A Categorical Data Analysis on Risk in Agriculture

Hiroki Uematsu

Graduate Research Assistant
Department of Agricultural Economics and Agribusiness
Louisiana State University
Room 28 Ag Admin Bldg
Baton Rouge, LA 70803
E-mail: huemat1@tigers.lsu.edu

Ashok K. Mishra
Professor
Department of Agricultural Economics and Agribusiness
Louisiana State University AgCenter
211 Ag. Admin. Bldg.
Baton Rouge, LA 70803
Tel: 225-578-0262
Fax: 225-578-2716
E-mail: amishra@agcenter.lsu.edu

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Corpus Christi, TX, February 5-8, 2011

A Categorical Data Analysis on Risk in Agriculture

Abstract

This study compares farm operators' risk perceptions and actual realization of risk attitudes revealed through off-farm labor, enterprise diversification, and use of contracts, crop insurance, and other types of insurance, using data from 2001 Agricultural Resource Management Survey (ARMS). Results from ordered logit model and multivariate probit models unexpectedly found that risk loving farmers are more likely to employ risk management strategies.

Keywords: Risk attitude, risk management strategies, ordered logit, multivariate probit

JEL Codes: D81, Q10, Q12

I. Introduction

Agricultural production is riskier than businesses in other sectors of economy (Hardeaker, Huirne et al., 2004). Riskiness of agriculture may be attributed to several factors that are beyond the control of producers. Biological processes of plant growth and climatic conditions inherent in agricultural production cause random production shocks, which causes price volatility due to inelastic demand for foods (Goodwin and Mishra, 2000; Holt and Chavas, 2002). Agricultural economists have relied on the expected utility framework as a basis of most empirical analysis of risk in agriculture (Holt and Chavas, 2002). The expected utility framework is a theoretical scheme derived based on the set of axioms developed by von Neumann and Morgenstern (1947). Because of its normative nature, the validity of the expected utility theory needs to be confirmed empirically (Hey, 1979). In fact, an increasing amount of empirical and experimental evidence has been accumulated to document the violations of the axioms in the expected utility theory (Machina, 1987; Starmer, 2000). Although the theoretical expectations of the expected utility theory often contradict with empirical evidence, it remains by far the most popular theoretical framework in agricultural economics due to its simplicity and the lack of better alternatives (Just and Peterson, 2010).

A large volume of literature has been devoted to risk analysis in agricultural economics. The literature can be broadly classified into three categories: (1) how to measure farmers' risk perceptions, (2) normative analysis to provide a guideline for the optimal risk management strategies, and (3) how risk attitudes, assuming that they are properly measured, influence farmers' actual decision-making (Holt and Chavas, 2002). The first category serves as a basis of empirical risk analysis and a wide variety of methods have been proposed to measure farmers' risk attitude. But any proposed method is never free from contradiction with empirical evidence, which are also subject to inconsistent findings within themselves (Lagerkvist, 2005). For example, Fausti and Gillespie (2006) examined consistency across five risk-attitude measurement instruments (RAMI). Not only did the authors find no consistency across different RAMI, they also found no significant relationship between levels of understanding of survey questions by respondents and their consistency across RAMI. Their study suggests that the inconsistency across RAMI cannot solely be attributed to respondents' understanding of survey questions or lack thereof. Bard and Barry (2001) employed the "closing-in" method to elicit Illinois farmers' risk attitude. The "closing-in" method is an iterative procedure in which respondents are repeatedly asked to choose between gambles until their preference converges to a narrow interval. The authors compared "closing-in" risk attitude against farmers' own assessment of risk attitude measured on a 11-point Likert scale, however, the authors found no correlation between them. The lack of consistency across different measures of risk attitude is disturbing not only to theoretical economists who propose them, but also to empirical economists who need to rely on them for empirical analyses.

This study shares a similar motivation to those of Fausti and Gillespie (2006) and Bard and Barry (2001) and attempts to examine the validity of one of the simplest but frequently used measures of risk attitude: own assessment of risk attitude on a Likert scale[1]. In so doing, however, we compare Likert Risk Attitude against five discrete variables representing actual realization of risk attitudes revealed through 1) off-farm labor, 2) enterprise diversification, 3) use of contracts, 4) purchase of crop insurance, and 5) purchase of other types of insurance. We first estimate an ordered logit model to find how Likert Risk Attitude is associated with the five variables holding constant the variables related to the operator and the farm. Further, we estimate a multivariate probit model in which Likert Risk Attitude serves as an explanatory variable to each of the five variables representing actual realization of risk attitudes.

The rest of the paper is organized as follows. The next two sections introduce conceptual and empirical frameworks, followed by data description in Section IV. Section V discusses econometric results. The final section concludes.

