Journal of Agricultural and Applied Economics, 40,3(December 2008):757–766

Crop Revenue and Yield Insurance Demand: A Subjective Probability Approach

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A multinomial logit is utilized to model the choice of whether to purchase yield or revenue insurance using subjectively elicited survey data. Our results indicate that the demand for crop insurance is inelastic (−0.40), consistent with most earlier yield elasticity estimates, but the elasticity for choices between yield and revenue insurance is found to be relatively more elastic (−0.88).

Key Words: crop insurance, elasticities, multinomial logit model, revenue demand, subjective elicitation, survey

JEL Classifications: Q18

In recent years, a significant body of research has focused on issues related to the expansion of the U.S. federal crop insurance program. In particular, agricultural economists have examined the demand for the products offered under this program because of the fundamental policy issues associated with government provision of subsidized insurance. Crop insurance demand research in the 1980s and early 1990s largely focused on 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 more than a dollar for every dollar producers paid in premiums, the participation rate was relatively low. Research by Coble et al. (1996) and Goodwin and Smith suggested that the program was likely affected by adverse selection, such that program participants were earning significant positive returns while nonparticipants perceived that they would not receive a benefit, either in terms of expected return or risk reduction, sufficient to justify the premium.

Knight and Coble, and more recently Glauber, point out that another major strand of literature has examined asymmetric information problems (i.e., moral hazard and adverse selection) in crop insurance. The adverse selection argument has been widely accepted, and policy makers have substantially increased subsidies in order to induce crop insurance participation by less risky producers (i.e., to provide a strong subsidy incentive to offset a negative actuarial incentive for low-risk producers). Participation levels have increased significantly, at least in part due to the additional subsidy, which mitigates the adverse selection problem.

In addition to increasing subsidies and expanding the program, recent changes in the

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U.S. crop insurance program have also significantly modified the nature of the products being offered to producers. In 1995, the program offered only yield insurance. Beginning in the late 1990s, a number of initiatives were undertaken to develop revenue insurance, and today there are three individual revenue insurance products and one area revenue insurance product available for some crops (Hennessy, Babcock, and Hayes). There has been a significant shift in participation toward the revenue insurance products. In 2004, 61% of corn and soybean crop insurance policies insured revenue rather than yield.

While there is a significant body of literature on crop insurance demand (e.g., Coble et al. [1996]; Smith and Baquet; Barnett and Skees; Schnitkey, Sherrick, and Irwin; Shaik and Atwood; and Serra, Goodwin and Featherstone), that literature largely concentrates on demand for yield insurance. Relatively little research has been conducted that specifically investigates the demand for crop insurance in the context of a revenue insurance program. Mishra and Goodwin examine the national demand for crop yield versus revenue insurance using the USDA Agricultural Resource Management Survey (ARMS) data. Also, Sherrick et al. model whether to participate in insurance, and the choice between yield and revenue insurance for a set of Illinois farms where long yield series were available. Both studies provide insights into the factors driving theses choices. However, Sherrick et al. suggest 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 analysis differs from the previous studies in that it explicitly models subjective perceptions of yield and price risk that underlie crop insurance choices.

A rich body of literature suggests that expectations that drive decisions under uncertainty are contained in the decision maker's subjective probabilities and that these subjective probabilities can be elicited (Smith and Mandac; Grisley and Kellogg; Norris and Kramer; Eales et al.). In this paper we look 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 price and yield variability, as well as perceived correlation. This information is used to develop estimates of expected yield and the variability of yield, which allows us to quantify the expected indemnity from an insurance policy. Also, the analysis is conducted in a way that allows us to investigate the demand for yield and revenue insurance. This is modeled in a multinomial logit framework to address the endogeneity of the insurance decisions—the choice of whether to purchase yield or revenue insurance. Finally, we also develop estimates of the elasticity of demand for insurance, which interestingly are found to conform to previous estimates from the 1980s and early 1990s. Further, we report an elasticity of demand for revenue insurance, which to our knowledge has not been previously reported.

A Model of Yield and Revenue Insurance Participation

A multinomial discrete choice model of crop insurance participation and whether to opt for yield or revenue insurance is developed building on the participation model developed by Coble et al. (1996). To model the unordered choices of participation, yield, and revenue insurance, we assume producers maximize expected utility according to a von Neuman-Morgenstern utility function defined over wealth (W). Due to the discrete nature, the producer compares the expected utility among alternative choices—no insurance, $EU_N(W)$ yield insurance, $EU_Y(W)$, and revenue insurance, $EU_R(W)$.

