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**Farmer response to crop insurance incentives under heterogeneous risk-  
management strategies**

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# **Farmer response to crop insurance incentives under heterogeneous risk-management strategies**

## **Abstract**

Understanding how farmers respond to premium subsidies and other incentives to purchase crop insurance is fundamental to evaluating how changes in these incentives affect the use of federal crop insurance and thus the Federal savings that can be expected. We use contract-level data for corn enterprise units in 2008 and 2009 to examine how modifications to the out-of-pocket cost of crop insurance affect farmers' insurance coverage level decisions and government expenditures. Unlike previous studies that have examined this question, we use a specialized discrete choice framework, an ordered generalized extreme value (OGEV) model. This approach explicitly accounts for the natural ordering of the choice set from low to high coverage. Our results suggest a significant difference in the response to changes in the unit price of federal crop insurance for farmers that are observed to choose a low coverage level versus those that are observed to choose a high coverage level. This has significant implications for the potential government cost savings and change in average farmer coverage level that can be expected from a change in the structure of premium subsidies.

The U.S. federal crop insurance program has become an important risk management tool for farmers, as well as an increasingly important source of government farm support (Glauber, 2004, 2012; O'Donoghue 2014; RMA 2014). Increased emphasis on crop insurance in successive U.S. farm bills and the attendant increases in participation have naturally increased the program's costs. As is evident from Congressional debate leading up to the 2014 Farm Bill, policy makers are certain to face continued pressure to limit spending and do more with less in the Federal budget. The crop insurance program is unlikely to be immune from calls for additional savings if it appears to be too generous to farmers or to the private crop insurance companies that partner with USDA to administer it.

The government incentivizes farmer participation in the crop insurance program by offering significant subsidies on premiums. The subsidy on a given policy depends on the coverage level, with the government offering higher subsidies on lower coverage levels. Institutions as diverse as the Government Accountability Office and White House Office of Management and Budget (GAO 2012, OMB 2013, OMB 2015), the American Enterprise Institute (Smith, Goodwin, and Babcock 2012), and the Environmental Working Group (Babcock 2013) have advocated cutting subsidies as a way to find savings from farm programs. Indeed, USDA's current budget for 2017 contains several options for cutting back on crop insurance outlays, including reducing premium subsidies for revenue coverage.<sup>1</sup>

Understanding how farmers respond to premium subsidies and other incentives to purchase crop insurance is fundamental to evaluating how changes in those incentives affect the use of crop insurance and thus the savings that could be expected. Small changes in the cost of crop insurance due to modifications of subsidy rates are more likely to induce changes at the intensive margin, i.e., farmers alter the extent of their crop insurance use (coverage level), than to switch insurance products or enter or exit the program entirely. Therefore we examine how modifications to the subsidies that affect the out-of-pocket cost of crop insurance affect farmers' insurance coverage *level* decisions.

Several studies, including Hojjatti and Bockstael (1988), Shaik et al (2008) and Sherrick et al (2004), and Mishra and Goodwin (2003) have examined demand for crop insurance with a focus on the decision to participate in the program and the choice among crop insurance products. However, few papers address the farmer's choice of coverage level. An exception is Du, Feng and

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<sup>1</sup> See details at <http://www.obpa.usda.gov/budsum/fy17budsum.pdf>.

Hennessey (2014),<sup>2</sup> which examined whether the observed relationship between out-of-pocket premiums and the choice of coverage level provides evidence that farmer behavior conforms to economic theory.

Whereas the focus in Du, Feng and Hennessey was on understanding farmer behavior, our interest is in the policy implications of changes to premium subsidies. We explicitly characterize the relationship between the subsidy rate and the choice of coverage level in order to evaluate the effects of changes in the subsidy structure on the cost of the program and on the average coverage level. We model this relationship using an ordered generalized extreme value (OGEV) model (Small (1987)), a discrete choice model that accounts for the natural ordering of the choice set from a low of 50 percent coverage to a high of 85 percent.

