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THE MEASUREMENT OF FARMERS' RISK ATTITUDES USING A NON-STRUCTURAL APPROACH

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Abstract
This study estimates farmers' risk attitudes in Missouri using a non-structural approach over time. The non-structural approach proposed by Antle (1989) allows for multiple outputs and various types of risk faced by farmers and doesn't require specific functional forms for utility or production. This approach can also provide farmers' risk attitudes over time. The results show that farmers' risk attitudes are risk loving and change over time, while farmers' risk attitude is generally assumed to be risk averse and very stable over time. Since this approach has the different definition of risk attitude, the results of this study may be a bit different from previous studies.

1. Introduction

Agricultural production is characterized by considerable risk and significant governmental intervention, and thus aggregate measures of risk aversion and their properties with respect to wealth have very important policy implications (Bar-Shira et al. 1997; Hennessy 1998; Pope and Just 1991). Measurement of risk attitude[1] has a long history and has several approaches. In order to measure

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[1] In this study, risk preference structure means the change of risk attitudes by that of wealth. Decreasing Absolute Risk Aversion (DARA) is an example of risk preference structure. However, risk attitude means decision makers' response to risk, such as risk averse and risk loving.

farmers' risk attitudes, the main methodologies are direct methods using interviews to elicit risk attitudes, and econometric methods using observed data to infer risk attitudes.

Most previous researches on measuring farmers' risk attitudes have focused on a specific region and time, a certain commodity and a specific type of risk. It is hard to find research done on risk attitude measurement over time and in the more aggregated level such as a country or a state. The results of this approach might have limited implications and usefulness since they can be different in accordance with another time, region or commodity. The non-structural approach developed by Antle (1989) can solve this problem and provide risk attitude estimates over time. Farmers' risk attitude over time is useful to analyze policy effects. For example, the effects of decoupled payments can be measured by the change of farmers' risk attitude over time.

Therefore, the main objective of this paper is to identify farmers' risk attitudes in the more aggregated level using Antle's non-structural approach over time.

2. Methodologies to measure risk attitudes

Econometric methodologies to measure farmers' risk attitudes can be grouped under three approaches, which are the reduced-form approach, the structural approach, and the non-structural approach (Saha et al. 1994; Antle 1989).

According to Saha et al. (1994), the reduced-form approach does not deal with estimating the underlying utility function but instead focuses on a certain risk preference structure (Chavas and Holt 1990; Pope and Just 1991). The structural approach has been used in many previous studies. It directly estimates utility functions or risk aversion coefficients, mostly using farm level data (Antle 1987; Love and Buccola 1991; Torkamani and Haji-Rahimi 2001).

The structural approach used in previous research can provide policy implications. However, it requires researchers to assume a specific utility functional form or production technology, and the resulting measured risk attitudes are not invariant to the assumed functional form. For example, if we assume a linear utility function, decision maker's risk attitudes should be Constant Absolute Risk Aversion (CARA) and Constant Relative Risk Aversion (CRRA).

The power expo utility function proposed by Saha (1993) is a more flexible function, as the decision maker's risk attitudes depend on the magnitude of α. Antle (1989) and Gardebroek (2002) pointed out some drawbacks of the structural approach. First, the structural approach mainly focuses on production risk or price risk. Other types of risk (e.g. the risk of policy changes) are usually not taken into account. Second, the stochastic Just-Pope production function often used in these studies only allows for one output. But in reality, most farmers face various types of risk and may produce more than one commodity.

The non-structural approach might solve some problems of the structural approach. It allows for multiple outputs and various types of risk faced by farmers. Moreover, it doesn't require specific functional forms for utility or production. However, the non-structural approach has also disadvantages. First, the use of the non-structural approach is limited due to unavailability of data. In reality, it is hard to obtain panel data at the farm level. Second, after estimating risk attitudes using a non-structural approach, a structural model incorporating the risk attitude estimates must still be estimated in order to study farm production decisions or analyze policy.

3. Models and data

Antle(1987, 1989) published a series of papers to measure decision makers' risk attitude using moments of the profit distribution. In 1989, he developed the non-structural approach based on his previous study. The current study mostly adopts Antle's non-structural approach to measure farmers' risk attitudes.

