C^* \ge 0$$

$$(6) \quad \frac{\partial L}{\partial L_e} : U_2' - \mu \le 0 \qquad L_e^* \ge 0$$

$$(7) \quad \frac{\partial L}{\partial L_a} : U_3' \frac{\partial E(.)}{\partial L_a} - \mu \le 0 \qquad L_a^* \ge 0$$

$$(8) \quad \frac{\partial L}{\partial K_a} : U_3' \frac{\partial E(.)}{\partial K_a} - r\lambda \le 0 \qquad K_a^* \ge 0$$

$$(9) \quad \lambda\left(P_q.F(K, L_{on}) + W.L_{of} - P_c.C - r.K - r.K_a - W.L_{on}\right) = 0$$

$$(10) \quad \mu\left(24 - L_{on} - L_{of} - L_a - L_e\right) = 0$$

where equations (5)-(8) are the first order conditions for consumption, leisure, labor and capital for adoption of new technology. Equations (9) and (10) reflect that either the constraints hold with equality, hence the inside of the parentheses equal zero and the Langrangian multipliers λ and μ are non-zero, or the Langrangian multipliers are zero and inside of the parentheses are positive. C^*, L_e^*, L_a^*, K_a^* are the optimal decision variables. U_1', U_2', U_3' represent first order partial derivatives of the utility function with respect to consumption, leisure and environmental quality.

Either the assumption that farmers will always have a positive amount of consumption and leisure, or a strict concavity assumption of the utility function (i.e. logarithmic utility function), will lead equation (5) and (6) to hold with equality. Hence, the values of the Langrangian multipliers λ and μ are; $\lambda = \frac{U_1'}{P_c}$, $\mu = U_2'$.

Empirical Model

For the empirical model, the adoption decision that farmers make for the practices can be represented as an extension of the theoretical model discussed in the analytical framework. After farmers make their optimal choices of the choice variables; C^*, L_e^*, L_a^*, K_a^*, the utility gained by optimal choice variables is compared to the utility gained by choosing the critical values L_a^C and K_a^C. If the utility gained by the optimal choices is bigger or equal than the utility from the critical value, then the farmer adopts the practice. It is also assumed that the maximized utility have a random factor, ε, which is assumed to have a normal distribution. The maximized utility function is also assumed to be impacted by fixed factors such as age, education, perceptions and so on. These factors are showed by Z, which is a vector, in the maximized utility function.

If $\mathrm{U}\left(C^*, L_e^*, E(L_a{}^*, K_a{}^*), Z, \varepsilon\right) \geq \mathrm{U}\left(C^*, L_e^*, E(L_c\ , K_c), Z, \varepsilon\right)$ then the technology is adopted and if $\mathrm{U}\left(C^{*}, L_{e}^{*}, E(L_{a}^{*}, K_{a}^{*}), Z, \varepsilon\right) < \mathrm{U}\left(C^{*}, L_{e}^{*}, E(L_{c}, K_{c}), Z, \varepsilon\right)$ then the technology is not adopted. Hence,

$$y_i = 1 \quad \text{if } \mathrm{U}(\mathrm{L}_{\mathrm{a}}^{*}, K_{\mathrm{a}}^{*};) \geq U(L_c, K_c;)$$

$$y_i = 0 \quad \text{if } \mathrm{U}(\mathrm{L}_{\mathrm{a}}^{*}, K_{\mathrm{a}}^{*};) < U(L_c, K_c;)$$

The multivariate probit model can be represented as;

$y_{1i} = \mathbf{X}_{1i}\boldsymbol{\beta}_{1i} + \varepsilon_{1i}$, $\mathrm{y}_{1\mathrm{i}} = 1$ if Rounup Ready Corn is adopted, 0 otherwise,
$y_{2i} = \mathbf{X}_{2i}\boldsymbol{\beta}_{2i} + \varepsilon_{2i}$, $\mathrm{y}_{2\mathrm{i}} = 1$ if Record Keeping is adopted, 0 otherwise,
$y_{3i} = \mathbf{X}_{3i}\boldsymbol{\beta}_{3i} + \varepsilon_{3i}$, $\mathrm{y}_{3\mathrm{i}} = 1$ if Switchgrass is adopted, 0 otherwise.

where $\boldsymbol{X}_{ki}$ is the vector that includes the values for the variables that form the deterministic part of the utility function for the observation *i*, where *k* ={1,2,3} and $\boldsymbol{\beta}_{ki}$ is the vector that includes the coefficients to be estimated. The distribution of the error terms ε_k is given as:

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \sim N\left[\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_2^2 & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 \end{bmatrix}\right]$$

The error terms ε_k have a multivariate normal distribution with mean zero and variances σ_k^2 equal to one and off-diagonal elements showing the covariances σ_{kj} between two error terms ε_k and ε_j, for which $k \neq j$ (Greene, 2008).

