Revenue Crop Insurance Demand

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Abstract

A two-stage simultaneous equation is utilized to model the choice of whether to purchase insurance and the choice of whether to purchase yield or revenue insurance using subjectively elicited survey data. Our results show an elasticity of demand for crop insurance that remains largely unchanged from earlier estimates (-0.40), but the elasticity for choices between yield and revenue insurance is found to be relatively more elastic (-0.76). Finally the link between adverse selection and the demand for insurance is examined.
Keywords: Subjective elicitation and Survey, Crop insurance, Revenue demand, Simultaneous probit model and Elasticities.

Significant research attention has been devoted to the expansion of the U.S. Federal Crop Insurance Program in recent years. In particular, agricultural economists have examined the demand for the products offered under this program because of the fundamental policy issues associated with the government provision of subsidized insurance. Crop insurance demand research in the 1980's and early 1990's largely centered upon explaining why producers were not participating in a program that appeared to be more than actuarially fair. While on average the program was paying out well more than a dollar for every dollar that the producer paid in premium, the participation rate was relatively low. Agricultural economists such as Coble, et al., Goodwin, and Smith suggested that the program was likely fraught with adverse selection such that those individuals choosing to participate in the program were earning significant positive returns, as well as receiving risk protection. Those opting out of the program perceived that they would not receive a benefit either in terms of expected return or risk reduction sufficient to justify the premium.

Coble and Knight point out that another major strand of literature in crop insurance has been to estimate the presence and magnitude of asymmetric information problems such as moral hazard and adverse selection. The adverse selection argument pertaining to crop insurance has been widely accepted, and policymakers have chosen to increase the subsidy associated with the program to induce greater participation. This has been carried out through two major pieces of legislation, the 1994 Crop Insurance Reform Act, and then the Agricultural Risk Protection Act of 2000, both of which increased the subsidy levels applied to crop insurance policies. Participation levels have increased significantly at least in part due to the additional subsidy which masks the adverse selection problem for some priced out of the market.

The literature pertaining to adverse selection in the U.S. federal crop insurance program and the literature pertaining to crop insurance demand have followed paths that have seldom truly intersected with each other. The demand literature has largely been attempting to estimate elasticities of demand, while the adverse selection literature has attempted to quantify the discrepancies between the yield distribution for the producer and the expected indemnity of the producer and the premium charged (Just and Calvin, Nelson and Loehman, and Ker and McGowan). However, conceptually these issues are intimately related to each other. A producer's perception of the value of crop insurance will be a function of the perceived adverse selection (Just and Calvin).

In addition to increasing subsidies and expanding the program, recent changes in the U.S. crop insurance program has also significantly modified the nature of the products being offered to a producer. In 1995, the program offered only yield insurance. Beginning in the late 1990's a number of initiatives to develop revenue insurance took place, and today there is one area revenue insurance design and three individual revenue insurance designs available to producers (Hennessy, Babcock, and Hayes). There has been a significant shift in participation toward the revenue insurance products. In 2004, sixty-one percent of corn and soybean crop insurance policies were revenue insurance rather than a yield insurance designs.

There has been a significant body of literature that looks specifically at crop insurance demand, for example, Coble, et al., Smith and Baquet and Barnett and Skees, all addressed the demand for yield insurance. However, relatively little research has been conducted that specifically investigates the demand for crop insurance in the context of a revenue insurance program. The most recent exception to that is the recent paper by Sherrick, et al. In that paper, two choices are modeled: the first is whether to participate in insurance, and then, the choice between yield and revenue insurance designs. Thus, Sherrick, et al. provides a first look at factors that drive the choice between producers and between yield insurance and a revenue insurance policy. Makki and Somwaru examined RMA data looking at products chosen, but did not have non-participants in the data, nor some key variables that would be suggested by theory, such as risk preferences and perceive risk levels.