The Cumulative Distribution Function (c.d.f) of profit is defined as

$$F(\pi \mid \mu_{jt}) \qquad j = 1,...N \quad t = 1,...,T \tag{1}$$

where $\mu_{jt} = (\mu_{1jt},....,\mu_{mjt})$ is a vector of m moments characterizing the profit distribution of farmer j in year t.

The j^{th} farmer's utility function can be expressed as

$$U_{jt} = U(\pi_{jt}, \gamma_{jt}) \tag{2}$$

where π_{jt} = the profit for the j^{th} farmer in year t

γ_{jt} = a parameter vector reflecting the j[th] farmer's risk attitudes in year t

Expected utility from eq (1) and eq (2) is

$$\int U\left(\pi_{jt}, \gamma_{jt}\right) dF\left(\pi \mid \mu_{jt}\right) = EU\left[\mu_{jt}, \gamma_{jt}\right] \quad (3)$$

Therefore, the change in expected utility from year *t-1* to *t* from a change in the profit distribution is expressed by

$$\Delta EU_{jt} = \sum_{i=1}^{m} \frac{dEU_{jt}}{d\mu_{ijt}} \Delta\mu_{ijt} \quad (4)$$

where the $\frac{dEU_{jt}}{d\mu_{ijt}}$ are partial differentials of the expected utility function and the symbol Δ means change from the previous year and *d* means differential.

The first moment μ_{1jt} is the mean value of the profit distribution and $\frac{dEU_{jt}}{d\mu_{1jt}}$ is defined as the marginal utility of mean profits.

Through scaling by $\frac{dEU_{jt}}{d\mu_{1jt}}$, eq (4) is transformed from units of utility to money units

$$\Delta NEU_{jt} = \sum_{i=1}^{m} r_{ijt} D_{ijt} \quad (5)$$

where $\Delta NEU_{jt} = \frac{\Delta EU_{jt}}{(dEU_{jt} / d\mu_{1jt})}$, which means changes in expected utility in money terms.

$r_{ijt} = \frac{\left(dEU_{jt} / d\mu_{ijt}\right)}{\left(dEU_{jt} / d\mu_{1jt}\right)}$, which implies farmers' risk attitude[2], and

2 The mathematical proof is given in the appendix 2 of Antle (1987)'s paper. In that paper,

$$r_{ij} = \frac{\partial u[\mu_j^m, \gamma_j]}{\partial \mu_{ij}} / \frac{\partial u[\mu_j^m, \gamma_j]}{\partial \mu_{1j}} = \frac{\partial EU}{\partial \mu_i} / \frac{\partial EU}{\partial \mu_1} = \frac{U^i(\mu_{1j})}{i!} / E[U^1] = \frac{U^i(\mu_{1j})}{E[U_j^1]i!}$$

where γ_j means a parameter vector reflecting the j[th] farmer's risk attitudes

$D_{ijt} = \Delta\mu_{ijt}$, which denotes a change in the profit distribution.

ΔNEU_{jt} is assumed to be distributed in the population in year t with a mean(α) and variance(σ^2_{jt}) that is,

$\Delta NEU_{jt} = \alpha_t + \varepsilon_{jt}$

where

$$E\left[\varepsilon_{jt}\right] = 0 \quad \text{and} \quad E\left[\varepsilon^2_{jt}\right] = \sigma^2_{jt} \tag{6}$$

Risk attitudes are also assumed to be distributed in the population in year t as

$$r_{ijt} = \beta_{it} + \nu_{ijt} \quad \text{for } i \geq 2 \tag{7}$$

where

$E\left[\nu_{ijt}\right] = 0$, $E\left[\nu^2_{ijt}\right] = \tau^2_{ijt}$ and $\beta_{it} =$ the i^{th} characteristic of risk attitudes at the population mean in year t.

Since $r_{1jt} \equiv 1$, eq (5) is rewritten by substituting with eq (6) and eq (7).

$$-\alpha_t + D_{1jt} + \sum_{i=2}^{m} \beta_{it} D_{ijt} = w_{jt} \tag{8}$$

where

$$w_{jt} = \varepsilon_{jt} - \sum_{i=2}^{m} \nu_{ijt} D_{ijt}$$

According to Antle(1989), $-2\beta_2$ approximates the absolute Arrow-Pratt measure of risk aversion and $6\beta_3$ is an approximation to the absolute measure of downside risk aversion.

In order to estimate farmers' risk attitudes from eq (8), we need the

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U^i denotes the i^{th} derivative of U.

