Specification and Estimation of Heterogeneous Risk Preference

Zhengfei Guan
Assistant Professor
Department of Agricultural, Food, and Resource Economics
Michigan State University
East Lansing, MI 48823
Email: guanz@msu.edu
Phone: 517-355-2161

Feng Wu
Research Assistant
Department of Agricultural, Food, and Resource Economics
Michigan State University
East Lansing, MI 48823
Email: wufeng@msu.edu
Phone: 517-355-1695

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Abstract

In this paper we specify and estimate producers' risk preference using farm data. We allow heterogeneous risk preference across individuals and propose a specification to model the heterogeneity. We base farmers' decision making on a utility maximization framework and incorporate both market and production risk in farmers' decision making. We do not assume any specific utility function or distribution of risk. The empirical application to farm level production data shows that risk preference does vary among individuals; demographic and institutional factors have significant effect on producers' risk attitude.

Key Words: Risk Preference, Heterogeneity, Production Risk, Price Risk, Demographics, Subsidy, GMM

Risk and uncertainty is the hallmark feature of agriculture. In the literature production risk has been widely studied. Just and Pope's (1978) seminal work provides an important framework for production risk analysis. This framework models the effect of inputs on both the yield level and the yield risk and allows for independence between the effects. Certain input use may reduce or increase risk. This property may be used as risk management means, and consequently lead to the joint analysis of production risk with risk preference analysis (see e.g., Love and Buccola 1991, Saha, Shumway, and Talpaz 1994, Saha 1997, Kumbhakar 2002) assuming farmers maximize their utilities. While joint analysis is relevant, the immediate problem is that it often imposes specific structures of risk preference with specific functional forms of utility functions. For example, Love and Buccola explicitly assume the negative exponential utility function that imposes a constant absolute risk aversion. However, there is substantial evidence in favor of decreasing absolute risk aversion (Saha 1997). Saha, Shumway and Talpaz (1994) propose Expo-Power utility function, which has the flexibility to accommodate decreasing, constant, or increasing absolute risk aversion and decreasing or increasing relative risk aversion. Less restrictive assumption on utility function is consistent with mixed findings on the nature of risk aversion in the empirical studies (Kumbhakar, 2002). There has been a trend of relaxing restrictive assumptions in the literature. However, in all these studies, homogeneous risk preference is assumed for all producers with no exception[1]. That is, given wealth level, producers all have the risk attitude, reflected by a single risk preference coefficient. Clearly, this is inconsistent with the reality. The main objective of this paper is to study the heterogeneity of risk attitude and factors affecting the heterogeneity, using observed farm production data.

[1] Antle (1987) estimated estimates a single risk coefficient for a sample of Indian farmers, but he further calculated the standard error of the risk aversion coefficient. Eggert and Tveteras (2004) estimated the population parameters that describe the distribution of individual parameters.

Decision Problems under Uncertainty

Assume the production technology is a general form of the Just-Pope production function. In particular,

(1) $y = f(x,z) + g(x,z)\varepsilon$

where x is a $j \times 1$ vector of variable inputs, z is a $q \times 1$ vector of quasi-fixed inputs, y denotes random output, and random variable ε captures production uncertainty, with mean 0 and variance of 1[2]. $f(\cdot)$ is the mean-yield function (or deterministic component), $g(\cdot)$ is the yield-variance function (or risk component). One of the central requirements JP propose for the specification of risky production technologies is that there should be no a prior restrictions on the risk effects of inputs, that is, $\partial \operatorname{var}(y) / \partial x_j = \partial g(\cdot)^2 / \partial x_j$ could take on positive, zero or negative values. In other words, the production function should be general enough to accommodate both increasing and decreasing output risk from inputs.