The expected utility model of the unordered alternative choices of no participation, yield, and revenue participation decisions can be written as

$$(1)\quad \begin{aligned} EU_N &= \beta'_N X + \varepsilon_N \\ EU_I &= \beta'_I X + \varepsilon_I \\ EU_R &= \beta'_R X + \varepsilon_R. \end{aligned}$$

The terms β_N, β_I, and β_R are vectors of coefficients on exogenous variables X, and ε_N, ε_I, and ε_R are random disturbances in Equation (1).

Conceptually, the expected utility evaluation of these choices will be conditioned upon the decision maker's risk preferences and subjective evaluations of the risks. Thus, the individual's risk preferences measured by risk aversion, r, and initial wealth, w, are 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. Because crop insurance is not free, premium costs also enter into the decisions.

Modeling of yield and revenue insurance demand can be accomplished with an aggregate expected return to insurance measure or expected return to insurance decomposed into first and second moments of yield and price, yield–price correlation, and premium. Next, we define the demand model with expected return to insurance decomposed into first and second moments of yield and price, yield–price correlation, and premium. Thus we posit a model of the decision to purchase yield insurance, revenue insurance, or no insurance that includes initial wealth and risk aversion along with the first and second moments of the subjective yield (μ_y and σ_y) and price (μ_p and σ_p) distributions; the yield–price correlation, μy_p, and crop insurance premium rate, p; and percentage of irrigated farm, *irr*, relative to no insurance. Since there are three unordered choices, the following discrete model is estimated:

$$\text{(2)} \quad Prob(Choice = j) = f\left(w, r, \mu_y, \sigma_y, \mu_p, \sigma_p, \mu_{yp}, p, irr\right),$$

where the choice j is equal to zero for no insurance, 1 for yield insurance, and 2 for revenue insurance.

Collapsing the first and second moment of yield and price, yield–price correlation, and premium in Equation (2) into expected return to insurance, *ERI*, provides us with the aggregate expected return to insurance model. This can be written as

$$\text{(3)} \quad Prob(Choice = j) = f(w, r, ERI).$$

Following Maddala, the unordered discrete choice of participation, yield and revenue insurance demand defined in Equations (2) and (3) can be defined using the general representation of the multinomial logit model as

$$\text{(4)} \quad Prob(y_i = j) = P_j = \frac{\exp\left(\beta'_j x_i\right)}{\sum_{j=0}^{2} \exp\left(\beta'_j x_i\right)}, \quad j = 0,1,2,$$

where zero is equal to no insurance, 1 for yield insurance, and 2 for revenue insurance; i is the number of observations used in the analysis. Since the probabilities sum to one, we can set one (no insurance) of the parameter vectors say β_0 equal to zero. Then the probabilities of the three alternatives can be represented as

$$\text{(5)} \quad \begin{aligned} P_0 &= \frac{1}{1 + \sum_{j=1}^{2} \exp\left(\beta'_j x_i\right)} \\ P_1 &= \frac{\exp(\beta'_1 x_{1,i})}{1 + \sum_{j=1}^{2} \exp\left(\beta'_j x_i\right)} \\ P_2 &= \frac{\exp(\beta'_2 x_{2,i})}{1 + \sum_{j=1}^{2} \exp\left(\beta'_j x_i\right)} \end{aligned}$$

The effect of the independent variables can be examined by the marginal effects (Greene), defined as

$$\text{(6)} \quad \frac{\partial P_j}{\partial x} = P_j\left(\beta_j - \beta\right), \quad j = 0,1,2,$$

