

# **A Two-Stage Model of the Demand for Specialty Crop Insurance**

by

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## A Two-Stage Model of the Demand for Specialty Crop Insurance

### Abstract

Proposals for reform of the federal multiple-peril crop insurance program for specialty crops seek to change fees for catastrophic (CAT) insurance from a nominal fifty-dollar per contract registration fee to an actuarially sound premium. Growers argue that this would cause a significant reduction in participation rates, thus impeding the program's goals of eventually obviating the need for *ad hoc* disaster payments and worsening the actuarial soundness of the program. The key policy issue is, therefore, empirical one - whether the demand for specialty crop insurance is elastic or inelastic. Previous studies of this issue using either grower or county-level field crop data typically treat the participation problem as either a discrete insure / don't insure decision or aggregate these decisions to a continuous participation rate problem. However, a grower's problem is more realistically cast as one of simultaneously making a coverage level / insurance participation decision. Because the issue at hand considers a significant price increase for only one coverage level (50%), differentiating between these decisions is necessary both from an analytical and econometric standpoint. To model this decision, the paper develops a two-stage estimation procedure based on Lee's multinomial logit-OLS selection framework. This method is applied to a county-level panel data set consisting of eleven years of the eleven largest grape-growing counties in California. Results show that growers choose among coverage levels based upon expected net premiums and the variance of these returns, as well as the first two moments of expected market returns. At the participation-level, the mean and variance of indemnities are also important, as are several variables measuring the extent of self-insurance, such as farm size, enterprise diversity, or farm income. The results also show that the elasticity of 50% coverage insurance is elastic, suggesting that premium increases may indeed worsen the actuarial soundness of the program. These increases will also cause a significant adjustment of growers among coverage levels.

**keywords:** California, crop insurance, discrete/continuous choice, grapes, multinomial logit.

## **A Two-Stage Model of the Demand for Specialty Crop Insurance**

### **Introduction**

Since the creation of “catastrophic” (CAT) multiple-peril crop insurance in the Federal Crop Insurance Reform Act (FCIRA) of 1994, many specialty crop growers have come to rely on this option as an inexpensive safety net in the event of a major crop failure. However, fruit and vegetable growers are now concerned that proposals to change the cost of CAT insurance from a flat, fully-subsidized fee to a more traditional actuarially determined premium would mean a dramatic rise in the premiums they must pay. Grower groups argue that these changes, intended to increase the financial viability of specialty crop insurance, will instead cause many growers to go without multiple-peril crop insurance (Jones) and thus exposed to significant losses in the event of a poor harvest. Whether these inevitable defections cause an overall deterioration of the financial viability of specialty crop insurance depends upon the elasticity of demand for insurance so is thus an empirical question (Goodwin 1993). In fact, if the demand for CAT insurance is price-elastic, then increasing premiums may actually worsen the actuarial soundness of the entire program if many “good risk” growers choose not to insure.

Typically, models of the demand for crop insurance that use farm-level data seek to explain a grower’s decision of whether to insure (Calvin; Just and Calvin; Coble et al.) or the joint decisions of whether and how much to insure (Goodwin and Kastens; Smith and Baquet). In aggregate or county-level data, the goal is more often to explain the proportion of growers who choose to insure or the proportion of their land they choose to cover (Gardner and Kramer; Barnett, Skees, and Hourigan; Goodwin; and many others). However, both types of study do not consider the decision to insure as encompassing two separate, but interrelated decisions. Participants in the federal multiple peril crop insurance program (MPCI) choose from among three coverage levels: 50%, 65%, and 75%, meaning that they receive indemnities if their actual yield falls below 50%, 65%, or 75%, respectively, of their

insurance yield.<sup>1</sup> Therefore, growers must not only choose how much of their land to insure, but the level of coverage as well. Hojjati and Bockstael pose a similar type of problem in which farmers choose from among a discrete set of crop and insurance alternatives. They, too, however, assume only one coverage level. Models that do not account for the sample selection process involved in first choosing a coverage level not only invite sample-selection bias, but also ignore a potential source of valuable information. While ignoring the choice of coverage level may be more tenable for relatively homogeneous field crop growers, this assumption is not acceptable for fruit growers. Moreover, because the policy reform proposal focuses specifically on increasing the price of one coverage level, differentiating between the demands for each is necessary to make meaningful comment on the effects of the proposed change. Fortunately, this bias is easily overcome and the information readily recoverable.