II. Conceptual Framework

Ordered Logit Model

The ordered logit model (also known as cumulative logit models for ordinal responses) takes a natural log of cumulative odds of the dependent variable that has an ordinal structure. That is,

[1] We call this variable "Likert Risk Attitude" hereafter.

$$\log\left[\frac{P(Y \le j)}{1 - P(Y \le j)}\right] = \log\left[\frac{\sum_{j=1}^{j} \pi_j}{\sum_{j=j+1}^{J} \pi_j}\right], j = 1, \cdots, J, \quad (1)$$

where Y is an ordinal dependent variable with J categories, π_j is the probability that Y_i is categorized in the jth category (Agresti, 2007). In this study, $J = 11$, as farmers' risk attitude is measured on a 11-point Likert scale. The first category is used as a base category and all of the interpretations that follow are relative to the base category. Equation (1) represents the log of odds: the ratio of the probability that, Y_i, ith farmer's risk attitude, is classified into jth or lower categories to the probability that Y_i is classified into $j + 1$st or higher categories. This log of odds is regressed against a set of explanatory variables, that is

$$\log\left[\frac{P(Y \le j)}{1 - P(Y \le j)}\right] = \boldsymbol{Z}'\boldsymbol{\gamma} + \varepsilon, \quad (2)$$

where $\boldsymbol{Z}$ is a vector of explanatory variables and $\boldsymbol{\gamma}$ is a vector of unknown parameters to be estimated.

An important econometric issue arises in constructing an empirical model using Likert Risk Attitude as a variable of interest. For example, suppose a positive correlation is found between Likert Risk Attitude and average interest rate charged on loans. It may indicate that farmers who think they are risk taking (a high score on Likert Risk Attitude) are willing to take higher interest rates on loans. However, it is awkward to draw a causal relationship from the opposite direction and assume that the ability to take on loans with higher interest rates induce farmers to choose a higher number in the Likert Risk Attitude question. Although the ordered logit model helps us to understand the association between Likert Risk Attitude and the explanatory variables, it is more appropriate to use Likert Risk Attitude as a regressor to explain the use of risk management tools such as crop insurance purchase.

Another concern in estimating the relationship between Likert Risk Attitude and use of the five risk management tools (off-farm labor, enterprise diversification, contracts, crop insurance, and other types of insurance) is the potential correlations between the five variables. For example, the entropy index measures the degree to which a farm diversifies across different enterprises. A high entropy index may indicate that the farm is actively managing various sources of risks, but doing so increases the labor requirements on the farm and thus it may decrease the probability of working off-farm, which is another way of hedging income risk for a farm household. There exists a wide variety of tools to manage risks in agriculture and thus some risk management tools can be complements or substitutes to other tools. Therefore, simply assuming that risk-related decision variables are all exogenous to each other forces us to ignore correlations that may exist between risk management tools.

Multivariate Probit Model

In order to capture the potential correlations between the error terms, we estimate a multivariate probit model which consists of five equations each of which use of a risk management tools. Likert Risk Attitude serves as an exogenous variable in each of the five equations. This model allows us to test if the error terms in the five equations are significantly correlated with each other.

We assume that farmers adopt a risk management tool if it increases their utility. Following notations in Walton et al. (2008), we can express the farmer's risk management problem as:

$$U_i^* = U_i^{AD} - U_i^{NA} \tag{3}$$

$$U_i^* = \boldsymbol{X}_i'\boldsymbol{\beta}_i + \boldsymbol{\varepsilon}_i, \qquad \forall\, i = 1, \cdots, 5, \tag{4}$$

where U_i^* is the net utility from adopting ith risk management tool, U_i^{AD} is utility from adopting ith risk management tool, U_i^{NA} is utility from not adopting ith risk management tool, $\boldsymbol{X}_i$ is the vector of exogenous variables that influences U_i^*, $\boldsymbol{\beta}_i$ is the vector of unknown parameters to be estimated, and $\boldsymbol{\varepsilon}_i$ is the error term assumed to be normally distributed with zero mean. $\boldsymbol{\varepsilon}_i$ and $\boldsymbol{\varepsilon}_j$ are assumed to be correlated with ρ_{ij} $\forall\, i \neq j$. Note that U_i^* is a latent variable that is unobservable to the researcher; what is observable instead is a discrete decision of whether the farmer adopts a risk management tool expressed as:

$$y_i = \begin{cases} 1 \text{ if } U_i^* > 0 \\ 0 \text{ otherwise} \end{cases} \quad \forall\, i = 1, \cdots, 5. \tag{5}$$

Since we have five dependent variables with two outcomes, there are $2^5 = 32$ possible states of the world. For example, the probability that the farmer adopts all of the five risk management tools or $\sum y_i = 5$ can be obtained by repeatedly applying the conditional probability theorem (Amemiya, 1994):

$$\Pr[y_1 = 1, y_2 = 1, y_3 = 1, y_4 = 1, y_5 = 1,]$$
$$= \Pr[y_1 = 1 |\, y_2 = 1, y_3 = 1, y_4 = 1, y_5 = 1] \times \Pr\,[y_2 = 1, y_3 = 1, y_4 = 1, y_5 = 1] \quad (6)$$

where the second term on the right hand side of equation (6) can be further rearranged as

$$\Pr[y_2 = 1, y_3 = 1, y_4 = 1, y_5 = 1] =$$
$$= \Pr[y_2 = 1 |\;\, y_3 = 1, y_4 = 1, y_5 = 1] \times \Pr\,[y_3 = 1, y_4 = 1, y_5 = 1], \quad (7)$$

and so on to eventually obtain

$$\begin{aligned} &\Pr[y_1 = 1, y_2 = 1, y_3 = 1, y_4 = 1, y_5 = 1,] \\ &= \Pr\,[y_1 = 1 |\, y_2 = 1, y_3 = 1, y_4 = 1, y_5 = 1] \\ &\times Pr[y_2 = 1 |\;\, y_3 = 1, y_4 = 1, y_5 = 1] \\ &\times Pr[y_3 = 1 |\, y_4 = 1, y_5 = 1] \\ &\times Pr[y_4 = 1 |\, y_5 = 1] \\ &\times Pr[\, y_5 = 1]. \end{aligned} \quad (8)$$