where

$$\beta = \sum_{j=0}^{2} P_j \beta_j.$$

Farm Survey and 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 of 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 grain sorghum production are important: Mississippi (cotton, soybeans), Texas (cotton, grain 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 (Dillman) was used to mitigate nonresponse bias. The surveys were sent to producers prior to planting in the spring of 1999. A reminder card was sent two weeks following the first mailing, and a second mailing was sent to those who had not returned a survey 2 weeks after the postcard reminder. The response rate for the survey was 27%. A response rate of 27% is somewhat low, but is consistent with response rates in mail surveys (Dillman) of this magnitude. Respondents to this survey were slightly older and farms slightly larger as compared to the 1997 Census of Agriculture with farms greater than $10,000 in sales. This is especially true for Indiana and Mississippi. Direct comparisons with the Census are difficult because this sample was restricted to those farms with more than $25,000 in sales. However, the similarity of the respondents to population estimates suggests that the sample is reasonably representative, with the caveat that the sample may be slightly biased towards larger farms. Even with 27% response, the distribution (see Table 1) of corn and soybean producers across the three choices—purchased no insurance, yield insurance, and revenue insurance allows us to model the behavioral response to explanatory factors. The focus of the analysis reported in this paper is corn and soybean farms from three states. Specifically, this study utilizes 367 and 411 usable questionnaires returned by corn and soybean producers, respectively, in the states of Indiana, Mississippi, and Nebraska.

Variables

First and second moments of producer yield and price distributions are computed based on elicited distributions. Similarly, the yield–price correlation and risk aversion are also subjectively elicited based on producers' perceptions. Percentage of irrigation and wealth are based on information provided by the producers. Information on the premium rate at the 65% coverage level was obtained from RMA rate tables for specific type, practice, and location by crop.

The first and second moments of each producer's yield and price distributions are computed based on questions capturing the mode, the tenth fractile, and the ninetieth fractile of each distribution. Using this information, the first and second moments (mean and variance) can be computed (Lau, Lau, and Zhang) as:

$$
\begin{aligned}
\text{Mean} &= (x\_0.10 \text{ fractile} + 2 * \text{Mode} + x\_0.90 \text{ fractile})/4 \\
\text{Variance} &= (x\_0.90 \text{ fractile} - x\_0.10 \text{ fractile})/2.65
\end{aligned} \tag{7}
$$

where x is yield or price.

Premium rate is the actual production history rate at 65% coverage provided by RMA based on the type, practice, and location by crop. If the producers perceived that prices moved inversely to yields, the yield–price correlation variable was coded as one and zero otherwise. Risk aversion was based on the farmer's self-perceived willingness to accept risk relative to other farmers. Finally, the wealth variable was computed as assets minus the borrowed percent of total dollars invested in the operation.

Table 1 provides definitions and summary statistics for the variables employed in the analysis. A mean of 1.114 on the choice variable for corn indicates that 23%, 42%, and 35% of corn producers purchased no

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

			Corn			Soybean		
Variable	Notation	Definitions	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Choice	0, 1, 2	Choice to purchase no insurance, yield insurance, and revenue insurance are coded as 0, 1, and 2 respectively	1.114	0	2	0.706	0	2
Ymean	μ_y	Average yield	137.667	77.500	207.500	36.492	7.176	66.750
Ystd	σ_y	Standard deviation of yield	28.599	7.481	84.528	9.546	1.319	29.434
Pmean	μ_p	Average price	1.952	1.225	2.750	4.953	3.838	6.698
Pstd	σ_p	Standard deviation of price	0.32	0.075	1.50	0.58	0	1.88
YPcorr	μ_{yp}	Yield–price interaction	0.668	0	1	0.430	0	1
Risk	r	Risk aversion	3.251	1	5	3.185	1	5
APH	p	Actual production history (APH) premium rates charged by RMA	0.046	0.022	0.118	0.088	0.021	0.272
SAPH	sp	Subsidized premium rates	0.027	0.013	0.069	0.051	0.015	0.158
ELC	ELC	Expected loss cost (equal to premium rate) generated from beta distribution	0.017	0	0.193	0.032	0	0.245
ERI	ERI	Expected return to insurance (ELC – subsidized APH premium rate)	−0.010	−0.046	0.160	−0.019	−0.100	0.210
IRR	irr	Percentage of irrigation	0.293	0	1	0.310	0	1
Wealth	w	Wealth (in $ millions)	0.985	0	5	0.810	0	5

Table 2. Regression Results of the Multinomial Logit Model Using Survey Data with Aggregate Expected Return to Insurance