To do so, this study uses a two-stage approach to account for growers' choice of coverage level and amount of insurance. In the first stage, a multinomial logit model is used to calculate the probability that growers in each county choose coverage level  $k$ . This fitted probability is used to calculate a correction factor similar to the inverse Mill's ratio employed by Heckman which, when included in a continuous model of insurance demand, corrects for the sample selection bias caused by growers' choice of coverage level. This second-stage model differentiates between the determinants of growers' demand for a minimal level of protection (50% coverage) or a more comprehensive level (75%). By using Lee's generalized selection procedure to estimate each second-stage equation, the two-stage model provides consistent estimates of the factors that determine the probability of purchasing each type of insurance, as well as the factors that drive aggregate participation rates.

Therefore, the primary objectives of this research are to determine the factors that contribute to

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<sup>1</sup> Although growers can now select from a greater number of coverage levels, a vast majority (>95%) of growers in the California grape data set used here chose one of these three levels.

a grower's decision among insurance coverage levels, and the decision as to how much insurance to buy. The following section presents an econometric approach that produces consistent parameter estimates of an aggregate insurance participation model while allowing for selection from among several discrete types of insurance. A description of an application of this approach to California grape growers follows. The remainder of the paper presents and discusses the empirical results of this application, including both the immediate implications of proposed changes to catastrophic insurance premiums and to crop insurance in general.

### **An Empirical Model of Insurance Demand**

A grower's decision to purchase multiple-peril crop insurance encompasses two related decisions: how much to insure, and the level of coverage.<sup>2</sup> The amount of insurance purchased, however, is only observed if a particular coverage level is chosen. Therefore, simple ordinary least squares estimates of insurance demand equations at each coverage level will be biased (Lee). Because the two decisions are logically dependent upon each other, the empirical procedure employed must reflect this fact to ensure consistent parameter estimates. Therefore, this study uses the two-stage discrete / continuous multinomial selection approach suggested by Lee. This method is similar to the familiar Heckman correction procedure, but because growers face more than two coverage alternatives, the selection process is multinomial rather than binomial. Consequently, at the first stage growers' decide between coverage levels according to the aggregate multinomial choice model of McFadden, while the second stage consists of separate, linear models of the amount of insurance bought.<sup>3</sup> Not only does this

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<sup>2</sup> Formally, the multiple-stage decision process also includes a price-election as well, but because this price is based on a market price, it is more appropriately thought of as exogenous and included in the measure of total liability. Further, there are often dozens of prices that apply to any one county each year, so it is not practical to include these in the discrete/continuous choice framework developed here.

<sup>3</sup> The logic behind this model is most clear if expressed as a sequential process, but neither the logical or statistical consistency of this model requires the actual decision process to be sequential.

approach yield consistent insurance demand parameter estimates, but by allowing the estimation of coverage-level specific demand models, provides more meaningful response elasticities than are currently available in the literature. Although the standard errors at this stage are inconsistent due to the estimated regressor problem, they are corrected using the asymptotic covariance matrix also described by Lee.

Formally, the insurance decision consists of a continuous participation equation similar to Goodwin (1983) where the percentage of eligible acres insured by a representative grower solves an expected utility maximization problem:

$$MAX_y E[V(y_k; R_k^g, \epsilon_{1k})], \quad (1)$$

where  $R_k^g$  is grower  $g$ 's random net revenue under coverage level  $k$  (net of operating costs and insurance premia),  $y_k$  is the amount of insurance purchased at coverage level  $k$ ,  $\epsilon_{1k}$  is a random error term, and  $V$  is a well behaved utility function. In this expression,  $R_k^g$  is equal to the level of market returns if no indemnifiable loss is incurred, or is equal to the insurance liability if a claim is made. Approximating growers' expected utility using a second-order Taylor series expansion provides an expression for grower  $g$ 's level of utility that consists of a deterministic and random component (Hojjati and Bockstael; Calvin). Writing the deterministic component in terms of the first and second moments of the distribution of revenue facing each grower, a grower's expected utility from insuring at a coverage level  $k$  becomes:

$$E[V_k^g] = \bar{V}_k^g + \epsilon_{1k}^g = v_k + E[R_k^g] - (\rho^g/2) Var[R_k^g] + \epsilon_{1k}^g, \quad (2)$$

where  $v_k$  represents a choice-specific preference parameter,  $E[R_k^g]$  is grower  $g$ 's expected net revenue,  $Var[R_k^g]$  is the variance of net revenue,  $\rho^g$  is the coefficient of absolute risk aversion for grower  $g$ , and  $\epsilon_{1k}^g$  is a random error term. Solving this problem produces an expression for the optimal amount of

insurance:

$$y_k = \mathbf{Z}_k^g + \epsilon_{1k}, \quad (3)$$

where  $\mathbf{Z}_k^g$  is a vector of other factors that influence the expected utility of insurance, including the mean and variance of  $R_k^g$ , attitudes towards risk, and various self-insurance strategies. In this application, however, the amount of insurance purchased at each coverage level ( $y_k$ ) is only observed if the particular coverage level  $k$  is chosen. A grower's choice of coverage level is, in turn, determined by the value of an unobserved index of coverage-level expected utility,  $E[U(R_k^g)]$ , which is also defined over the level of net revenue. Assuming growers are risk averse, and that net revenues are inherently random, a grower's choice of coverage level reflects the relative expected utility of net revenue available from each option. In a random utility framework (McFadden), the probability that a grower chooses coverage level  $k$  (ie. that  $y_k$  is observed) is given by the conditional probability that the expected utility from doing so is greater than all the alternatives, given that the grower has chosen to insure. Mathematically, this decision is written as:

$$P(k = 1 | i) = P(E[U(R_k^g)] \geq E[U(R_j^g)], \forall j \in K), \quad (4)$$

Again approximating growers' expected utility of coverage choice using a second-order Taylor series expansion, a grower's expected utility from insuring at a coverage level  $k$  becomes:

$$E[U_k^g] = \bar{U}_k^g + \epsilon_{2k}^g = u_k + E[R_k^g] - (\rho^g/2) \text{Var}[R_k^g] + \epsilon_{2k} = \mathbf{X}_k^g + \epsilon_{2k}^g, \quad (5)$$

where  $u_k$  represents a choice-specific preference parameter and the other variables are as defined above. Although this mean-variance approach is subject to some criticism, primarily due to the assumption of normality and quadratic utility (Newbery and Stiglitz), it nonetheless remains a common maintained hypothesis and has a considerable body of empirical support (Hojjati and Bockstael). Assuming this

simple linear specification for each grower's random utility, grower  $g$  chooses option  $k$  according to a given realization of the random error term,  $\epsilon_{2k}^g$ . Assuming  $\epsilon_{2k}^g$  are type I extreme value distributed (McFadden), the conditional coverage choice probability is:

$$P(k=1|i) = \frac{\exp(\bar{U}_k^g)}{\sum_j \exp(\bar{U}_j^g)}, j \in K, \quad (6)$$

which is the familiar multinomial, or conditional logit choice model. In estimating an aggregate multinomial logit model, the probability of choice  $k$  is simply replaced by the sample relative frequency of choice  $k$ . Using Lee's two-stage framework, this probability is then substituted into the insurance participation equation in (3) to obtain consistent estimates using least squares.

Specifically, assuming the marginal distributions of the  $\epsilon_{1k}^g$  are  $N(0, 1)$ , the estimated participation rate equation becomes (Lee; Maddala):

$$y_k = \mathbf{Z}_k^g - \rho_{kk} (J_{1k}(\mathbf{X}_k^g))/P(\mathbf{X}_k^g) + \epsilon_{2k}^g, \quad (7)$$

where  $\rho_{kk}$  is the correlation coefficient between  $\epsilon_{1k}^g$  and  $\epsilon_{2k}^g$ ,  $\phi$  is the standard normal density function, and  $J_{1k}$  is the transformation function:  $J_{1k} = \phi^{-1}P_k$ . This equation is estimated consistently with least squares once the arguments of  $U_k$  and  $V_k$  are defined.