Substituting equations (4) and (5) into equation (8), we obtain

$$\begin{aligned} &\Pr[y_1 = 1, y_2 = 1, y_3 = 1, y_4 = 1, y_5 = 1,] \\ &= \Pr\,[\boldsymbol{X}_1'\boldsymbol{\beta}_1 < \varepsilon_1 |\, \boldsymbol{X}_2'\boldsymbol{\beta}_2 < \varepsilon_2, \boldsymbol{X}_3'\boldsymbol{\beta}_3 < \varepsilon_3, \boldsymbol{X}_4'\boldsymbol{\beta}_4 < \varepsilon_4, \boldsymbol{X}_5'\boldsymbol{\beta}_5 < \varepsilon_5] \\ &\times \Pr\,[\boldsymbol{X}_2'\boldsymbol{\beta}_2 < \varepsilon_2 |\, \boldsymbol{X}_3'\boldsymbol{\beta}_3 < \varepsilon_3, \boldsymbol{X}_4'\boldsymbol{\beta}_4 < \varepsilon_4, \boldsymbol{X}_5'\boldsymbol{\beta}_5 < \varepsilon_5] \\ &\times \Pr\,[\,\boldsymbol{X}_3'\boldsymbol{\beta}_3 < \varepsilon_3 |\, \boldsymbol{X}_4'\boldsymbol{\beta}_4 < \varepsilon_4, \boldsymbol{X}_5'\boldsymbol{\beta}_5 < \varepsilon_5] \\ &\times \Pr\,[\,\boldsymbol{X}_4'\boldsymbol{\beta}_4 < \varepsilon_4 |\, \boldsymbol{X}_5'\boldsymbol{\beta}_5 < \varepsilon_5] \\ &\times \Pr[\boldsymbol{X}_5'\boldsymbol{\beta}_5 < \varepsilon_5]. \end{aligned} \quad (8)$$

Similarly one can obtain other 31 states of the world. As apparent in equation (8), estimation of the multivariate probit model requires intensive calculation of multivariate standard normal distribution. The standard method is simulation-based approaches instead of algorithms based on standard linear numerical approximation (Cappellari and Jenkins, 2003). The Geweke Hajivassiliou Keane (GHK) smooth recursive conditioning simulator is the most popular simulator as it possesses a number of desirable properties, such as unbiasedness of the simulated probabilities, and the simulator is continuous and differentiable in the parameters of interest (Cappellari and Jenkins, 2003). Although these desirable properties are asymptotic, finite sample bias can be reduced to negligible levels when the number of draw is set close to the square root of the sample size (Cappellari and Jenkins, 2003).

III. Empirical Framework

In order to establish empirical models, we need to specify the vector, $\boldsymbol{Z}$, in equation (2) consisting of factors associated with Likert Risk Attitude for the ordered logit model and the vectors, $\boldsymbol{X}_i$, in equation (4) consisting of factors affecting use of risk management tools for the multivariate probit model.

Factors associated with Risk Attitude

The vector of exogenous variable, **Z**, consists of factors associated with Likert Risk Attitude. It includes the five discrete variables related with risk management tools: off-farm labor, enterprise diversification represented by the entropy index, contracts, crop insurance, and other types of insurance. Each of these variables is coded as a binary variable that takes a value of one when the farmer uses the corresponding risk management tool. For enterprise diversification, the variable takes a value of one when the entropy index is greater than 0.1, which holds for approximately 30% of farmers in the sample. Contracts include production, marketing or forward pricing contracts. The variable takes a value of one when the farmer makes use of at least one contract. Other types of insurance include casualty insurance such as hail insurance, livestock insurance, motor vehicle liability and blanket insurance policies, but exclude crop insurance, health insurance and other payroll insurance items. The vector, **Z,** also includes variables related to the farm operator, the farm, the farm household, and the location of the farm. See Table 1 for a complete list of variables used in this study and their summary statistics.

Factors affecting the use of risk management tools

The vectors, $\boldsymbol{X}_i$, in equation (4) includes exogenous variables that influence the farmer's decision of whether or not to use each of the five risk management tools. Variables related to the operator include age, its squared, farming experience, its squared, primary occupation of the operator, a dummy variable for farmers who were raised on the farm, and years of education. Primary occupation is included only in the off-farm labor equation, due to multicollinearity. We expect that older farmers are more likely to employ risk management tools, regardless of farming experience, simply because of shorter planning horizon and thus they are more reluctant to take on risks, especially if that could cause a financial adversity. Age squared is used to see quadratic relationship. In contrast, we expect that farming experience, holding age constant, reflects learning effects in decision making on the premise that more experienced farmers are more familiar and comfortable with making complex decisions in the face of risk. We also believe that being raised on the farm has a positive effect on the use of risk management tools – the effect we expect to be distinct from the effects of age and farming experience. Farmers raised on the farm are likely to gain some tips and rules of thumbs in farming operation from the predecessors that may seem inconceivable to others. To the extent that this is true, the "insider-knowledge" unattainable to others may give farm-raised farmers an edge necessary to make successful decisions, even after controlling for farming experiences.