When analyzing farmers' decision making when faced with risks, expected utility is the common analytical framework. It can be specified as

(2) $\underset{x}{Max}\, H = \left[E[U(W_1)]\right]$

where $U(\cdot)$ is the utility function, and W_1 is the ending wealth, and is defined as

(3) $W_1 = W_0 + py - r'x - C$

where W_0 is real initial wealth, ***r*** is the vector of variable inputs price, *C* is fixed costs. Substituting the JP production technology into eq. (3) and optimizing with respect to the level of input use with the framework in (2) can provide some insights into the producers' risk preferences with certain assumptions on the functional form of utility function and the

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[2] $g(x,z)$ contains the constant term to normalize the error term. In the absence of the constant term, the variance of ε has to be rescaled to σ_ε^2.

distribution. This framework only looks at production risk when analyzing farmers' decision making, which is unlikely to be the case in reality. We further incorporate market risk into this framework. When producers' make production decision, market price risk is an important factor to be considered. This is particularly true for agriculture: when farmers make production decisions, they don't observe the price of their products when they are harvested. Their perceptions about the price risk will certainly impact on their production decision. We specify the price risk as:

(4) $p = p^* + e$

where p* is the expectation of the future output price, and the error term e captures the price risk. e has symmetric distribution with mean zero, variance σ^2. Substitute (4) into (3) and the utility of ending wealth becomes

(5) $U(W_1) = U(W_0 + (p^* + e) f(x,z) + (p^* + e) g(x,z)\varepsilon - rx - C)$

To maximize the expected utility, the j first-order conditions corresponding to j inputs are:

(6) $E[U'(W_1)((p^* + e) f_j + (p^* + e) g_j \varepsilon - r_j)] = 0$

Where $U'(.)$ is the first derivative of the utility function, f_j and g_j are the first derivative of the f(.) and g(.) with respect to input x_j, r_j is the price of the x_j. After expansion and algebraic manipulation, eq. (6) becomes:

(7) $$p^* f_j - r_j + \frac{f_j E[U'(W_1)e] + g_j p^* E[U'(W_1)\varepsilon] + g_j E[U'(W_1)\varepsilon e]}{E[U'(W_1)]} = 0$$

The difficulty with the eq. (7) lies in the expectation terms. To derive the first derivative of the utility function and the subsequently the expectation of the multiplicative terms within the square brackets, different specifications of the utility function and the distributions have been assumed in the literature. As discussed earlier, an explicit analytical solution often requires restriction assumptions. Here we take the Taylor expansions of the $U'(W_1)$ term at the point where $\varepsilon = e = 0$, that is, at the point $W_1 = W_0 + p^* y - r' x - C \equiv \pi$, this gives:

(8) $$U'(W_1) = U'(\pi) + U''(\pi)(e \cdot f(x,z) + (p^* + e) g(x,z)\varepsilon) + \frac{1}{2} U'''(\pi)(e \cdot f + (p^* + e) g \cdot \varepsilon)^2$$

Substitute eq. (8) into the first order conditions (FOCs) in eq. (7), we have

(9)

$$p^* f_j - r_j + \frac{f_j(U''(\pi) f(.)\sigma^2 + U'''(\pi) p^* g^2(.)\sigma^2) + g_j p^*(U''(\pi) g(.) p^* + U'''(\pi) f(.) g(.)\sigma^2) + g_j U''(\pi) g(.)\sigma^2 + U'''(\pi) f(.) g(.) p^* \sigma^2]}{U'(\pi) + \frac{1}{2} U'''(\pi)[f^2(.)\sigma^2 + g^2(.)\sigma^2 + p^{*2} g^2(.)]} = 0$$

Note that the Arrow-Pratt absolute risk aversion (AR) is defined $-\frac{U''(.)}{U'(.)}$ and that the down-side risk (DR) is $\frac{U'''(.)}{U'(.)}$. Divide the denominator and numerator of eq. (9) with $U'(\pi)$ and use the AR and DR definitions and rearrange, eq. (9) becomes

(10)

$$p^* f_j - r_j + \frac{f_j[f(.)\sigma^2(-AR) + p^* g^2(.) \cdot DR \cdot \sigma^2] + g(.) \cdot g_j \cdot [(p^{*2} + \sigma^2)(-AR) + 2 f(.) p^* DR \cdot \sigma^2]}{1 + \frac{1}{2} DR(f^2(.)\sigma^2 + g^2(.)\sigma^2 + p^{*2} g^2(.))} = 0$$

The equations in (10) can be used to estimate the risk preferences of the producer. Note $DR = -AR' + AR^2$, where AR' is the first derivative of AR w.r.t. π.