At the coverage-choice stage, the components of  $U_k$  determine the proportion of growers choosing each coverage level. Specifically, the utility index is given by:

$$\bar{U}_k = \alpha_0 + \sum_j \alpha_{1j} E[P_j] + \sum_j \alpha_{2j} Var[I_j] + \alpha_3 E[R] + \alpha_4 Var[R] + \alpha_5 T, \quad (8)$$

where:  $E[P_j]$  = expected premium for coverage level  $j$ ;  
 $Var[I_j]$  = variance of indemnities for coverage level  $j$ ;



$E[R]$  = expected market revenue;  
 $Var[R]$  = variance of market revenue;  
 $T$  = time trend.

The determinants of expected utility at this stage thus reflect the relative desirability of each coverage level, the particular risk-history of growers in each county and their expectations of a profitable return to choosing a particular coverage level. Therefore, the elements of  $\bar{U}_k$  include the mean and variance of both market returns and the first- and second-moments of the returns to insurance (Coble et al.). Specifically, arguments of the choice model (8) include the county-level expected net premiums, or premiums net of expected indemnities and government subsidies where expected indemnities are calculated assuming a truncated normal yield distribution for each coverage level and county as described below (Goodwin 1984).

At the county level, aggregating representative growers' insurance decisions for each county means that the insurance-quantity model consists of a participation-rate equation for each coverage level. Among the studies reviewed by Knight and Coble, alternative measures of the aggregate insurance participation rate include either the proportion of eligible acres insured in each county (Gardner and Kramer; Hojjati and Bockstael; Barnett, Skees, and Hourigan; Goodwin 1993), the change in MPCl participation between two sample years (Cannon and Barnett), or liability per acre (Goodwin 1993). Although Goodwin finds significant differences between parameter estimates for each dependent variable, this study adopts a proportion of acreage measure for the sample of California grape growers. Defining participation in this way, the estimated version of equation (7) becomes:

$$\begin{aligned}
 y_k = & \alpha_0 + \alpha_1 E[P_k] + \alpha_2 Var[I_k] + \alpha_3 E[R] + \alpha_4 Var[R] + \alpha_5 T + \alpha_6 T\% \\
 & + \alpha_7 R\% + \alpha_8 INC + \alpha_9 GR\% + \alpha_{10} LV\% + \alpha_{11} SZ + \alpha_{12} k + \epsilon_{1k},
 \end{aligned} \tag{9}$$

where variables unique to this stage include:

$T\%$  = proportion of county grape acreage in table grapes;  
 $R\%$  = proportion of county grape acreage in raisin grapes;  
 $INC$  = average income from farming;  
 $GR\%$  = average proportion of farm enterprise in grape production;  
 $LV\%$  = average proportion of farm enterprise in livestock;  
 $SZ$  = average size of grape enterprise (acres);  
 $k$  = Lee's multinomial correction factor.

Whereas the coverage choice model includes the mean and variance of expected premiums for all coverage levels in each levels' set of attributes, at the insurance-quantity level each equation includes only the expected net premium and indemnity variance unique to that coverage level. Similar to Coble et al., this study includes variables measuring expected market returns and the variability of market returns. Assuming naive expectations,  $E[R]$  is equal to lagged average grape-revenues, while the variability of returns is found by calculating the variance of historical revenues for each county over the entire sample period. If the results show a positive relationship between participation and the variability of market revenue, then adverse selection is likely to exist. Most of the existing research in this area, however, shows that insurance participation depends not only upon relative returns to insurance, but also growers' willingness and ability to self insure.

The tendency to self insure is captured by including variables describing a typical grape grower in each county, thereby accounting for unobserved heterogeneity among counties, the effect of size economies on the tendency to insure, and the extent of financial, operational, and geographical diversification. Data for variables measuring each of these factors is readily available from public sources.