Sherrick, et al. suggests at the end of their paper that, “Future work might further address the relationships between farmers’ preferences for insurance products and their formation of expectations about yield and revenue risk.” Our survey experience indicates that farmers can readily provide subjective probabilities (and likely use them intuitively in decision making). In this paper we follow the suggestion of Sherrick, et al., and further their analysis by looking specifically at producer expectations for yield and price variability as well as their perceptions of correlation between price and yield. This is done by eliciting subjective probability distributions from producers on both price and yield variability, as well as perceived correlation. This information is then explicitly used to develop both an estimate of the expected yield and the variability of yield, which allows one to then quantify the expected indemnity from an insurance policy. Thus, a measure of adverse selection is computed using actual producer perceptions rather than using indirect objective data.

Given that producer demand is to be related to adverse selection, the perceived adverse selection is the relevant measure even if objective data contradicts this calculation. It also allows the computation of the premium rate that would be offered to a producer with that specific set of characteristics. Given that premium rates general vary by several-fold within a county, an accurate measurement of individual producer premium is needed to accurately measure adverse selection. Based upon that information, as well as other risk related characteristics of the individual, one is able to quantify on a producer-by-producer basis a measure of adverse selection, which then is intimately tied to the demand for insurance. In this analysis a direct and obvious link is constructed between adverse selection and the demand for insurance. Also the analysis is conducted in such a fashion that one can investigate the demand for yield versus revenue insurance following upon the proposal by Sherrick, et al. This is modeled in a two-stage simultaneous equation framework so that the choice of whether to purchase insurance and the choice of whether to purchase yield or revenue insurance are tested for simultaneity. Finally we are also able to develop estimates of the elasticity for demand for insurance, which interestingly are found to conform to many of the estimates that were previously developed based on data from the 1980s and early 1990s. We also report an elasticity of demand for revenue insurance, which to our knowledge has not been reported previously.

A Model of Participation and Revenue Insurance

In this section a simultaneous model of the crop insurance participation decision and whether to opt for revenue insurance or yield insurance is developed building on the existing participation model (Coble et al, 1996). Both the participation and revenue insurance decision are treated as a dichotomous choice.[1] To account for simultaneity the participation decision is treated as an exogenous variable in the revenue insurance decision and vice versa.

To model the discrete choice of participation and revenue insurance decision, we assume producers maximize expected utility according to von Neuman-Morgenstern utility function defined over wealth (W). Due to the discrete nature, the producer compares the expected utility with insurance, $EU_I(W)$ to the expected utility without insurance, $EU_N(W)$ for participation decision given revenue insurance decision. Similarly, for revenue insurance decisions, the producer compares the expected utility with revenue insurance, $EU_R(W)$ to the expected utility with yield insurance, $EU_Y(W)$ given the participation decision. Although the distribution of the individual producer's EU evaluation of wealth under each alternative, insure or not to insure, yield and revenue insurance is unknown, the objective measures of risk can be obtained from factors that influence the distribution.

The model of expected utility for the two alternatives of participation decisions given revenue insurance decision can be written as:

$$(1a)\quad \begin{aligned} EU_N &= \beta_N{}' X + \varepsilon_N \\ EU_I &= \beta_I{}' X + \varepsilon_I \end{aligned}$$

and for revenue insurance decision given participation decision is:

$$(1b)\quad \begin{aligned} EU_Y &= \beta_Y{}' X + \varepsilon_Y \\ EU_R &= \beta_R{}' X + \varepsilon_R \end{aligned}$$

The terms $\beta_N, \beta_I, \beta_Y \text{ and } \beta_R$ are vectors of coefficients of exogenous variables **X** to be estimated with $\varepsilon_N, \varepsilon_I, \varepsilon_Y \text{ and } \varepsilon_R$ representing the error terms.