Farm variables include total acres, total acres squared, dummy variables for full owners and tenants, and total government payments received by the farm. Farms with large scale operation are likely to be exposed to greater amount of risks, and thus they are expected to make extensive use of risk management tools (Mishra and Goodwin, 1997), but they would be less likely to work off-farm to diversify income risk. Land tenancy variables are expected to have similar effects; because it is part owners who on average operate largest farms in the United States (USDA, 1998), coefficients for full owners and tenants are expected to be positive in the off-farm equation but negative in all other equations. Farmers receiving a large amount of government payments are expected to work less off the farm as the payments can mitigate income risk and they are often tied with agricultural production. Empirical evidence (Mishra and Goodwin, 1997; Ahearn, El-Osta et al., 2006) suggests that the income effect outweighs the substitution effect (Uchida, Rozelle et al., 2009).

To represent farm financial status, we include average interest rate charged on loans and debt-to-asset ratio. Their impacts are *a priori* ambiguous. On one hand, farmers who are willing to and capable of borrowing more at a higher interest rate may be risk prone and thus they may not see the necessity of managing risks. On the other hand, a higher debt-to-asset or a higher average interest rate on loan may be a signal that the farmer is capable of managing financial risk than average farmers.

To account for heterogeneous characteristics of farming operation across the country, we include variable representing farm types (livestock sales and dummy variables for cash grain farms, high value crop farms, and dairy farms) and the ERS farm resource regions. Farm type variables should have significant impact on the choice of risk management tools. To account for farm household characteristics, we include farm household income and miles to the closest city with population of 10,000 or more. Although miles to the closest city is only included in the off-farm labor equation, we expect both of these variables to positively affect off-farm labor supply. Variable definitions are provided in Table 1.

Finally, in order to estimate the relationship between off-farm labor and the rest of the four on-farm risk management strategies, we estimate a univariate probit model to obtain the predicted probability of off-farm work and include it in the four on-farm risk management equations: entropy index, contracts, crop insurance and other types of insurance. This procedure, proposed by Nelson and Olson (1978) obtains asymptotically consistent estimates of unknown parameters of interest. Since working off-farm reduces managerial time available on the farm, we expect the predicted probability of off-farm labor to be negatively correlated with all of the other four risk management strategies.

IV. Data

This study uses data from the 2001 Agricultural Resource Management Survey (ARMS) conducted by the National Agricultural Statistics Service (NASS) and the Economic Research Service (ERS). The ARMS provides information about the relationships between agricultural production, resources, and the environment as well as about the characteristics and financial conditions of farm households, management strategies and off-farm income. Operators associated with farm businesses representing agricultural production in the 48 contiguous states make up the target population of the survey. Data are collected from the senior farm operator, who makes most of the day-to-day management decisions. For statistical purposes, USDA currently defines a farm as an establishment that sold or normally would have sold at least $1,000 of agricultural products during the year (USDA 2005). For the purpose of this study, our sample only includes farms that are classified as family farms that are organized as sole proprietorships, partnerships, or family corporations because they are closely controlled by their operators and the operator's household (USDA 2005). Any operator households organized as nonfamily corporations or cooperatives and farms run by hired managers are excluded from this study because we are interested in farm business decisions made by individual farmers and his/her families not by hired managers.

The 2001 ARMS contains a question that queries the respondents' risk preference. Specifically, the respondents were asked to choose a number between 0 and 10 on a Likert scale to represent the level of risk with which they are comfortable in making decisions, with 0 being "avoid risks as much as possible" and 10 being "take risks as much as possible."[2] In this study, we compare this variable, which can be seen as perceptions about their own risk attitude, against variables representing actual realization of their risk attitude revealed by decisions they make in farming operation, which are also obtained from 2001 ARMS data.

Figure 1 presents the histogram of Likert Risk Attitude measured on a 11-point Likert scale. A huge spike in the middle of distribution (Figure 1) shows that the majority of respondents chose 5 at the center of the Likert scale, indicating that most farmers consider themselves as neither risk taking or risk averse. However, this may not necessarily mean that those who chose 5 are risk neutral in terms of curvature of utility function, as there is no theoretical connection between this question and respondents' utility function.

Table 2 presents correlation coefficient estimates between Likert Risk Attitude and the five risk management strategies. Four of the five risk management strategies are positively correlated with Likert Risk Attitude, which seems counter intuitive: the higher degree of risk taking (in a relative sense measured on a Likert scale) is correlated with use of the risk management strategies. On the other hand, a negative correlation between Likert Risk Attitude and off-farm work is expected. Those farmers who are willing to take risks are less likely to work off-farm, even though income from off-farm sources can diversify income risk. However, correlation coefficients are simply linear measurements of how the two variables of interest are moving. They do not control for the effects of other variables, nor

[2] This question is exactly the same as the one used in Bard and Barry (2001).

do they capture any non-linear relationships between the two variables of interest. Econometric analyses are need for more in-depth understanding of the relationship between these variables.

V. Results

Ordered Logit Model

Parameter estimates from the ordered logit model are presented in Table 3. Contrary to our expectation, the coefficients for all of the five risk management strategies are positive and significant. The degree of correlation represented by the estimated odds ratio is the strongest between Likert Risk Attitude and other types of insurance. Again, we are surprised to find the negative correlation between Likert Risk Attitude and all of the five risk management strategies, *ceteris paribus*.