Heterogeneous Risk Preference

We believe that risk preference varies across individuals and do not pursue a single risk preference coefficient for all producers. In this paper, we allow for heterogeneity of risk preference by specifying individuals' risk preference as a function of producers characteristics. It is natural that certain factors such as education and age may well have an impact on producers' risk attitude. The relationship of farmers' risk preference with his socioeconomic characteristics has been tested (Binswanger 1980; Dubois 2001). We directly specify AR as

(11) $$AR_i = h(W_i, O_i, \gamma)$$

where W is wealth status, O are other factors that impact risk preference. γ are parameters to be estimated.

Factors one can think of immediately is the demographic characteristics, including age and education of the individual. In addition, some institutional factors can also influence the risk preference. For example, the agricultural policy may significantly impact the risk aversion of farmers.

Data

The farm data used in this study were from the farm accountancy data network of the Dutch Agricultural Economics Research Institute (LEI). Panel data from 343 cash crop farms with a total of 1,709 observations were available for the period 1990–99. The panel is unbalanced

One aggregate output and 6 inputs are distinguished. Inputs include land, labor, capital, fertilizer, pesticide, and seeds. Labor is measured in man-years, and land is measured in hectare. All other inputs are measured in thousand euros at 1990 prices. Capital was capital stock aggregated over machinery, equipment, and buildings in replacement values. As the crop rotation affects yield, we also account for its effect by a proxy variable: the percentage of farm area under root crops.

We also have farmer demographic information, which includes age, education, number of family members involved in the production. Wealth information (measure with the amount of equity) and the amount of subsidy the producer received from the EU and national government are also available.

Empirical Model and Estimation

The empirical application requires specific function forms of the aforementioned models. In this section, we present empirical functions and then describe the estimation techniques.

Model Specification

Our production function is specified as

$$(12) \qquad E(y_{it}) = f(x) = \sum_{t=91}^{99} d_t D_t + \delta R + \alpha_0 + \sum_{j=1}^{6} \alpha_j x_{jit} + \sum_{j=1}^{6}\sum_{k=1}^{6} \alpha_{kj} x_{kit} x_{jit} + c_i$$

where y_{it} is farm output of the *i*-th producer at period *t*. D_t is the year dummy; α are slope parameters to be estimated. $x_1, x_2, x_3, x_4, x_5, x_6$ represent land, labor, capital, fertilizer, pesticide, and seed, respectively. c_i is the individual effect.

The risk function is specified as:

$$(13) \qquad g(x,\varepsilon) = \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6) \cdot \varepsilon$$

where β are parameters, and ε is white noise which is assumed to have zero mean and unit variance.

So we specify AR as a function of wealth, demographic, and institutional factors:

(14) $$AR = \gamma_0 + \gamma_1 \pi + \gamma_2 AGE + \gamma_3 EDU + \gamma_4 FAM + \gamma_5 SUB + \zeta$$

where γ are parameters to be estimated, AGE is age of the producer, EDU is the education level, FAM is the family information (e.g. family involvement in the production) , SUB is the amount of subsidy the producer received, ζ is error, which may contain other characteristics impacting risk preference. To avoid biased analysis due to potential omitted variables, robust estimation procedure is required. Generally, older farmers have higher risk aversion, as they generally are in the farm consolidation or exit phase, in which case they are more conservative in management and investment. A lower education level is associated with increased risk aversion (Rosen, Tsai, and Downs 2003), which may be due to the lack of the judgment. However, some argue that better educated individuals are more informed of the risk and its consequences and therefore might be more risk averse. The degree of family members' involvement in the business presumably influences the farmer's risk perception. More family participation may make farmers more cautious in decision making and make them more motivated to run the business efficiently in order to have a secure livelihood for the whole family. The linear function does not dictate that AR be positive (risk aversion), because of heterogeneity. Therefore, we can test hypotheses on risk preferences based on the specification: (i) Risk neutrality $\gamma_0 = \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0$; (ii) Heterogeneity of farmer's preferences can be tested with the null hypothesis of $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0$. Each factor's effect on risk preference can be concluded from the sign of respective parameters and their statistical significance.