Variables	Parameter Coefficients	*t*-Ratio	Marginal Effects	Elasticity
Choice to purchase yield insurance relative to no insurance				
Intercept	0.585	3.40	0.069	0.199
ERI	9.886	3.54	0.732	−0.081
Risk aversion	0.0003	−0.85	0.0001	0.010
IRR	0.806	3.63	0.170	0.123
Wealth	−0.122	−1.48	−0.017	−0.044
Dummy (soybean = 1)	−0.875	−4.88	−0.074	−0.189
Choice to purchase revenue insurance relative to no insurance				
Intercept	0.647	3.57	0.058	0.261
ERI	15.404	5.13	1.772	−0.165
Risk aversion	0.0003	0.54	0.0001	−0.019
IRR	0.139	0.54	−0.055	−0.079
Wealth	−0.110	−1.17	−0.008	−0.033
Dummy (soybean = 1)	−1.277	−6.42	−0.141	−0.411

insurance, yield insurance, and revenue insurance, respectively. Similarly, a mean of 0.706 on the choice variable for soybean indicates that 47%, 34%, and 18% of the soybeans producers purchased no insurance, yield insurance, and revenue insurance. The first and second moments of corn yield, based on the subjective distributions, averaged 137.67 and 28.59 bushels per acre respectively, while the first and second moments of soybean yield averaged 36.59 and 9.55 bushels per acre, respectively. The first and second moments of corn (soybean) price were \$1.95 and \$0.32 (\$4.95 and \$0.58) per bushel, respectively. The dichotomous negative yield–price correlation variable averaged 0.66 for corn and 0.43 for soybeans. The average risk aversion response of 3.25 and 3.19 for corn and soybean producers respectively, seems consistent with a fairly high level of risk aversion. Expected loss costs (ELC) generated from the beta distributions were 1.7% for corn and 3.2% for soybeans. Average actual production history (APH) premium rates charged to corn and soybean producers were 4.6% and 8.8%, respectively. Subsidized APH premium rates charged to corn and soybean producers were 2.7% and 5.1%, respectively. Expected return to insurance (ERI) is defined as expected loss cost minus the subsidized actual production history premium rate (note both are on a percentage basis). The average expected return to insurance for corn and soybean farms were −1.0% and −1.9%. On average, the wealth of corn and soybean farms was around \$0.98 and \$0.81 million, respectively.

Empirical Application and Results

An empirical application of the producer decision to purchase yield or revenue insurance is modeled using data from a survey of corn and soybean producers in Nebraska, Indiana, and Mississippi. Aggregate expected return to insurance result from the multinomial logit model (Equation 4) is reported in Table 2. Results from the multinomial logit model (Equation 4) with expected return to insurance decomposed into first and second moments of yield and price, yield–price correlation, and premiums are reported in Table 3. Parameter estimates, marginal effects, and elasticities of all the variables are presented.

Table 2 presents the ERI results. The signs of parameter estimates on expected return to insurance in the demand for yield or revenue insurance relative to no insurance are positive and significant. Producers with high expected returns would be more likely to purchase yield or revenue insurance, while those with low expected returns to insurance would become

Table 3. Regression Results of the Multinomial Logit Choice Equation Using Survey Data with the Decomposed Expected Return to Insurance

Variables	Parameter Coefficients	*t*-*R*atio	Marginal Effects	Elasticity
Choice to purchase yield insurance relative to no insurance				
Intercept	4.439	3.59	0.606	1.778
Ymean	−0.018	−2.52	−0.002	−0.411
Ystd	0.009	0.73	−0.002	−0.126
Pmean	−0.491	−1.78	−0.050	−0.670
Pstd	−0.003	−0.68	−0.001	−0.146
YPcorr	0.142	0.78	−0.002	−0.010
Risk aversion	−0.001	−1.53	0.0001	0.015
Premium rate	−15.291	−4.47	−1.191	−0.397
IRR	0.701	2.67	0.155	0.113
Wealth	−0.116	−1.37	−0.014	−0.037
Dummy (soybean = 1)	−0.448	−0.40	−0.092	−0.155
Choice to purchase revenue insurance relative to no insurance				
Intercept	3.860	2.86	0.218	1.199
Ymean	−0.019	−2.43	−0.002	−0.489
Ystd	0.039	2.87	0.006	0.405
Pmean	−0.597	−1.77	−0.053	−1.052
Pstd	0.005	1.24	0.001	0.235
YPcorr	0.340	1.61	0.044	0.096
Risk aversion	0.0003	−0.50	4.21E-06	0.0009
Premium rate	−22.313	−5.15	−2.292	−0.885
IRR	0.018	0.06	−0.067	−0.093
Wealth	−0.124	−1.26	−0.010	−0.044
Dummy (soybean = 1)	−0.078	−0.06	0.031	0.050

less likely to participate. Percentage of irrigated acreage is positive and significant in the demand for insurance equation but not in the revenue insurance demand equation. This indicates producers perceive, *ceterus paribus*, a better insurance value with irrigated acreage; hence, they are more likely to insure their crops but are less likely to purchase revenue insurance. Risk aversion and wealth variables are not significant in either equation. The dummy variable for soybean crop is negative and significant in the yield and revenue insurance participation decisions. This indicates that soybean producers are less willing than corn producers to purchase yield or revenue insurance.

