Estimating Willingness to Pay for Crop Insurance under Price and Yield Uncertainty

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Introduction

- Farmers in the United States continue to face uncertainty since adverse weather, inefficient farm practices, and market shocks contribute to price and yield risk.
- Most farmers purchase crop insurance to guard against these risks.
- Existing evidence (Just, Calvin and Quiggin (1999)) suggests that, instead of averting risk, farmers purchase crop insurance to maximize income through reduced premiums.
- This claim is not hard to believe. For example, in Lancaster county Nebraska, the average premium for 200 acres was approximately 450 dollars in 2013. Subsidy rates were: 0.38 for 85% coverage-level (CL), 0.48 for 80% CL and 0.55 for 75% CL.
- Since farmers are risk-averse, we expect they would purchase insurance even without subsidies.

Question

Do real world premiums accurately reflect farmers' willingness-to-pay (WTP) for insurance?

Main Objectives

1. Develop a structural model to define risk premiums and measures of risk aversion.
2. Use results from the structural model and data on production and insurance purchases to calculate the average risk premiums.
3. Determine if the estimated WTP varies significantly across regions.

Identifying Risk Premium and Risk Aversion

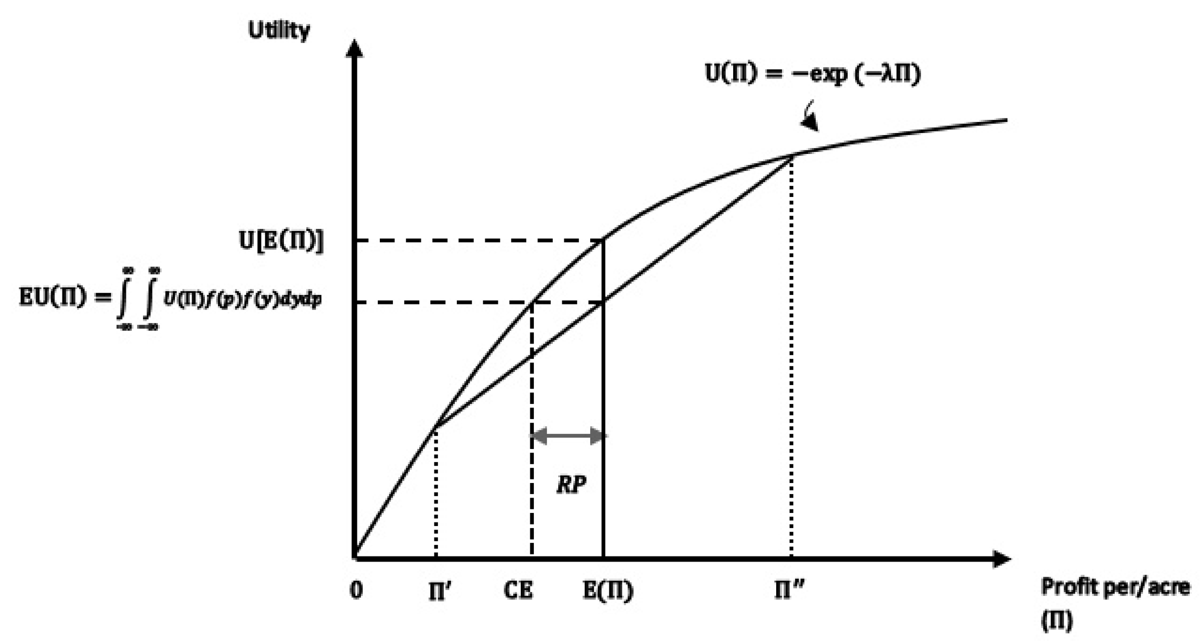
- Let the i^{th} farmer be an expected utility (EU) maximizer, where his utility is a function of profit (Π).
- Profit is a random variable due to random output price and the yield variables.
- Input use is decided before price and yield are known.

$$\Pi = py - \mathbf{wx} \tag{1}$$

Where, $p = \bar{p} + \sigma_p \theta$ and $y = f(\mathbf{x}) + h(\mathbf{x})\varepsilon$ are the output price and yield, respectively (Love and Buccola (1991) and Just and Pope (1979)).

- $E(p) = \bar{p}$, $V(p) = \sigma_p^2$ and $E(y) = f(\mathbf{x})$, $V(y) = h^2(\mathbf{x})$ are the mean and variance of p and y respectively.
- We assume that θ and ε are independent and distributed standard normal.
- $\mathbf{w}$ and $\mathbf{x}$ are the input price and quantity vectors.