The difference in expected utility of participation decision given revenue insurance decision is:

$$(2a)\quad EU_I - EU_N = \beta_I{}'X + \varepsilon_I - (\beta_N{}'X + \varepsilon_N)$$
$$= (\beta_I - \beta_N)'\,X + (\varepsilon_I - \varepsilon_N)$$
$$= \beta'\,X + \xi$$

and difference in expected utility of revenue decision given participation decision is:

$$(2b)\quad EU_R - EU_Y = \beta_R{}'X + \varepsilon_R - (\beta_Y{}'X + \varepsilon_Y)$$
$$= (\beta_R - \beta_Y)'\,X + (\varepsilon_R - \varepsilon_Y)$$
$$= \beta'\,X + \xi$$

The decision to insure results if $EU_I - EU_N > 0$ and if a farmer chooses not to insure, then $EU_I - EU_N < 0$. Similarly the decision to purchase revenue insurance reveals that $EU_R - EU_Y > 0$ and if a farmer chooses to purchase yield insure, then $EU_R - EU_Y < 0$.

Conceptually the expected utility evaluation of these choices will be conditioned upon the risk preferences of the decision maker and the decision maker's subjective evaluation of the risk and the risk context. Thus, the individual's risk preferences as measured by risk aversion, *r*, and initial wealth, *w*, are obvious explanatory variables for the insurance decision. The producer's perception of the risk context can be expressed by the subjective moments of random yield and price and the perceived correlation between the two.[2] Because crop insurance is not provided free, premium costs are also clearly a factor in demand.

Thus we propose a model of the decision to purchase insurance, Y_1 that includes initial wealth and risk aversion along with the first and second moment of the subjective yield (μ_y and σ_y) and price (μ_p and σ_p) distributions; the yield-price correlation, μ_{yp} and crop insurance premium rate, p; and percentage of irrigated farm, irr given revenue insurance decision, Y_2:

$$(3a)\quad Y_1 = f(w, r, \mu_y, \sigma_y, \mu_p, \sigma_p, p, irr, Y_2)$$

Similarly the decision to purchase revenue insurance, Y_2 depends on the same set of variables defined above given the participation decision, Y_1:

$$(3b) \quad Y_2 = f(w, r, \mu_y, \sigma_y, \mu_p, \sigma_p, p, irr, Y_1)$$

Our null hypothesis is that perceived yield-price correlation and subjective price risk would drive the choice between yield and revenue insurance.

The proposed estimation of insurance demand and revenue insurance demand is modeling the two choice equations simultaneous as:

$$(4) \quad \begin{aligned} Y_1 &= f(w, r, \mu_y, \sigma_y, \mu_p, \sigma_p, p, irr, Y_2) \\ Y_2 &= f(w, r, \mu_y, \sigma_y, \mu_p, \sigma_p, p, irr, Y_1) \end{aligned}$$

Empirical Application

An empirical application of the producer decision to purchase yield or revenue insurance is modeled from the survey data of corn and soybean producers in the states of Nebraska, Indiana and Mississippi. Table 1 provides the definition of the variables as well as the summary statistics for the variables employed in the analysis.

Data

A survey was conducted in the spring of 1999 to identify the risk management objectives of grain and cotton producers’ and their perceptions and understanding alternative risk management tools and strategies (for details see Coble et al, 1999). The survey was conducted in four states in which corn, soybeans, cotton, and sorghum production are important: Mississippi (cotton, soybeans), Texas (cotton, sorghum), Indiana (corn, soybeans), and Nebraska (corn, soybeans). These states were chosen to reflect differing production regions and crops. Each state's Agricultural Statistical Service was contracted to sample from their pool of commercial farms. After excluding small, noncommercial farms generating less than $25,000 in gross income, the sample was stratified across four categories of gross farm income. A Dillman three-wave design was used to mitigate non-response bias. A total of 6,810 mail surveys were sent to producers prior to planting in the spring of 1999. A follow-up reminder card was sent two weeks following the first mailing, and a second mailing was sent to those who had not returned a survey two weeks after the postcard reminder. This study utilizes 367 and 411 usable questionnaires returned by corn and soybean producers respectively spread across the states of Indiana, Mississippi and Nebraska. Table 1 provides a description and summary statistics of the variables involved in this study.