Results of the multinomial logit model with expected return to insurance decomposed into first and second moments of yield and price, yield–price correlation, and premium are reported in Table 3. For the yield insurance participation decision, the parameter estimate on mean yield is negative and significant, indicating that high yield producers would be less likely to purchase insurance, with an elasticity of −0.41. This result is consistent with earlier results of Goodwin, Skees and Reed, Smith and Baquet, and Sherrick et al. based on varying crops and regions. Yield standard deviation has a positive sign but is not statistically significant at the 10% level. The sign on expected price is negative and significant at the 10% level, with an elasticity of −0.67. This result suggests that farmers perceive a need to purchase insurance when expected prices are low. However, the parameter estimate on price standard deviation is not statistically significant, indicating that perceived price risk does not affect the insurance purchase decision. 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 strongly significant and takes a negative sign as expected. The associated elasticity is −0.40, which falls in a range similar to previous yield insurance demand elasticity estimates. 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 that risk preferences play a diminished role in this decision. The soybean crop dummy variable is not statistically significant in the yield insurance participation equation, indicating that the producer decision to participate is indifferent compared with corn.

In the revenue insurance decision, the parameter estimate on mean yield is negative and significant, indicating producers with higher expected yields are more likely to purchase revenue insurance relative to no insurance. With a positive and significant parameter estimate and an elasticity of 0.40, higher variation in the yield is found to encourage producers to purchase revenue insurance. In this model, the expected price level is significant at the 10% level, but the parameter estimate on price variability is positive and not significant. Producers realizing higher mean prices are less likely to purchase revenue insurance. Being insignificant, producers with larger acreage are indifferent to the purchase of revenue insurance. However, the positive and significant sign in the yield insurance decision suggests that producers with larger irrigated acreage are more interested in mitigating yield risk than price risk.

Price elasticities of crop and revenue insurance demand have the expected negative signs and are statistically significant. Our estimated elasticity for yield insurance demand of −0.40 is higher than Barnett and Skees's price elasticity of −0.15 but lower than those of Coble et al. (−0.65 [1996]), Goodwin and Kastens (−0.51), and Smith and Baquet (−0.58 to −0.69). Results on the price elasticity of revenue insurance demand indicate an elasticity of −0.88, which is somewhat higher than the elasticity of demand for yield insurance. This is consistent and correlates with the introduction of revenue insurance products like income protection, crop revenue coverage, and revenue assurance.

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 a program with subsidized rates. In the mid-1990s and again in 2000, subsidies were increased dramatically and revenue insurance was introduced and widely adopted during this period. The net result is a program with much higher participation rates and evidence of improved actuarial soundness. Our results show an elasticity of demand for yield insurance that remains largely unchanged from earlier estimates (−0.40) even though our estimates are derived from subjective data and almost all previous estimates were based upon objective data. We go on to estimate the elasticity for choices between yield and revenue insurance, an area where there are essentially no previous estimates for comparison. We find this elasticity to be relatively greater (−0.88) than the yield insurance elasticity. 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. In other words, producers who perceive high yields or prices feel less at risk. Thus, they demand less insurance. 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 to choose revenue insurance. There appears to be no direct reason why farmers with relatively high yield risk would desire revenue insurance, however it may relate to the "upside" price risk coverage offered by the CRC or RA–HPO products that provide greater per unit indemnities if prices have risen prior to harvest.

Finally, there are clear policy implications of this work. First the inelastic demand for yield insurance confirms that relatively large subsidies would be required to entice new participants and further reduce the justification for ad hoc disaster legislation. Although, revenue insurance has been widely adopted and has a slightly more elastic demand than yield insurance, it still has an inelastic demand, which suggests that it will not likely entice many more people into the program.

[Received March 2007; Accepted January 2008.]

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