When i=2, $r_{2j} = \dfrac{U''}{U'2}$. So $-2r_{2j} = -\dfrac{U''}{U'}$ means the absolute Arrow-Pratt measure of risk aversion.

change in the moments of the profit distribution ($D_{ijt} = \Delta\mu_{ijt}$). Suppose the Probability Density Function (p.d.f) of profit, $f(\pi \mid x_{jt}, p_t, w_t)$, is conditional on a vector of variable inputs x_{jt}, output prices p_t, and input prices w_t.

By definition, the moments of the profit distribution are

First moment: $\mu_{1jt}(x_{jt}, p_t, w_t) = \int \pi f(\pi \mid x_{jt}, p_t, w_t) d\pi$ (9)

Higher Moments: $\mu_{ijt}(x_{jt}, p_t, w_t) = \int (\pi - \mu_{1jt})^i f(\pi \mid x_{jt}, p_t, w_t) d\pi, i \geq 2$

By assuming a linear relation between the moments and the explanatory variables,

$$\mu_{ijt}(X) = \delta_i X_{jt} \quad (10)$$

where X_{jt} = explanatory variables(x_{jt}, p_t, and w_t)

Then, since profits are random and $E(\pi_{jt}) = \mu_{1jt}$, the first moment equation is

$$\pi_{jt} = \delta_1 X_{jt} + \eta_{1jt} \quad (11)$$

where $E(\eta_{jt}) = 0$

Higher moment equations are[3]

$$\mu_{ijt}(X) = E[(\pi_{jt} - \mu_{1jt})^i] = E(\eta_{1jt}^i) \equiv \delta_i X_{jt} + \eta_{ijt}, \quad i \geq 2 \quad (12)$$

In order to obtain higher moments, we first need to estimate eq (11) and then save the residual (η_{1jt}). By multiplying by itself, η_{1jt}^i is calculated. Then equation (12) can be estimated by regressing η_{1jt}^i on X_{jt}. From the estimation of eq (11) and eq (12), we obtain the first and the higher moments, and make a difference of moments from t-1 to t ($D_{ijt} = \Delta\mu_{ijt}$).

To estimate eq (8), it is rearranged as

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[3] To derive higher moment equations, mathematical manipulations are applied as the following; $\pi_{jt} - \mu_{1jt} = \delta_1 X_{jt} + \eta_{jt} - \mu_{1jt} = \delta_1 X_{jt} + \eta_{1jt} - \delta_1 X_{jt} = \eta_{1jt}$

$$D_{1jt} = \alpha_t - \sum_{i=2}^{m} \beta_{it} D_{ijt} + w_{jt} \tag{13}$$

If mean risk attitude (β_{it}) changes over time, it can be specified as $\beta_{it} = \beta_{i0} + \beta_{i1} d_t$, where $d_t =$ time dummy variables. And time varying parameter (α_t) is also expressed as $\alpha_t = \alpha_0 + \alpha_1 d_t$.

By substituting those two specifications into eq (13), the final equation to be estimated for measuring farmers' risk attitudes is derived as

$$D_{1jt} = \alpha_0 + \alpha_1 d_t - \sum_{i=2}^{m} (\beta_{i0} + \beta_{i1} d_t) D_{ijt} + w_{jt} = \alpha_0 + \alpha_1 d_t - \sum_{i=2}^{m} \beta_{i0} D_{ijt} - \sum_{i=2}^{m} \beta_{i1} d_t D_{ijt} + w_{jt} \tag{14}$$

Although Antle (1989) and Gardebroek (2002) developed and used the non-structural approach they did not measure farmers' risk attitude over time. They estimated an average farmers' risk attitude for several years assuming risk attitudes are stable over time. However, Antle (1989) left the possibility of time dependence of the mean risk attitudes and argued that it can be measured by the above manipulation ($\beta_{it} = \beta_{i0} + \beta_{i1} d_t$). In actual estimation of moment equations for eq (11) and eq (12), implicit inputs, the crop portion of receipts, the agriculture portion of proprietors, and time dummy variables are used as explanatory variables. Other characteristic variables are used as exogenous instruments where necessary[4]. Input and output prices are not included in the estimated equations. In reality, each county within a state may face similar input and output prices. As Antle (1987) pointed out, the profit distribution is equivalent to a revenue or output distribution if input prices and output prices are nonstochastic.