Results show that experienced farmers or farmers with higher education whose primary occupation is farming are more likely to be risk loving in their risk preferences. Total acres are also positively associated with risk loving, but at a decreasing rate, as indicated by the negative coefficient of total acres squared. Livestock sales, average interest rate on loans, and high value crop farms are all positively associated with a higher degree of risk taking, while full owners, relative to part owners, are highly risk averse. All of the regional variables are found insignificant, suggesting that farmers' own assessment of risk attitude is not dependent on geographical location of the farm.

Multivariate Probit Model

Table 4 provides parameter estimates from the multivariate probit model, consisting of five equations each of which represents the use of a risk management strategy. The likelihood ratio test examines the null hypothesis that the error terms in all five equations are not correlated with each other. The chi-square statistic for this test has 10 degrees of freedom because there are a total of 10 combinations of two error terms out of five[3]. The

[3] $C_2^5 = \frac{5!}{(5-2)!2!} = 10$

chi-square statistic of 350 and the p-value of 0.00 are clear evidence against the null hypothesis, which justifies the use of multivariate probit model.

The primary interest of this study lies in estimating the impact of Likert Risk Attitude on the use of five different risk management tools. Likert Risk Attitude obtained positive and significant coefficients in four of the five equations. Unlike the ordered logit model, Likert Risk Attitude no longer has a significant association with the farmer's decision to work off the farm, after controlling for the correlation between the five error terms. The four other risk management strategies, enterprise diversification, contracts, crop insurance, and other types of insurance, remain positively associated with Likert Risk Attitude as they were in the ordered logit analysis.

An important question remains as to why using these on-farm risk management strategies are positively correlated with risk loving attitudes, exhibited by the self-assessment of risk attitude. We offer a few alternative explanations to this unexpected result. First, risk attitude in general may have two opposing effects on farmers' decisions to use risk management strategies. For one, risk averseness may impose a negative impact on doing something new, including addition of new risk management strategies. Risk loving farmers may be more willing to initiate risk management strategies, which is consistent with our results. On the other hand, risk-averse farmers may initially be reluctant to adopt a new risk management strategy, but gradually become more willing to adopt it at a greater intensity if it is found to be working well to reduce and diversify risks that the farmers intended to address. Because all of the dependent variables are binary and discrete, our model is unable to capture the effect of risk attitude on adoption intensity of risk management tools, if any. Alternatively, as suggested by previous studies (Bard and Barry, 2001; Fausti and Gillespie, 2006), the self-assessment of risk attitude on a Likert scale may not represent the true risk preference of individuals as accurately as researchers would hope for, despite its simplicity of the question in the elicitation procedure.

The predicted probability of working off the farm has a negative and significant coefficient in all of the four equations, suggesting that farmers who rely on off-farm employment to diversify income risk are less likely to use the other risk management strategies available on the farm. Results here lends support to our earlier discussion that some risk management tools are compliments while others are substitutes.

Variables representing operators' characteristics mostly obtain significant coefficients with expected signs. The positive and significant coefficient on age in all of the five equations provide strong evidence in favor of our expectation that older farmers are more likely to manage various types of risks due to shorter time horizon remaining in farming operation. The positive effect of age, however, is increasing at a decreasing rate, as indicated by negative and significant coefficient of age squared. Farming experience and its squared also obtained expected signs in three of the five equations: **Contract**, **Crop Insurance** and **Other Types of Insurance**. Greater farming experience would allow farmers to acquaint themselves with new and already available risk management strategies. Again the effect is increasing at a decreasing rate due to the negative coefficient of farming experience squared. Being raised on the farm has a positive influence on the use of all risk management tools except for off-farm labor, even though the effect is not significant for **Entropy Index** and **Other Types of Insurance.** Predictably, off-farm labor and farming as a primary occupation are negatively correlated and education has a positive and significant impact on all of the five risk management strategies.

Total acres has a negative coefficient in the off-farm labor and the crop insurance equations. Farms with large acres require higher labor requirements on the farm, leaving the operator with fewer economic incentives and less time available to work off-farm. Although we expected total acres to be positively correlated with use of risk management strategies, we unexpectedly found the negative impacts of total acres on crop insurance. As expected, full owners are less likely to use all of the five risk management tools relative to the base group of part owners, even though the effect is insignificant for off-farm labor. However, tenants, relative to part owners, are likely to adopt other types of insurance. Government payments have clearly different impacts on off-farm labor and other on-farm risk management tools. While farmers who receive more government payments are less likely to work off-farm, as confirmed in previous studies (Mishra and Goodwin, 1997; Ahearn, El-Osta et al., 2006), such farmers are more likely to diversify across different enterprises, use contracts, and purchase crop insurance and other types of insurance. Although we did not have a definite expectation about the impact of average interest rate on use of risk management tools, the variable obtained positive and significant coefficients in all but the off-farm labor equation. The result supports our earlier hypothesis that farmers who are capable of taking on loans at a higher interest rate are more likely to hedge their income risk by adopting other management strategies in their farming operation.