## **Data and Methods**

Specifically, the data for this analysis are from FCIC, California Department of Food and Agriculture (CDFA), and Bureau of Census sources. The insurance data includes county-level measures of the number insurance contracts, total premiums, liabilities, and indemnities for grape growers at each coverage and price election level for the years 1986-1996. Although FCIC records include many more counties than those considered here, the data used in this analysis includes the eleven counties for which there are eleven consecutive years of data in both the insurance and grape production data. Data on historical grape production performance was provided by CDFA officials, as compiled from county agricultural commissioners' reports, and includes county-level harvested acres, total production, average yield, and average prices disaggregated by intended usage (wine, table, or raisin). For grapes, the available insurance data typically consist of upwards of twenty price election levels for each county/coverage/year observation. Therefore, insurance prices are averaged across all election levels. Data on farm income, size, and enterprise diversification are from the 1982, 1987, and 1992 editions of the *Census of Agriculture*. The resulting data set provides 121 panel observations that are used to estimate both the coverage choice and aggregate participation models. For each model, consistent parameter estimates are obtained using the two-stage method described above within a general fixed effects estimation framework.

## **Results and Discussion**

Because elasticities provide a more intuitive interpretation than structural parameters in the MNL model, table one provides the elasticity estimates from the coverage-choice stage. These results show that the variability of returns to insurance has very little impact on the choice of 50% coverage, but a significantly greater effect on the probability of choosing 75% coverage. This is also true with respect to the cross-elasticities -- the variability of indemnities at the 65% level has a relatively large impact on

the probability of choosing a high level of coverage, but little effect on the lowest level. Both the own and cross-elasticities suggest that growers who choose a minimal level of insurance are less sensitive to risk, a result that is indeed consistent with their choice of coverage. Although some may interpret these results as implying the existence of adverse selection, this is not necessarily the case in the choice model because the probability of choosing 50% coverage rises in the variability of expected indemnities at a 75% level. This suggests that such changes have significant allocative effects, but does not address the participation question raised by adverse selection. However, the aggregate participation parameters and elasticities provide both a more direct test for adverse selection and more complete evaluation of the policy implications of a premium increase.

These results are shown in table two. Legislators and policy analysts' interest lie primarily in these parameters as they reflect the constraints on federally-underwritten crop insurance as a viable agricultural policy tool. If participation is price-inelastic, then financial viability may be improved by a premium increase. However, if participation is price-elastic, then a premium increase (or a reduction in subsidies) will reduce participation proportionately more than the increase in premiums (Goodwin 1993). As a result, program performance suffers by both measures. In the grape insurance example, the price-elasticity of participation at the 50% coverage level is -1.252, while the elasticities at 65% and 75% are -0.276 and -0.492, respectively. This suggests that an increase in CAT insurance premiums is likely to cause a relatively large number of growers to leave the program altogether, reducing the actuarial soundness of the CAT program. This result should be of particular concern given California growers' expressed desire for an effective and affordable risk management tool (Blank and McDonald). However, premium increases at both the 65% and 75% levels may indeed have the desired effect of raising program revenue without drastically reducing participation rates. Clearly, this suggests that the

FCIC can improve the overall financial performance of the program through price discriminating between growers who choose to insure at different levels. This result is not unexpected as growers who choose CAT-level insurance are likely those who are at the margin between insuring and not insuring. While the elasticities at 65% and 75% are consistent with those found by previous researchers (see Knight and Coble and references therein) none report elastic demand. Our results suggest that this discrepancy may be due to the fact that they do not differentiate between participation at different levels of coverage. Nonetheless, the implications of an elastic demand for insurance are likely to be more severe if participation is also subject to adverse selection. In table 2, growers at the 50% and 75% levels are less likely to insure the more variable are the returns to insurance simply because insurance offers less of a benefit to market returns. However, growers are more likely to insure at their chosen coverage level the more variable are market returns. This constitutes evidence of adverse selection.

### **Conclusions and Implications**

In order to account for differences in the structure of insurance demand among different coverage levels, this study applies a two-stage empirical method suggested by Lee. With this approach, growers are assumed to choose the amount of insurance they wish to buy and the coverage level in two separate, but interrelated decisions. We demonstrate an application of this method to a county-level sample of insurance choice and participation rates by California grape growers over the period 1986 - 1996.