Actual model specifications for the first and higher moments are

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4 In order to estimate moment equations, Gardebroek (2002) used fertilizer, seeds and plants, pesticides, contractor work, hired labor, family labor, machinery, and land as a set of independent variables. Antle (1989) used land in crops, total fertilizer quantity used in crop production, machinery input, human labor input, animal labor input, total value of land owned, area irrigated, an interaction term between area irrigated and fertilizer used, an index of crop diversification, and time dummy.

$$FM = \alpha_f + \beta_{f1} NLIVE + + \beta_{f2} NFEED + \beta_{f3} NSEED + \beta_{f4} NFERT + \beta_{f5} NLABR$$
$$+ \beta_{f6} NRATIO + \beta_{f7} NNUM + \gamma_{ft} DM + e_f \qquad (15)$$

where

FM=first moment(net realized income, $ million) deflated by CPI
NLIVE(million $)=Live animal purchased($1,000)/live animal price index×100/1000
NFEED(million $)=Feed purchased($1,000)/feed price index×100/1000
NSEED(million $)=Seed purchased($1,000)/seed price index×100/1000
NERT(million $)=Fertilizer purchased($1,000)/fertilizer price index×100/1000
NLABR(million $)=Labor purchased($1,000)/wage index×100/1000
NRATIO(%)=Crop revenue/(crop revenue+livestock revenue)×100
NNUM(%)= # of farm proprietors/(# of farm proprietors+# of non farm proprietors)×100
DM=time dummy variables from 1993 to 2002

$$HM = (e_f)^h = \alpha_h + \beta_{h1} NLIVE + + \beta_{h2} NFEED + \beta_{h3} NSEED + \beta_{h4} NFERT + \beta_{h5} NLABR$$
$$+ \beta_{h6} NRATIO + \beta_{h7} NNUM + \gamma_{ht} DM + e_h \qquad (16)$$

where HM = higher moments. If superscript $h=2$, HM is the second moment.

To estimate the empirical model for measuring farmers' risk attitudes in Missouri, data on production costs, profits and farmers' characteristics are needed. This study uses county-level data from the Regional Economic Information System (REIS) database of the Bureau of Economic Analysis (BEA) to measure farmer's risk attitude in each state. Each county is treated as if it is a single farm. Using this approach, we can measure changes in the level and variance of profit over time and thus measure changing levels of absolute risk aversion at the state level.

The data covers the period from 1993 to 2002. The appendix 1 is a data summary showing the mean and standard deviation for each variable used in this study. Profit in this study means realized net income, defined as cash receipts from marketing plus other income, including government payments, minus total production expenses. Profits are expressed in real terms by deflating by the Consumer Price Index (CPI). Input variables used in the estimation of farmers' risk attitudes are purchased livestock, feed, seed, fertilizer and agricultural chemicals, petroleum products, and hired farm labor. Those variables in the original data are expressed in value terms. Thus, to convert these value terms to implicit quantity terms, the value variables are deflated by their respective own-price indices having 1990-92 bases. Input prices were obtained from U.S. Department of Agriculture-National Agricultural Statistics Service (USDA-NASS).

Since the value of fertilizer and agricultural chemicals are combined in the original data, a weighted input price index was calculated using annual weights for input components (Agricultural Prices, USDA-NASS). As county characteristic variables, the farm portion of proprietors is defined as the number of farm proprietors over the number of farm and non-farm proprietors, which may indicate the share of agriculture in the economy of each county. The crop portion of revenues is calculated by dividing crop revenue by crop and livestock revenue. This indicator reflects the relative importance of crop production in the agriculture of each county.

4. Estimation and Results

As mentioned earlier, the first moment and higher moments have to be estimated in order to measure risk attitudes. The first, second and third moment equations derived in the previous section are estimated for farmers in Missouri. Appendix 2 shows the results of parameter estimation.

In the first moment equation, most input variables have a positive sign as we expect. Although the coefficient of *SEED* is negative, it is not statistically significant. Net realized income is increasing with the crop portion of total receipts (*NRATIO*) and the agriculture portion of total proprietors (*NNUM*). There may exist heteroskedasticity[5] and multicollinearity problems in the estimation. The estimated parameters are still consistent although not efficient when those problems exist (Kennedy 1998; Wooldridge 2003). So, those issues are not a serious problem in this study because they don’t affect the consistency of the difference in the moments. We don’t have much interest in the results of the moment equations themselves. We use the difference of estimated moments to estimate a risk attitude equation. Testing the overall significance of

[5] In the estimation results, standard errors have been corrected for heteroskedasticity

the regression for the first moment equation using a F-test rejects the null hypothesis that all slope parameters are zero.