Livestock sales are negatively correlated with off-farm labor and crop insurance, conceivably for different reasons. While the negative impact of livestock sales are most likely due to limited availability of time for large scale farmers to work off-farm, farms with higher livestock sales are less likely to purchase crop insurance simply because they do not need them as much as crop farms. In fact, cash grain farms and high value crop farms are more likely to use crop insurance. On the contrary, dairy farms are less likely to work off-farm, diversify enterprises and purchase other types of insurance. The negative correlations can be attributed to intensive labor requirement in dairy farming (Sumner, 1982; Mishra and Goodwin, 1997). The positive and significant coefficient of **Household Income** in the entropy index equation may be a manifestation that enterprise diversification is not only risk reducing but profit increasing as well.

Most regional dummy variables have a significant coefficient in all of the five equations. Because the Heartland region – the largest cropland of all the regions – serves as the base group, it is no surprise that all the regional dummy variables obtain a negative and significant coefficient in the "other types of insurance" equation and all but one region obtain a negative and significant coefficient in the "crop insurance" equation. The only exception in the "crop insurance" equation is the Northern Great Plains where farmers may be induced to rely on crop insurance to grow program crops eligible for government payments. A similar pattern holds true for the use of contracts; farmers in all but one region are less likely to use contracts relative to their counterparts in the Heartland region. The exception is farmers in the Fruitful Rim region, which has the largest share of very large family farms[4]. The regional dummy variables are significantly correlated with off-farm labor and entropy index, however, there seems to be no clear-cut pattern in signs of the coefficients.

VI. Conclusion

[4] Very large farms are defined as farms with Gross sales of $500,000 or more (USDA, 2010)

The objective of this study was to examine the associations between one of the simplest measurement of farmers risk attitude, the self-assessment of risk attitude measured on a 11-point Likert scale, and the variables that represent actual risk management decisions farmers make in farming operation. We estimated the ordered logit model and the multivariate probit model to accomplish the objective. In both models, we unexpectedly found that risk loving operators were more likely to use enterprise diversification, contracts, crop insurance, and other types of insurance. We posited two explanations to this unexpected result.

First, the validity of the self-assessment of risk attitude on a Likert scale may be in question, as suggested by Bard and Barry (2001) and Fausti and Gillespie (2006), despite its extremely simple and intuitively appealing elicitation procedure. Evaluating the impact of other risk attitude measurement instruments in the empirical models that were found uncorrelated with Likert Risk Attitude in Fausti and Gillespie (2006) may be one way to go, but data requirements are considerable.

Second, risk averseness may impose a negative impact on doing something new, even if it is to diversify and reduce risks, while risk averseness may be positively correlated with the intensity at which farmers are willing to use risk management strategies that are proven to be successful with the existing operation. In order to empirically verify if this is the case, one can estimate the two potentially conflicting impact of risk averseness on the adoption of a particular risk management strategy by a double hurdle model or the number of risk management strategies adopted by a count data analysis. Further empirical analyses are warranted to confirm the above explanations and eventually to reduce the gap between theoretical expectation of how a rational agent would behave and how real people with imperfect information and bounded rationality would behave in the face of risk.

References

Agresti, A. *An Introduction to Categorical Data Analysis*, Wiley-Interscience, 2007).

Ahearn, M.C., H. El-Osta and J. Dewbre "The Impact of Coupled and Decoupled Government Subsidies on Off-Farm Labor Participation of U.S. Farm Operators." *American Journal of Agricultural Economics*, Vol. 88, (2006) pp. 393-408.

Amemiya, T. "Introduction to Statistics and Econometrics", (Cambridge, MA: Harvard University Press, 1994).
Bard, S.K. and P.J. Barry "Assessing Farmers' Attitudes Toward Risk Using The "Closing-In" Method." *Journal of Agricultural and Resource Economics*, Vol. **26**, (2001).
Cappellari, L. and S.P. Jenkins "Multivariate probit regression using simulated maximum likelihood." *Stata Journal*, Vol. **3**, (2003) pp. 278-294.
Fausti, S. and J. Gillespie "Measuring risk attitude of agricultural producers using a mail survey: how consistent are the methods?", *Australian Journal of Agricultural & Resource Economics*: Blackwell Publishing Limited, 2006, pp. 171-188).
Goodwin, B.K. and A.K. Mishra "An Analysis of Risk Premia in U.S. Farm-Level Interest Rates." *Agricultural Finance Review*, Vol. **60**, (2000) pp. 1-16.
Hardeaker, J.B., R.B.M. Huirne, J.R. Anderson and G. Lien *Coping with Risk in Agriculture*, CABI, 2004).
Hey, J.D. *Uncertainty in microeconomics* (New York, New York University Press, 1979).
Holt, M.T. and J.-P. Chavas "The Econometrics of Risk", in R.E. Just and R.D. Pope (eds.), *A Comprehensive Assessment of the Role of Risk in U.S. Agriculture*: Kluwer Academic Publishers, chapter 11, 2002, pp. 214 - 241).
Just, D.R. and H.H. Peterson "Is Expected Utility Theory Applicable? A Revealed Preference Test." *American Journal of Agricultural Economics*, Vol. **92**, (2010) pp. 16-27.
Lagerkvist, C.J. "Assessing farmers' risk attitudes based on economic, social, personal, and environmental sources of risk: evidence from Sweden", *American Agricultural Economics Association Annual meeting* (July 24-27 Providence, RI, 2005).
Machina, M.J. "Choice Under Uncertainty: Problems Solved and Unsolved." *Journal of Economic Perspectives*, Vol. **1**, (1987) pp. 121-154.
Mishra, A.K. and B.K. Goodwin "Farm Income Variability and the Supply of Off-Farm Labor." *American Journal of Agricultural Economics*, Vol. **79**, (1997) pp. 880-887.
Nelson, F. and L. Olson "Specification and Estimation of a Simultaneous-equation Model with Limited Dependent Variables." *International Economic Review*, Vol. **19**, (1978) pp. 695.
Starmer, C. "Developments in Non-Expected Utility Theory: The Hunt for a Descriptive Theory of Choice under Risk." *Journal of Economic Literature*, Vol. **38**, (2000) pp. 332.
Sumner, D.A. "The Off-Farm Labor Supply of Farmers." *American Journal of Agricultural Economics*, Vol. **64**, (1982) pp. 499-509.
Uchida, E., S. Rozelle and J. Xu "Conservation Payments, Liquidity Constraints, and Off-Farm Labor: Impact of the Grain-for-Green Program on Rural Households in China", *American Journal of Agricultural Economics*: Agricultural & Applied Economics Association, 2009, pp. 70-86).
USDA "Agriculture Fact Book 1998", in USDA (ed.), 1998).
USDA " Farm Household Economics and Well-Being: Glossary" 2010. Available at http://www.ers.usda.gov/briefing/wellbeing/glossary.htm.
von Neumann, J. and O. Morgenstern *Theory of games and economic behavior* (Princeton, NJ, Princeton University Press, 1947).
Walton, J.C., D.M. Lambert, R.K. Roberts, J.A. Larson, B.C. English, S.L. Larkin, S.W. Martin, M.C. Marra, K.W. Paxton and J.M. Reeves "Adoption and Abandonment of Precision