Variables

Individual producer level yield and price first and second moments are computed based on the subjective elicitations of the producers' perceived expected minimum, maximum and mean yield and price. Similarly the yield-price correlation and risk aversion are also subjectively elicited based on producers' perception. Percentage of irrigation and wealth were based on information provided by the producers. Information on the premium rate at 65 percent coverage level was obtained from RMA rate tables for specific type, practice and location by crop.

The first and second moment of the yield distribution are computed based on the following three subjectively elicited questions – a) what yield do you consider most likely for your crop this year, b) what would you expect your low yield to be in the next ten seasons of growing the crop, and c) what would you expect your high yield to be in the next ten seasons of growing the crop. Similarly for the first and second moment price the questions are – a) what do you expect the most likely harvest time price will be, b) what price would you consider to be the low price you could reasonably expect, and c) what price would you consider to be the high price you could reasonably expect. These three questions in that order provide the mean, the tenth fractile and the ninetieth fractile respectively and the first (mean) and second (variance) can be computed (Lau, Lau, and Zhang) as:

$$(6)\quad \begin{aligned} Mean &= \left(x\_0.10\ fractile + 2 * x\_mean + x\_0.90\ fractile\right)/4 \\ Variance &= \left(x\_0.90\ fractile - x\_0.10\ fractile\right)/2.65 \end{aligned}$$

where x is yield or price.

Premium rate is the actual production history rate at 65% coverage provide by RMA based on the type, practice and location by crop. The subjectively elicited yield-price correlation variable is based on the five choices for the following question - If your farm's crop yield fell 30% below your normal yield how would you expect the prices to change, relative to the price you would expect to get if your yield were normal. Risk aversion was elicitated by the question- "relative to other farmers, how would you describe your willingness to accept risk in your farm business". Producers were asked to rank their risk aversion level on a five-point Likert-type scale. This variable takes a value of one if producers feel much less willing and 5 if producer is much more willing. Finally, the wealth variable was computed as assets minus the borrowed percent of total dollars invested in the operation.

Estimation and Results

The discrete choice of participation and revenue insurance demand was estimated using the two-stage simultaneous equation probit model (see Greene for details). Results from the simultaneous probit model are reported in Table 2. Along with the parameter coefficients, the marginal effects and elasticities computed at the means of all the variables are presented. The perceived adverse selection results are presented in Table 3.

For the participation decision, the parameter estimate on mean yield is negative and significant indicating high yield producers would be less likely to purchase insurance with an elasticity of -0.48. The yield standard deviation is found to have a significant positive sign and an elasticity of 0.14. As expected, greater perceived yield risk is associated with a greater willingness to purchase insurance. Interestingly, a negative sign is associated with the expected price level. With an elasticity of -0.72 this indicates with higher crop prices producer are less likely to purchase insurance. Yield-price correlation is not found to be significant in this model. Producers with larger acreage under irrigation are more likely to purchase insurance. Premium rate is found to be strongly significant and take negative sign as expected. The associated elasticity is -0.40 which falls into a very similar range as previous crop insurance demand elasticities. Other variables of interest from the expected utility framework - risk aversion and wealth are not statistically significant. Our only explanation for this result is that perhaps crop insurance is so highly subsidized, risk preferences play a diminished role in this decision.

Due to the simultaneous estimation, revenue insurance decision the endogenous variable is included as an exogenous variable in the participation decision equation. It is statistically insignificant indicating that the producer decision to participate is not conditioned upon the decision to purchase revenue insurance.