The results of the second and the third moment equations indicate that many coefficients are not statistically significant. The test of overall significance of the second moment equations rejects the null that all parameters are equal to zero, while the test does not reject this hypothesis for the third moment equations. Therefore, the first moment and the second moment are selected to estimate a risk attitude equation.

Using the difference of the first and the second moments estimated from the previous step, equation (14) is estimated. According to Gardebroek (2002), there are two potential problems in the estimation. First, the residual terms (w_{jt}) may be expected to be heteroskedastic given the relation between the w_{jt} and D_{ijt} as shown in eq (8). Also, there is likely to be an endogeneity problem. The residuals(w_{jt}) partly reflect differences in risk attitudes that are expected to affect the moments of the profit distribution. That is, the covariance between w_{jt} and D_{ijt} may not be expected to be zero in eq (14). In that case, we should use Instrumental Variable(IV) or Generalized Method of Moments (GMM) estimation instead of Ordinary Least Square (OLS) estimation. Therefore, the choice of econometric methods depends on the results of hypothesis tests. First, we need to conduct an endogeneity test using the Hausman test. The choice between OLS estimation and IV or GMM estimation depends on the testing results. If endogeneity exists, an OLS estimator is not consistent even asymptotically, so we have to use either an IV or GMM method (Hayashi 2000; Baum, Schaffer, and Stillman 2003). Second, we test for heteroskedasticity with a White test or a Breusch-Pagan test. The result is the criteria for choosing between IV and GMM. When there is a heteroskedasticity problem, a GMM estimator is more efficient than an IV estimator. If heteroskedasticity is not present, a GMM estimator is no worse asymptotically than an IV estimator (Baum, Schaffer, and Stillman 2003). But Hayashi (2002) points out the disadvantage of using a GMM estimator - the optimal weighting matrix $\hat{S}$ at the core of an efficient GMM is a function of fourth moments, and obtaining reasonable estimates of fourth moments requires very large sample size. Therefore, if the error is homoskedastic, IV is preferable to an efficient GMM (Baum, Schaffer, and Stillman 2003). Lastly, we need to choose appropriate instruments. Relevant instruments have to satisfy two requirements. Appropriate instruments should be correlated with the included endogenous variables and orthogonal to the error term as well (Wooldridge 2002; Baum, Schaffer, and Stillman 2003). To test the relevance and validity of instruments, we have to check the correlation between endogenous variables and instruments and conduct the overidentifiying restriction test using Sargan's statistic or the J-statistic. In reality, it is hard to find appropriate instruments that fully satisfy both requirements. Recently, some papers (Klepinger, Lundberg, and Plotnick 1995; Staiger and Stock 1997; Stock, Wright, and Yogo 2002) point out the problem of weak or wrong instruments[6]. In some cases, OLS estimation is better than IV/GMM estimation with weak instruments. Thus, we also need to consider the pertinence of instruments.

Candidates of excluded instruments for a potential endogenous variable such as the difference of the second moment (*DSMOM*) are the difference in government payments (*GOVERN*), the crop portion of revenues (*NRATIO*), the agriculture portion in the economy of each county(*NNUM*), and input variables.

Instruments should be correlated with an endogenous variable and uncorrelated with the error term. Wooldridge (2002) mentions that the first requirement of instruments to have a high correlation with an endogenous variable can be examined by the fit of the first stage regression[7]. Table 1 gives F-statistic in the case of one potential endogenous variable (*DSMOM*). This rejects the null that all excluded instruments are different from zero at the conventional critical level, which indicates that instrument candidates satisfy the first requirement.

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[6] In actual practice, it is hard to identify a set of appropriate instruments. Klepinger et al.(1995) suggested a technique for choosing a set of instruments.

(1) Regress the residuals from IV estimation on all potential instruments and conduct the overidentifying restriction test. If the test fails, drop the instrument having the highest t-value. And do the first step again until satisfying the result of the overidentifying restriction test.

(2) With a set of instruments passed the first step, run backward-stepwise regression until each identifying instrument remaining in the first stage model achieves a certain level of significance.