If the covariances become zero, this model becomes four univariate probit models. The probabilities of adopting practices are calculated by evaluating multiple integrals, using the numerical methods (Cameron and Trivedi 2005). For example, the probability of adopting all three of the technologies is;

$$\Pr[y_1 = 1, y_2 = 1, y_3 = 1] = \int_{-\infty}^{X_1\beta_1} \int_{-\infty}^{X_2\beta_2} \int_{-\infty}^{X_3\beta_3} \varphi(\varepsilon_1, \varepsilon_2, \varepsilon_3) d\varepsilon_1 d\varepsilon_2 d\varepsilon_3$$

where $\varphi(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ is the standardized multivariate normal density function.

Results

A mail survey of 2995 farmers that have livestock and land for crop production or pasture in Missouri and Iowa was conducted in spring 2011. Before random sampling, farmers were stratified by farm sales. Farmers with farm sales less than $10,000 were not sampled. This eliminates most of the hobby farmers (Hoppe and Banker, 2006). The survey was designed and conducted following the methodology of Dillman (2000). A pretest was conducted and the survey was modified in response to feedback received. A cover letter and survey were sent, followed by a postcard reminder and a second cover letter and survey. The response rate for the survey was 21 percent.

Summary statistics and the hypothesized impact of each variable are presented in table 1. For the education, the highest category was high school education. Thirty-four percent of the farm operators had year round off-farm employment. Relatively smaller portion of farm operators had seasonal off-farm employment. Forty-three percent of the survey respondents were from Missouri and the rest were from Iowa. Forty percent of the respondents had farm sales (including both crop and livestock sales) between $100,000 and $249,999, which was the largest category. Fifty-eight percent of the farmers had leased land. For the influence on the agricultural production decisions, other farmer had the highest influence.

For the regression results, the hypothesis that all the regression coefficients except the constant term are zero is rejected with a p-value of 0.000, so the multivariate probit regression is significant at 1% significance level. Education of the farm operator is not found to be significant for switchgrass, however farmers with less than high school education and farmers with graduate degree are less likely to adopt Roundup ready corn than farmers with high school education. Hence, there is no linear relationship between education and adoption of roundup ready corn. On the other hand farmers with bachelor degree are more likely to adopt record keeping than farmers with high school degree. Overall, education shows different impact for different technologies.

Off-farm income, unearned off-farm income of the operator negatively impacted adoption of Switchgrass and roundup ready corn. On the other hand, earned off-farm income of the operator positively impacted adoption of Switchgrass and roundup ready corn. The opposite is true for record keeping. Farmers in Missouri are less likely to adopt roundup ready corn than farmers in Iowa. However, location differences are not influential for switchgrass and maintaining setbacks. Farm sales have negative impact on adoption of Switchgrass and maintaining setbacks, while it has positive impact on roundup ready corn. Hence, larger farm are more likely to adopt a GM crop, but less likely to adopt energy crops and conservation practices. This could be due to profit orientation of the farm. Information sources have different impact on three technologies. For Switchgrass, other farmers have negative, but university extension has positive impact. For roundup ready corn, banking institutions have positive impact. For maintaining record keeping, none of the information sources have statistically significant impact.

Conclusion

The future of the US agriculture relies on sustainable resource use and income generation for farmers, and maintaining the environmental quality. Hence, farmers are expected to adopt various technologies and practices, such as energy crops, genetically modified crops, and conservation practices. The objective of this study was, by using a multivariate probit model, to conduct a comprehensive analysis of the impact of earned and unearned off-farm income on adoption of switchgrass, Roundup Ready® corn, and record keeping. The results of the current study show that as the off-farm employment increases for the farm households, adoption of various technologies and practices will be impacted. Extension educators and policy makers should take into account the impact of off-farm employment on technology adoption, when new technologies are promoted. For example, the recent focus on promoting adoption of energy crops for bioenergy production, which requires farmers' devotion of extra labor, should take into account the off-farm employment status of the farmers.