Estimation

The parameters of equations (12), (13) and (14) may be estimated jointly with the first order conditions in (10).. However, such a procedure involves a costly iterative solution of nonlinear equation systems. Convergence in the iterative procedure depends critically on appropriate parameter starting values (Saha, Shumway and Talpaz 1994, pp. 178). To avoid the impact of optimization error in the behavioral functions (10) on the pure technical parameters of the production technology, we first estimate the production function, and then use the parameters to construct regressors in the first order conditions. The main difference of this method to Just-Pope type estimates is accounting for inputs endogeneity. Under the utility optimization framework, variable inputs are control variables and therefore endogenous. We use instrumental variables to address endogeneity.

First, we estimate the parameters in Eq. (12) with GMM. Instrumental variables include all fixed inputs (i.e., land, labor, and capital). Due to strict labor protection policy in the Netherlands, labor is treated as a fixed input. Also, most of the farm labor are family labor, the supply of which is rather rigid. This is an additional reason to treat it as fixed. Lag variable inputs and the their second order terms are also used as instruments.

We used the differenced GMM (Arellano and Bond, 1991) to address the fixed effects in the panel data estimation. We take the residuals from the estimation of eq. 12 and use it for the estimation of the variance function g(.). It follows

(15) $$\hat{u}^2 = g(x)^2 \varepsilon^2$$

Taking logs of (15), We obtain the following:

(16) $$\frac{1}{2}\log(\hat{u}_t^{\ 2}) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \frac{1}{2}\log \varepsilon_t^{\ 2}$$

Again, we used the difference GMM to estimate (16). 2SLS is applied to the above function to estimate the parameters β .

After we estimated the technology parameters, we proceed with the estimation of the FOCs in eq. (10) which includes risk preference of eq. 14. The technology parameters are used to compute $f(x)$, $g(x)$, $f_j(x)$ and $g_j(x)$ needed for the estimation. Eq. (10) is highly nonlinear, and there are no closed form solutions for risk preferences. We used GMM as it does not require a closed form for estimation, and it also accounts for endogeneity. We use previous-year output prices as the expected price in farmers' optimization problem. This is equivalent to assuming that the price follows random walk, which is frequently assumed in the literature.

The first order conditions in eq. (10) were derived based on the assumption that all agents (producers) maximize using exactly the same rule and, in addition, there is no deviation from that rule. This is common practice in the literature when estimating FOCs. However, we believe this assumption is unlikely to hold and should be relaxed, because agents' optimization rule may vary across individuals, and there may be optimization error. Therefore, we allow 1) systematic optimization error, represented by a constant, 2) individual specific deviations from the FOCs, which is addressed in the nonlinear estimation by using the Mundlak approach (Mundlak, 1978).

Results

Our main estimation results are presented in table 3, and table 4 contains estimates of the risk aversion measures.

Table 1. Estimates of Mean Production Function Parameters

Parameter	Estimate	Std Err
t91	-0.514	3.644
t92	-1.291	5.587
t93	46.699***	7.569
t94	44.181***	8.111
t95	8.103	8.031
t96	-9.842	7.566
t97	24.710***	9.422
t98	-2.702	9.302
t99	-29.239***	10.642
Rotation Rate	56.583*	30.644
x1	1.944**	1.056
x2	-0.766	16.795
x3	0.122	0.138
x4	3.168	3.431
x5	1.570	2.783
x6	1.150	1.629
x1x1	-0.004	0.006
x1x2	0.015	0.497
x1x3	-0.001	0.002
x1x4	0.010	0.064
x1x5	-0.004	0.033
x1x6	0.012	0.015
x2x2	-3.537	9.399
x2x3	0.214***	0.073
x2x4	-1.667	1.714
x2x5	1.088	1.528
x2x6	-0.456	0.566
x3x3	-0.001***	0.000
x3x4	-0.010	0.010
x3x5	0.004	0.007
x3x6	0.000	0.004
x4x4	0.113	0.152
x4x5	-0.269	0.164
x4x6	0.270**	0.120
x5x5	0.095	0.076
x5x6	-0.147**	0.067
x6x6	-0.007	0.028
constant	-49.515	40.939