Determinants of both the demand for insurance at each level and the choice of coverage level include the mean and variance of the returns to insurance, as well as the mean and variance of market returns. The study finds empirical support for each of these variables. More importantly, however, the results show the demand for insurance at a 50% coverage level to be elastic, while higher coverage levels are inelastic in demand. Thus, the proposed premium changes would have the perverse effects

cited above. Growers at both the 65% and 75% levels are also more likely to insure the greater the variability of their market-based returns. This suggests that adverse selection is likely to exacerbate the participation problems caused by a premium increase. Because the least-adversely selected growers are the first to drop out, the remaining growers will tend to be the worse risks, so indemnities will likely rise due to this indirect, unintended side effect as well.

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**Table 1. Multinomial Logit Coverage Choice Parameter Estimates: CA Grape Growers**

Variable:	50% Coverage			75% Coverage		
	Estimate <sup>1</sup>	t-ratio	Elasticity	Estimate	t-ratio	Elasticity
Constant	-46.112*	-3.841		16.321*	4.404	
E[Prem50]	-0.059*	-2.313	-0.091	-0.014	-0.168	-0.014
E[Prem65]	0.039*	2.748	0.134	0.024*	2.616	0.188
E[Prem75]	0.001	0.098	0.003	-0.025*	-2.441	-0.068
V[Indem50]	-202.490*	-5.946	-0.001	-10.275*	-6.924	-0.552
V[Indem65]	-28.284*	-5.982	-0.005	1.456*	6.524	0.845
V[Indem75]	2.353*	6.031	0.050	-0.125*	-3.399	-0.293
V[Rev]	1.576	1.616	0.085	0.604	1.717	0.042
E[Rev]	-0.003	-1.878	-0.072	-0.006	-1.593	-0.127
Year	0.523*	3.963	3.893	-0.163*	-3.261	-0.829
LR <sup>2</sup>	75.490					

<sup>1</sup> A single asterisk indicates significance at a 5% level.

<sup>2</sup> The chi-square likelihood ratio statistic is  $LR = 2(LLF_U - LLF_R) \sim \chi^2_q$  which compares the estimated model with a null model,  $\beta = 0$ . The critical chi-square value at 18 degrees of freedom at a 5% level of significance is 28.869.

**Table 2. CA Grape Grower Insurance Demand by Coverage Level: 50%, 65%, 75%.**

	Coverage Level								
	50%			65%			75%		
	1	t-ratio	1	2	t-ratio	2	3	t-ratio	3
Constant	-3.031*	-9.685		-2.812*	-3.072		5.465*	6.458	
E[Prem]	-0.005*	-7.220	-1.252	-0.002*	-2.177	-0.276	-0.003*	-4.840	-0.492
V[Indem]	-0.020*	-3.980	-0.222	-0.002	-0.968	-0.058	-0.003*	-6.244	-0.221
E[Rev]	-0.001*	-3.801	-1.536	-0.001	-0.434	-0.151	-0.007*	-2.940	-0.500
V[Rev]	0.096*	2.673	1.024	-0.051	-0.456	-0.161	0.683*	6.853	1.235
Trend	0.035*	10.320	46.161	0.041*	4.064	16.148	-0.048*	-5.413	-10.660
Table %	-0.058	-0.625	-0.064	-0.153	-0.492	-0.050	0.574*	2.249	0.107
Raisin %	0.115*	2.419	0.327	-0.064	-0.404	-0.054	-0.343*	-2.502	-0.165
Income	-0.029	-0.735	-0.397	-0.163	-1.321	-0.650	-0.134	-1.259	-0.304
Grape %	-0.069	-0.710	-0.118	-0.975*	-2.969	-0.493	-0.143*	-4.887	-0.412
Livestock %	0.064	0.633	0.330	-0.936*	-2.436	-1.423	-0.122*	-3.858	-1.059
Firm Size	0.215	0.370	0.152	-0.461	-0.253	-0.096	-0.209	-1.287	-0.249
	0.003*	2.938	0.107	-0.008*	-2.068	-0.034	0.001*	2.040	0.017
R <sup>2</sup>	0.735			0.354			0.741		

<sup>1</sup> A single asterisk indicates significance at a 5% level. Variables: E[Prem] = premiums net of expected indemnities; V[Indem] = variance of expected indemnities; E[Rev] = expected market revenue; V[Rev] = variance of mkt. revenue.

Parameters:  $\beta_i$  = coefficients for coverage level  $i$ ,  $\alpha_i$  = elasticity vector for coverage level  $i$ .