Next in the revenue insurance decision equation, the parameter estimate on mean yield is negative and significant at 10% level indicating producers with higher yields would be more likely to purchase yield insurance. With a positive and significant sign and an elasticity of 0.44, higher variation in the yield is found to also be encouraging the producers to purchase revenue insurance. In this model, the expected price level is not significant, but price variability is positive and significant. With an elasticity of 0.24, producers facing higher variation in crop prices would be more likely to purchase revenue insurance. With an elasticity of -0.10 and significant at 10% level, producers with larger acreage under irrigation are less likely to purchase revenue insurance. Due to the simultaneous estimation, participation decision an endogenous variable is included as an exogenous variable in the revenue insurance decision equation. It is positive and statistically significant at 11% level indicating, producer is more likely to purchase revenue insurance given the decision to participate in crop insurance program.

The variable of interest, price elasticity of crop and revenue insurance demand indicates the appropriate negative and statistically significant signs. Our estimated elasticity for crop insurance demand of -0.40 is higher than Barnett's price elasticity of -015 but less than Coble et al's elasticity of -0.65, Goodwin and Kastens (-0.51) and Smith and Baquet (-0.58 to 0.69). Results on the price elasticity of revenue insurance demand indicates an elasticity of -0.76 much higher than the demand for crop insurance. This is consistent and correlates with the introduction of revenue insurance products like income protection, crop revenue coverage and revenue assurance.

Adverse Selection

To further understand the factors driving insurance participation we also examined perceived adverse selection among the producers studied. Specifically, we calculated the expected loss cost ratio (expected indemnity/liability) for 65% coverage yield insurance from the elicited subjective probability. This is then compared to the premium rate charged the producer. Specifically, perceived adverse selection (AS) is defined as the difference in the information available with the insurer and insured that is reflected in the premium rates is examined by:

$$(5) \quad AS = f(w, r, \mu_y, \sigma_y, \mu_p, \sigma_p, p, irr, Cdum, Sdum)$$

where $Cdum$ and $Sdum$ are the crop and state dummies respectively, and the remaining variables have been defined earlier.

Empirical results explaining the perceived adverse selection presented in Table 3 indicate the importance of price and yield first and second moments as all four are statistically significant. Higher yielding producers perceive greater adverse selection. As expected, perceiving greater yield risk is associated with greater adverse selection. Interestingly, expected prices have a negative relationship with the amount of perceived adverse selection. That is, as expected price goes up the less adverse selection is perceived. Conversely, greater perceived price variability results in larger adverse selection. Price-yield correlation, risk aversion and wealth do not explain perceived adverse selection. A negative and significant sign on percent of acreage under irrigation indicates irrigated producers are less likely to perceive the presence of adverse selection. A positive sign on the crop dummy indicates soybean producers perceive greater adverse selection. Similarly, Nebraska producers perceive greater adverse selection than do Indiana and Mississippi producers.

Conclusions

This paper revisits the demand for crop insurance a topic widely examined in the 1980s and early 1990s as economists attempted to explain why participation was relatively low in program that was more than actuarially fair. In the mid to late 1990s subsidies were increased dramatically and revenue insurance was widely adopted. The net result is a program with much higher participation rates and apparently improved actuarial soundness. Our results show an elasticity of demand for crop insurance that remains largely unchanged from earlier estimates (-0.40), but the elasticity for choices between yield and revenue insurance is found to be relatively more elastic (-0.76). Not surprisingly, farmers who perceive greater yield risk are more likely to insure. However, our results also show that farmers who perceive relatively higher expected yields or prices are less likely to insure. Taken together, we would characterize this result as a 'revenue effect' on insurance demand. When evaluating the relatively recent option to purchase either yield or revenue insurance, we find a clear tendency for farms with greater perceived yield risk and price risk are more likely to choose revenue insurance.

In our decomposition of adverse selection, we confirm that, on average, farmers perceive that unsubsidized RMA rates are slightly actuarially unfair. However, there is strong evidence that as perceived yield variability increases the more expected indemnities exceed premium for yield insurance. Furthermore, the moments of the price distribution are related to the perception of yield insurance adverse selection.   Producers with a lower expected price perceive less gain from yield insurance. We also observe that a greater perceived price risk is associated with a greater perceived gain from yield insurance. Noting that yield-price correlation is not significant (i.e. producer perceptions of adverse selection are not significantly affected by yield-price correlation), this appears consistent with the background risk effect discussed in Lusk and Coble.