Note: *, **, and *** imply that the coefficients are statistically significant at the 0.10, 0.05 and 0.01 levels, respectively.

Table 2. Estimates of Variance Production Function Parameters

Parameter	Estimate	Std Err
x1	0.016**	0.007
x2	0.159	0.158
x3	0.001	0.001
x4	-0.109*	0.065
x5	0.018	0.042
x6	-0.015	0.012

Note: *, **, and *** imply that the coefficients are statistically significant at the 0.10, 0.05 and 0.01 levels, respectively.

Technology Parameters Estimation

From year dummies in the mean function, we can see the year effects (from, e.g. weather) do vary over the years in terms of both signs and significance, which indicate the crop production is risky due to its high susceptibility to factors such as weather. A higher percentage of root crops increases farm output. Parameters presented in table 2 are of particular interest. Table 2 shows that larger farms (β_1) in terms land area) tend to have high production risk, probably due to difficulty in managing larger farms, which is consistent with a priori expectation. Fertilizer use is found to decrease yield risk. In the literature, the empirical evidence with respect to risk-fertilizer relationship is mixed. The expected risk-reducing effect of pesticides is not found.

Risk Preference Measure

The estimation results of risk preferences are presented in table 3.

Table 3. Estimates of Heterogeneous Risk Preference Function Parameters

Parameter	Estimate	Std Err
r0	-0.019***	0.004
r1	-0.000004***	0.000
r2	0.000004	0.000
r3	0.003	0.002

r4	0.003***	0.001
r5	-0.001***	0.000

The AR function measures the degree of risk aversion of producers. Instead of estimating the parameters of distribution moments of AR, we estimate each producer's risk aversion level by specifying AR as a function of a series of characteristics and wealth. The results are very interesting. First, based on the specification of risk preference function, we tested the null hypothesis of risk neutrality. The Wald test rejected the null at the 1% significance level. Meanwhile, we also tested heterogeneity of farmers' preferences, which is also strongly rejected (p-value 0.000). This result rejects homogeneity of risk preferences which is routinely assumed in the literature.

Regression results show that risk aversion decreases with wealth (γ_1) which suggests decrease absolute risk aversion (DARA), consistent with the general belief of economists. Farmer age and education do not have significant effects on risk preferences. The number of family members participating in production is found to increase risk aversion. This is a reasonable result because when farming provides for the livelihood of more family members, farmers become more risk averse. Subsidy is found to decrease farmers' risk aversion, which is very interesting finding and has important policy implications. In interpreting the results from the risk aversion regressions, it should be noted that sign and significance of the parameter estimates, and not the magnitudes, are of interest, since we are determining the nature of absolute risk aversion.

Conclusion

This paper has focused on measuring production risk and heterogeneous risk preference. We allow heterogeneous risk preference and propose a flexible risk preference function. We further investigated and tested the impact of underlying factors on producers' risk preferences. In our model, we did not impose any utility functional form and distributional assumption of production and market risk. We used robust estimation procedures in the analysis.

The theoretical model is applied to a sample of Dutch cash crop farms. In production risk analysis, we found that larger farm scale increases production risk, whereas fertilizer use decreases risk, both of which are reasonable results. Empirical findings clearly rejected the null hypothesis of risk neutrality in favor of risk aversion. We also found decreasing absolute risk aversion. Results show that risk preference does vary across individuals, and family involvement and subsidy have significant effect on farmers' risk aversion.

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