Soil Sampling in Cotton Production." *Journal of Agricultural and Resource Economics*, Vol. **33**, (2008) pp. 428-448.

Table 1: Variable Definitions and Summary Statistics

Variable	Definitions	Mean	Std Dev
Dependent Variables			
Risk attitude	Own assessed risk measured on a 11-point Likert Scale	5.02	2.50
Off-farm labor	=1 if operator works off-farm, 0 otherwise	0.36	0.48
Entropy dummy	=1 if entropy index of diversification is greater than 0.1.[1]	0.30	0.46
Contracts	=1 if farm uses either marketing, production or forward contract, 0 otherwise	0.44	0.50
Crop insurance	=1 if farm purchases crop insurance, 0 otherwise	0.35	0.48
Other insurance	=1 if farm purchases other types of insurance, 0 otherwise	0.88	0.32
Operator Variables			
Age	Operator's age	53.94	12.79
Age squared	Operator's age squared	3073.31	1437.68
Experience	Operator's farming experience	43.21	190.53
Experience squared	Operator's farming experience squared	38160	384942
Primary occupation	=1 if operator's primary occupation is farming, 0 otherwise	0.69	0.46
Raised on farm	=1 if operator was raised on farm, 0 otherwise	0.81	0.39
Education	Operator's years of education	13.42	2.16
Farm Variables			
Acres	Total acres operated	1414.76	5928.78
Acres squared	Total acres operated squared	37100000	105000
Full owners	= 1 if farm is a full owner, 0 otherwise	0.39	0.49
Part owners	= 1 if farm is a part owner, 0 otherwise	0.48	0.50
Tenants	= 1 if farm is a tenant, 0 otherwise	0.12	0.33
Government Payments	Total government payments received ($)	29649	101708
Interest rate	Average interest rate charged on loans	1.69	2.10
Debt-to-asset	= total liability divided by total assets	0.18	1.09
Livestock sales	Sales from livestock operation ($)	170122	903833
Cash grain	=1 if farm is a cash grain farm	0.19	0.39
High value crops	=1 if farm is a high value crop farm	0.12	0.32
Dairy	=1 if farm is a dairy farm	0.09	0.28
Household Income	Farm household' total income ($)	114247	423338
Miles	Distance to the closest city with population of at least 10,000	0.03	0.20
Regional Dummy Variables			
Heartland	= 1 if farm located in the Heartland region, 0 otherwise	0.13	0.34
Northern Crescent	= 1 if farm located in the Northern Crescent region, 0 otherwise	0.12	0.33

Northern Great Plains	=1 if farm located in the Northern Great Plains region, 0 otherwise	0.07	0.25
Prairie Gateway	=1 if farm located in Prairie Gateway region, 0 otherwise	0.12	0.32
Eastern Upland	=1 if farm located in Eastern Upland region, 0 otherwise	0.13	0.34
Southern Sea Board	=1 if farm located in Southern Sea Board region, 0 otherwise	0.14	0.34
Fruitful Rim	=1 if farm located in Fruitful Rim region, 0 otherwise	0.15	0.36
Basin and Range	=1 if farm located in Basin and Range region, 0 otherwise	0.05	0.22
Mississippi Portal	=1 if farm located in Mississippi Portal region, 0 otherwise	0.09	0.29
Number of observations=5099			Source: ARMS, 2001

[1] Diversification Index ranges from 0 (no diversification) to 1(perfect diversification) before converting to a discrete variable.