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Table 1. Variable Names, Description, Means and Hypothesized Effect

Variable	Description	Mean	Hypothesized Effect
Education			
Less than high school	1 if has, 0 otherwise	0.20	-
High school degree	1 if has, 0 otherwise	0.29	Base
Some college or Vocational school	1 if has, 0 otherwise	0.24	+
Bachelor degree	1 if has, 0 otherwise	0.16	+
Graduate degree	1 if has, 0 otherwise	0.05	+
Off-Farm Income (Farm Operator)			
Unearned	1 if has retirement, dividend or interest income, 0 otherwise	0.35	+
Seasonal Earned	1 if has year round off-farm work, 0 otherwise	0.11	?
Year Round Earned	1 if has year round off-farm work, 0 otherwise	0.34	-
Off-Farm Income (Spouse)			
Unearned	1 if has retirement, dividend or interest income, 0 otherwise	0.45	+
Seasonal Earned	1 if has year round off-farm work, 0 otherwise	0.09	?
Year Round Earned	1 if has year round off-farm work, 0 otherwise	0.15	-
Hire Non-Family Labor	1 if hires non-family labor, 0 otherwise	0.33	-
Missouri	1 if the farm is located in Missouri, 0 if the farm is located in Iowa	0.43	?
Farm Sales			
$10,000 - $99,999	1 if has, 0 otherwise	0.27	Base
$100,000-$249,999	1 if has, 0 otherwise	0.40	+
$250,000 - $499,999	1 if has, 0 otherwise	0.21	+
$500,000 +	1 if has, 0 otherwise	0.12	+
Leased Land	1 if has leases land, 0 otherwise	0.58	-
Erosion Problem	1 if has erosion problem, 0 otherwise	0.66	+
Number of Animals	Total number of animals in animal units	212	-
Hay	1 if grows, 0 otherwise	0.49	-
Pasture	1 if grows, 0 otherwise	0.47	+
I am concerned about global warming	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.70	+
Other farmers have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.55	+
Banks have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	1.96	-
Extension have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.16	+

Table 2. Regression Results

Variable	**Switchgrass**		**RR Corn**		**Record Keeping**	
	Coeff.	p-value	Coeff.	p-value	Coeff .	p-value
Education						
(*Base = High School*)						
Less than High School	-0.34	0.669	-1.19	0.006	-0.57	0.130
Some College or Vocational School	-0.26	0.668	-0.18	0.599	-0.08	0.824
Bachelor	0.48	0.462	-0.20	0.606	0.94	0.056
Graduate	-0.09	0.898	-1.46	0.031	-0.04	0.940
Off-Farm Income						
(Operator)						
Unearned	-0.10	0.005	-0.35	0.093	-0.28	0.566
Seasonal Earned	0.18	0.088	0.12	0.899	-0.40	0.119
Year Round Earned	0.58	0.322	0.33	0.024	-0.24	0.089
Off-Farm Income						
(Spouse)						
Unearned	0.10	0.836	0.35	0.253	0.28	0.349
Seasonal Earned	-0.28	0.478	0.52	0.522	0.10	0.233
Year Round Earned	0.18	0.544	0.23	0.232	0.20	0.797
Hire Non-Family Labor	-0.29	0.636	-0.39	0.206	0.12	0.691
Missouri (*Base = Iowa*)	-0.19	0.702	-0.90	0.002	-0.18	0.524
Farm Sales						
(Base = $10,000-$99,000)						
$100,000-$249,999	-0.26	0.014	0.27	0.071	-0.36	0.005
$250,000 - $499,999	-6.71	0.976	0.55	0.006	-0.45	0.347
$500,000 +	-0.90	0.483	0.39	0.532	5.19	0.986
Leased Land	-0.25	0.607	0.23	0.469	0.61	0.040
Erosion Problem	-0.03	0.955	0.37	0.255	-0.10	0.736
Total Animal Units	0.00	0.630	0.00	0.472	0.00	0.982
Hay	-1.08	0.086	1.00	0.005	0.72	0.026
Pasture	1.25	0.060	0.21	0.532	0.29	0.354
Global Warming	0.18	0.312	-0.22	0.049	0.24	0.024
Influence on Agricultural Production						
Other Farmers	-0.49	0.071	0.08	0.537	-0.02	0.847
Bank	0.55	0.100	0.13	0.094	0.22	0.307
Extension	0.64	0.057	-0.08	0.574	-0.08	0.547
N	270					
Pseudo R-squared	0.50					
Wald Chi-square	199					
p-value for Wald chi-square	0.000					

Note: Three asterisks (***) indicate significance at 1% level, two asterisks (**) at the 5% level, and one asterisk (*) at the 10% level.