1 Certainty Equivalent and Risk Premium



Where the risk premium can be expressed as:

$$RP = CE - E(\Pi) = -\frac{\lambda}{2}(\bar{p}^2 h^2 + f^2 \sigma_p^2) \tag{2}$$

2 Risk Aversion

The farmer maximizes $EU(\Pi)$ by choosing relevant inputs:

$$\underset{\mathbf{x}}{Max}\ EU(\Pi) \tag{3}$$

Let the $f(\mathbf{x})$ and $h(\mathbf{x})$ have a Cobb-Douglas production technology with two inputs. The first order conditions can be obtained by differentiating (3):

Estimation Strategy

- We assume that the i^{th} farmer fails to satisfy the first-order conditions stated above, due to random errors u_1 and u_2, respectively.
- $E(u_1) = 0$,$E(u_2) = 0$ and $V(u_1) = S_1^2$, $V(u_2) = S_2^2$.
- The simultaneous equation model can be written as:

$$yx_1^{-b_1}x_2^{-b_2} = Ax_1^{a_1-b_1}x_2^{a_2-b_2} + B\varepsilon \tag{4}$$

$$w_1 = \bar{p}Aa_1x_1^{a_1-1}x_2^{a_2} + \beta_\lambda^A\left[\sigma_p^2 a_1 x_1^{2a_1}x_2^{a_2}\right] + \beta_\lambda^B\left[-b_1x_1^{b_1}x_2^{2b_2}(\bar{p}^2+\sigma_p^2)\right] + u_1 \tag{5}$$

$$w_2 = \bar{p}Aa_2x_1^{a_1}x_2^{a_2-1} + \beta_\lambda^A\left[\sigma_p^2 a_2 x_1^{a_1}x_2^{2a_2}\right] + \beta_\lambda^B\left[-b_2x_1^{2b_1}x_2^{b_2}(\bar{p}^2+\sigma_p^2)\right] + u_2 \tag{6}$$

- The parameters identified in this system: A,a_1,b_1,a_2,b_2,β_λ^A and β_λ^B.
- Where, β_λ^A=λA^2 and $\beta_\lambda^B = \lambda B^2$.
- Endogenous variables: Y(yield), x_1(fertilizers), x_2(chemicals), $\bar{p}$(output price) and σ_p^2.
- Exogenous variables: w_1 and w_2..
- Nonlinear estimation method: Nonlinear three-stage least squares (N3SLS).

Data

Most of the variables included in our model are obtained from the database provided by National Agricultural Statistics Service (NASS).

- 78 counties in Nebraska and 99 counties in Iowa.
- Y (yield): measured in bushels/acre.
- w_1 (price of fertilizers) and w_2 (price of chemicals) obtained from crop budget reports prepared by University of Nebraska - Lincoln and Iowa State University.
- x_1 and x_2: derived from input expenditure data available in the NASS database.

	Year	Mean Yield	Mean Crop Price (indexed)	Mean Fertilizer use (lbs)	Mean Chemical use(ounces)
Nebraska					
	2012	173.74	6.35	221.87	73.99
	2007	244.78	4.06	248.21	27.17
	2002	191.166	3.13	205.29	68.67
	1997	196.188	3.72	236.02	72.13
Iowa					
	2012	174.53	7.49	247.24	101.25
	2007	226.32	4.43	247.49	113.95
	2002	214.49	3.48	169.38	116.09
	1997	205.69	4.71	168.91	54.18

Premiums (2012, dollars/acre) after subsidy

Coverage level	Nebraska	Iowa
50	3.09	1.29
55	6.14	3.05
60	9.14	4.50
65	12.12	7.04
70	16.23	11.49
75	19.98	14.41
80	24.42	18.65
85	40.42	29.72

Results

- Table 1: Risk premium (dollars/acre) under the internally derived risk aversion parameter.
- Table 2 Risk premium under exogenously imposed risk aversion parameters.
- The estimated parameters are calculated at the state level.

Table 1: Risk premium under derived risk aversion

	A	a_1	a_2	B	b_1	b_2	λ	Risk Premium	Observed Average Premium (2012/Revenue Protection)
Nebraska	7.37 (17.09)	0.278 (13.17)	0.056 (2.94)	0.099 (2.38)	1.163 (11.03)	−1.614 (−12.55)	−0.047 (−15.53)	4.885 (10.98)	16.44
Iowa	16.40 (71.61)	0.057 (16.27)	0.028 (61.12)	0.006 (8.00)	0.977 (35.57)	1.79 (48.32)	−0.010 (−19.89)	1.018 (28.39)	11.27

t-values in brackets

Table 2: Risk premium ($/acre) under external risk aversion measures

Risk Aversion Scenario		$\lambda = -0.006$	$\lambda = -0.047$	$\lambda = -0.100$
	Nebraska	0.079 (10.98)	4.885 (10.98)	45.11 (11.22)
Risk Aversion Scenario		$\lambda = -0.006$	$\lambda = -0.047$	$\lambda = -0.100$
	Iowa	0.345 (28.39)	21.19 (28.39)	95.97 (28.39)

t-values in brackets

Conclusions

- The estimated state-level risk aversion parameters are in line with previous work.
- The obtained average risk premium is lower than the observed average premium paid by farmers for both Nebraska and Iowa. This result seems to suggest that the willingness-to-pay of the farmers in both states does not exceed the actual premiums they paid.
- Based on our data Iowa is less risk averse than Nebraska. This might seem counterintuitive since, Iowa is primarily a dryland crop production state and we would expect farmers to be more risk averse due to potentially higher price and yield uncertainty.
- However, according to the simulation exercise conducted in table 2, an increase in risk aversion leads to a higher willingness-to-pay than Nebraska.

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