In the study, we partially use their technique to find relevant instruments.

[7] The first regression is a reduced form regression of the endogenous variable on the full set of instruments (Baum, Schaffer, and Stillman 2003)

Table 1. Tests and choice for relevant instruments[8]

1st requirement	2nd requirement		Excluded Instruments
F-statistic	Hansen's J statistic	Prob > χ^2_{L-K}	
F(2, 947) = 25.33	2.60	0.11	*DFERT, DFARM*

Note: F-test is the joint significance test of the excluded instruments in the first-stage regression.
Where *DFERT*: the difference of fertilizer and ag.chemical from t-1 to t,
DFARM: the difference of the number of farm proprietors from t-1 to t.

Regarding the second requirement of relevant instruments, we can test whether or not the instruments are uncorrelated with the error term, using an overidentifying restriction test when the number of instruments excluded from the equation exceeds the number of included endogenous variables (Baum, Schaffer, and Stillman 2003). In the GMM estimation, Hansen's J-statistic is generally used for testing the overidentifying restrictions. The result of an overidentifying restriction test using the Hansen J-statistic shows that all states accept the null that all instruments are uncorrelated with the error term at the conventional critical level (Table 1). It implies that the instruments satisfy the orthogonality condition.

From the two tests for instruments, we conclude that selected instruments are appropriate as excluded instruments (Table 1), which satisfy the two requirements.

Now, given those instruments, an endogeneity test is conducted for the difference of the second moment (*DSMOM*). For the endogeneity test, Durbin-Wu-Hausman (DWH) test is used. The result of DWH test rejects the null hypothesis that the regressor is exogenous (DWH statistic=492.58, p-value =0.0). It implies the second moment variable is endogenous, so that we must use the IV or GMM method instead of OLS estimation.

The conclusion of these hypothesis tests is that GMM estimation is

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8 As instruments, Gardebroek (2002) used family labour, machinery, land, seeds and plants, contractor work, a standardized measure of size and an indicator of the region for organic farms and labour, land, pesticides, a standardized measure of size and an indicator of the region for non-organic farms. Antle (1989) chose acreage, machinery input, animal labor and their squares and interaction terms, value of land owned, irrigated area, an index of farm size, and time dummy as appropriate instruments. All variables except time dummies are in difference form.

adopted. Since total observations used in this study are very large, the choice of GMM estimation is desirable, regardless of the result of a homoskedasticity test. The GMM estimates for the derived risk attitude equation are given in Appendix 3. All variables are significant at the conventional critical level. And the result of the overall significance test (F-test) rejects the null that all parameters are equal to zero.

The coefficient of absolute risk aversion (ARA) is calculated as $-2\beta_{it} = -2(\beta_{i0} + \beta_{i1})$ from the risk attitude equation (Antle 1987, 1989)[9]. The calculated ARA is shown in Table 2. Farmers' risk aversion coefficients are negative and change over time. Although negative risk aversion coefficients means producers are risk loving, we cannot be sure whether it is risk loving or risk neutral, because there are no formal criteria for how large the ARA coefficient can be and still be considered risk neutral. The coefficients of Relative Risk aversion (RRA) are also calculated as all negative over time (Table 2).

Table 2. The coefficients of risk aversion

	ARA	RRA
1995	-0.48	-1.03
1996	-0.31	-0.77
1997	-0.24	-1.24
1998	-0.34	-0.76
1999	-0.52	-0.53
2000	-0.47	-1.23
2001	-0.23	-0.58
2002	-0.29	-0.07

Note: RRA is calculated as multiplying ARA by an average net income.

5. Conclusion

This research unlike many previous studies using a structural approach adopted Antle’s non-structural approach since it is a more appropriate method for farmers’ actual situation. In other words, farmers face many types of risk and produce more than one commodity in many cases. The non-structural approach

[9] A positive number of ARA means risk loving and a negative value of ARA indicates risk averse.

considers this situation of farmers, while other methods focus on a certain type of risk and a specific commodity.