Table 2: Correlation between Risk Attitude and Use of Risk Management Tools

Variables	Likert Risk Attitude	Off-farm Labor	Entropy dummy	Contracts	Crop Insurance	Other types of Insurance
Likert Risk Attitude	1.00					
Off-farm Labor	0.16	1.00				
Entropy Dummy	-0.03	-0.24	1.00			
Contracts	0.19	0.37	-0.20	1.00		
Crop Insurance	0.18	0.12	-0.18	0.29	1.00	
Other types of Insurance	0.15	0.17	-0.11	0.19	0.20	1.00

All correlation coefficients are statistically significant at 1%

Table 3: Ordered Logistic Regression

Variables	Coefficient	Odds Ratio
Risk Management Variables		
Off-farm labor	0.12*	1.13*
Entropy dummy	0.23***	1.26***
Contracts	0.25***	1.28***
Crop insurance	0.16**	1.17**
Other insurance	0.30***	1.34***
Operator Variables		
Age	0.0015	1.0015
Age squared	-0.0002*	0.9998
Experience	0.01**	1.01**
Experience squared	-0.00001	0.99999
Primary occupation	0.26***	1.30***
Raised on farm	-0.01	0.99
Education	0.04***	1.05***
Farm Variables		
Acres	0.03***	1.03***
Acres squared	-0.0001***	0.9999***
Full owner	-0.23***	0.79***
Full tenant	0.02	1.02
Government Payments	0.0003	1.0003
Interest rate	0.07***	1.07***
Debt-to-asset	0.01	1.01
Livestock sales	0.0001*	1.0001*
Cash grain	0.02	1.02
High value crops	0.41***	1.50***
Dairy	-0.02	0.98
Household Income	0.00002	1.00002
Regional Dummy Variables		
Northern Crescent	0.05	1.05
Northern Great Plains	0.16	1.18
Prairie Gateway	0.14	1.15
Eastern Upland	-0.01	0.99
Southern Sea Board	0.15	1.16
Fruitful Rim	0.12	1.13
Basin and Range	0.20	1.22
Mississippi Portal	-0.02	0.98
Number of Observaions =5323		**LR chi2(16)**=1007.17
Log likelihood = -11574.512		**Prob > chi2**=0.000

***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Table 4: Multivariate Probit Model

Variables	Off-farm Labor	Entropy Index	Contract	Crop Insurance	Other types of Insurance
Intercept	-1.38***	-3.87***	-2.23***	-5.43***	-1.72***
Likert Risk Attitude	0.01	0.05***	0.05***	3.70***	0.04***
Off-farm Labor		-0.49***	-0.47***	-10.56***	-0.38***
Operator Variables					
Age	0.12***	0.10***	0.07***	3.29***	0.11***
Age Squared	-0.001***	-0.001***	-0.001***	-5.340***	-0.001***
Farming Experience	0.0001	0.0013	0.0038*	4.6800***	0.0116***
Farming Experience Squared	-0.00	-0.00	-0.000002**	-4.73***	-0.00001***
Primary Occupation	-1.68***				
Raised on Farm	-0.06	0.08	0.15**	2.64**	0.05
Education	0.02**	0.03**	0.02**	3.26***	0.04***
Farm Variables					
Total Acres	-0.03***	0.00	-0.01	-2.42**	0.00
Total Acres Squared	0.0001	0.0000	0.0000	1.96**	0.0000
Full Owner	-0.02	-0.09*	-0.08*	-11.03***	-0.30***
Tenant	0.10	0.07	0.08	1.45	-0.35***
Government Payments	-0.002***	0.003***	0.001***	10.230***	0.002
Interest Rate	0.01	0.08***	0.09***	6.53***	0.15***
Debt-to-asset	0.01	0.02	0.03	0.67	0.03
Livestock Sales	-0.0002***	0.001***	0.00	-5.37***	0.00
Cash Grain Farms	0.08	-0.29***	0.30***	14.19***	0.19**
High Value Crop Farms	-0.66***	0.41***	-0.11	4.94***	-0.04
Dairy Farms	-0.64***	-0.81***	0.08	-1.15	-0.43***
Household Income	0.00	0.0005***	0.00	-0.50	0.00
Miles	0.02				
Regional Dummy Variables					
Northern Crescent	0.19***	-0.44***	-0.22**	-4.16***	-0.22*
Northern Great Plains	0.18***	-1.12***	-0.36***	4.31***	-0.56***
Prairie Gateway	0.10	-0.71***	-0.55***	0.70	-0.61***
Eastern Upland	0.02	0.74***	-0.13*	-5.45***	-0.21*
Southern Sea Board	-0.14*	0.62***	0.32***	-4.56***	-0.54***
Fruitful Rim	0.01	0.55***	-0.03	-4.09***	-0.59***
Basin and Range	0.10	-0.32**	-0.53***	-4.49***	-0.25
Mississippi Portal	-0.44***	0.43***	-0.53***	-4.22***	-0.72***
Number of Observation = 5099			LR test of $\rho_{ij} = 0 \; \forall \, i, j = 1, \cdots, 5, i \neq j$		
Number of Draws = 73			chi2(10) = 350.744		
Log-Likelihood = -10394.197			Prob > chi2 = 0.00		

***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

Figure 1: Histogram of Risk Attitude measured on Likert Scale