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Table 1. Definitions, Notation and Summary Statistics of Variables used in the Analysis

Variable	Notation	Definitions	Mean	Min	Max
Y1		Choice to purchase insurance or not coded as 1 and 0 respectively	0.633	0	1
Y2		Choice to purchase revenue or yield insurance coded as 1 and 0 respectively	0.256	0	1
Ymean	μ_y	Average yield	81.774	7.176	207.500
Ystd	σ_y	Standard deviation of yield	18.073	1.319	84.528
Pmean	μ_p	Average price	360.983	122.500	669.750
Pstd	σ_p	Standard deviation of price	46.453	0	188.679
YPcorr	μ_{yp}	Yield-price interaction	0.537	0	1
Risk	r	Risk aversion	3.216	1	5
APH65	p	Expected premium rate generated from beta distribution	0.069	0	0.272
IRR	irr	Percentage of irrigation	0.302	0	1
Wealth	w	Wealth	0.888	0	5
AS	AS	Perceived adverse selection	-0.015	-0.100	0.210

Table 2. Regression results of the simultaneous binomial choice equation using survey data

Variables	Parameter Coefficients	t-ratio	Marginal Effects	Elasticity
Choice to purchase insurance or not (Y1)				
Intercept	2.8624	4.5730	1.0651	
Ymean	-0.0101	-3.6360	-0.0038	-0.4772
Ystd	0.0131	1.9380	0.0049	0.1360
Pmean	-0.0035	-3.3190	-0.0013	-0.7207
Pstd	0.0003	0.1430	0.0001	0.0079
YPcorr	0.1272	1.2580	0.0474	0.0394
Risk Aversion	-0.0185	-0.3220	-0.0069	0.5249
Premium rate	-10.0350	-6.1000	-3.7341	-0.4018
Irr	0.2746	2.0000	0.1022	0.0479
Wealth	-0.0656	-1.4240	-0.0244	-0.0336
Y2	0.0182	0.3170	0.0068	-0.5576
Choice to purchase revenue or yield insurance (Y2)				
Intercept	0.4664	0.7700	0.1414	
Ymean	-0.0047	-1.6890	-0.0014	-0.5066
Ystd	0.0185	3.1520	0.0056	0.4422
Pmean	-0.0013	-1.2470	-0.0004	-0.6305
Pstd	0.0039	1.8040	0.0012	0.2408
YPcorr	0.1278	1.2190	0.0386	0.0903
Risk Aversion	-0.0946	-1.5950	-0.0287	6.1663
Premium rate	-8.2269	-4.2410	-2.4950	-0.7551
Irr	-0.2405	-1.7420	-0.0729	-0.0961
Wealth	-0.0217	-0.4330	-0.0066	-0.0254
Y1	0.0949	1.5950	0.0288	-6.5213

Table 3. Regression results of the perceived adverse selection using survey data

Variables	**Parameter Coefficients**	**t-ratio**
Intercept	-0.0811	-6.86
Ymean	0.0001	1.67
Ystd	0.0025	20.61
Pmean	-0.00013	-4.41
Pstd	0.0001	2.62
YPcorr	0.0023	1.18
Risk Aversion	0.000002	0.55
Irr	-0.0123	-4.05
Wealth	0.0002	0.22
Cdum (Soybean=1)	0.0887	8.51
SDum (Nebraska=1)	0.0153	6.68

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[1] We fully recognize producers have a choice of multiple coverage levels. However in the year the data were obtained 65 percent coverage dominated.

[2] The relationship between price risk and yield insurance is less obvious than if revenue insurance is being evaluated. Where yields are independent, one might argue price risk is a background risk (see Lusk and Coble). Where price and yield are correlated, then the implication of yield insurance on revenue variability will depend on the degree on yield-price correlation.