This study has a different result than conventional wisdom about farmers' risk attitudes. The analysis found that farmers' risk attitudes are risk loving and change over time, while farmers' risk attitude is generally assumed to be risk averse and very stable over time. However, some empirical studies show that this is not always true (Burfisher and Hopkins 2004). Some studies show farmers' risk attitudes are risk loving, although risk aversion cases are more frequent. Moreover, it is hard to find an empirical study estimating risk attitudes over time. The fundamental difference between this study and others is the definition of risk attitude. Other studies measuring risk attitude focus on a specific type of risk like production risk, price risk or policy risk, and a specific place and year. But in this study, risk attitude is defined as the response of farmers to the change of their circumstances for agricultural production. It includes all types of risk. In other words, risk attitude is revealed as their resource allocation reacts to changes in their production circumstances. Also, farmers' risk attitude is measured at a more aggregate level as risk attitude at the state level. That is why the results of this study may be a bit different from previous studies.

Appendix 1. Data summary, 1993-2002

Variable name	Unit	Mean	S.D.
Profit	Million $ of 1990-1992	2.45	4.65
Live	Million $ of 1990-1992	5.24	7.49
Feed	Million $ of 1990-1992	6.80	10.70
Seed	Million $ of 1990-1992	1.48	1.41
Fert	Million $ of 1990-1992	5.17	4.80
Fuel	Million $ of 1990-1992	1.56	1.02
Labr	Million $ of 1990-1992	2.63	3.16
Crop portion	%	41.51	27.33
Number of farmers	1,000	1.02	0.40
Agriculture portion	%	35.42	15.38

Note: 1) profit and government payment are deflated by CPI.
2) The portion of crop is calculated as crop revenue/(crop revenue+livestock revenue)
3) Agriculture portion is # of farm proprietors/(# of farm proprietors + # of nonfarm proprietors)

Source: Bureau of Economic Analysis

Appendix 2. The estimation results of moment equations

MO	1st		2nd		3rd	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
y94	-0.98*	0.47	-9.50*	3.72	-99.94	64.62
y95	-0.82	0.57	0.57	6.69	98.96	154.17
y96	-0.61	0.48	-8.77*	3.85	-64.95	63.76
y97	2.21*	0.50	-6.39	3.95	-59.91	64.86
y98	-1.06*	0.46	-13.11*	3.79	-107.45*	64.65
y99	-2.15*	0.48	-9.31*	3.68	-127.87*	64.88
y00	-0.57	0.46	-11.55*	3.73	-122.45*	65.61
y01	-0.43	0.47	-8.29*	4.12	-158.67*	77.92
y02	-2.81*	0.49	-6.41*	3.89	-144.42*	69.23
nratio	0.03*	0.01	0.03	0.08	-1.45	1.55
nlive	0.02	0.02	-0.26	0.17	-5.51	3.60
nfeed	0.13*	0.01	0.26*	0.08	2.36	1.60
nseed	-0.11	0.40	-6.69*	3.46	62.95	67.26
nfert	0.47*	0.11	3.90*	1.14	0.79	24.23
nlabr	0.23*	0.05	0.98*	0.34	13.04*	6.93
nnum	0.01	0.01	-0.13*	0.04	-0.75	0.85
_cons	-2.37*	0.45	6.80*	3.34	73.00	59.19
obs	1068		1068		1068	
R-squared	0.58		0.21		0.05	
F(16, 1051)	54.48		3.55		1.24	
Prob >F	0.00		0.00		0.23	

Note: a. Standard errors(S.E.) have been corrected for heteroskedasticity
b. * indicates that the coefficients of those variables are significant at the 10% critical level.

Appendix 3. The result of GMM estimation for risk attitudes

	Coef.	Std. Err	t	p-value
y95	-21.948	3.520	-6.240	0.000
y96	-18.094	3.555	-5.090	0.000
y97	-17.234	3.517	-4.900	0.000
y98	-21.871	3.518	-6.220	0.000
y99	-21.862	3.516	-6.220	0.000
y00	-17.759	3.518	-5.050	0.000
y01	-19.939	3.517	-5.670	0.000
y02	-22.552	3.517	-6.410	0.000
s95	-2.055	0.391	-5.250	0.000
s96	-2.137	0.397	-5.380	0.000
s97	-2.173	0.395	-5.510	0.000
s98	-2.123	0.392	-5.410	0.000
s99	-2.032	0.394	-5.160	0.000
s00	-2.061	0.393	-5.240	0.000
s01	-2.179	0.392	-5.560	0.000
s02	-2.148	0.396	-5.430	0.000
dsmom	2.294	0.392	5.850	0.000
_cons	19.778	3.517	5.620	0.000
obs	966			
F(17, 948)	5590.77			
Prob >F	0.00			

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