Much of the previous literature characterizes the demand for crop insurance using a multinomial logit (MNL) framework. The MNL model assumes unobservable factors influencing a farmers' choice, such as his or her risk management preferences, are independent across alternatives. In contrast, the OGEV model allows a farmer's unobservable risk management preferences to make all low coverage levels systematically more attractive than high coverage levels or vice versa. Du, Feng and Hennessey (2014) likewise weakened the assumption of independence of unobservables across alternative coverage levels. They estimated a mixed logit model, in which unobservable heterogeneity across farmers' preferences for policy characteristics such as the premium paid by farmers affects their responses to changes in those costs. A mixed logit model using our data does

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<sup>2</sup> Makki and Somwaru (2001) also include coverage level as a characteristic in their study of demand for crop insurance choice. Their approach is very different from the others we examine here.

not reveal significant heterogeneity in farmer preferences for the policy characteristics included in our utility specification.

Like Du, Feng and Hennessey we use contract level data from the RMA on farmers participating in the crop insurance program. In a substantial advantage in terms of precision, our data include information on the premium for coverage levels not selected by the farmer, whereas Du, Feng and Hennessey reconstruct these premiums following RMA guidelines. In addition, our records cover all contracts in all states for 2008 and 2009, whereas their data cover a subset of states for the year 2009 only.

We contrast the predictions for farmer behavior generated by the OGEV model with those of an MNL model. Whereas the MNL model predicts the same pattern of substitution regardless of the farmer's observed choice of coverage, the OGEV model offers distinct predictions for farmers choosing low versus high coverage. We find that farmers choosing a low coverage level are disproportionately more responsive to changes in subsidies on low coverage level alternatives relative to high coverage level alternatives. The reverse holds for farmers choosing a high coverage level. These results suggest that farmers decide on a risk management strategy characterized either by low levels of crop insurance coverage or high levels of crop insurance coverage.

We conduct three policy reform scenarios in which we examine the response to changes in the structure of subsidy rates across coverage levels for a particular revenue insurance product covering corn. We find that cutting the relatively lower subsidy rates on high coverage levels both decreases the cost of the program to the government and increases the average coverage level. In contrast, cuts to the relatively higher subsidy rates on low coverage levels would actually serve to

*increase* the cost of the program. A fourth scenario explores the impact of a flat subsidy rate across all coverage levels. We find this reform induces many more farmers to choose the maximum coverage level, in line with the predictions of economic theory.

In the next section we will outline the relevant features of the federal crop insurance program and the decision faced by farmers who choose to participate. A formal framework for our analysis follows. Next we describe our contract-level data set. We then estimate our OGEV model alongside an equivalent MNL model and compare their implications. Finally, we use the models to explore three policy reform scenarios and finish with concluding comments.

## **BACKGROUND**

Uncertainty is ubiquitous in agriculture and stems from both from systemic and idiosyncratic sources. Farmers develop risk management strategies to cope with unforeseen events. Federal crop insurance is only one tool used by farmers to reduce exposure to risk. A risk management strategy may also include investments in technology, farm and non-farm income diversification, borrowing, saving, investment, and hedging.

Since the 2008 Farm Bill, producers of major field crops including corn, soybeans, and wheat who elect to purchase federal crop insurance have been able choose among several yield and revenue-based “deep loss” federal insurance policies each year. In 2016, for these crops substantially more acres were enrolled in revenue-based policies than in yield-based policies (relative acreages in these two types of policies were closer in 2008 and 2009). In 2008, around 73 percent of the 179 million insured acres of corn, soybeans and wheat had revenue-based policies. By 2015 around 89 percent of 199 million insured acres were covered by revenue-based policies. In addition to

choosing the type of indemnification, farmers also choose the insurable units on which to base their policy. Given a choice of product, farmers choose from among a finite number of coverage levels over which both premiums and subsidy rates vary. The farmer chooses the product and coverage level that fits best in his or her overall risk management strategy, given his or her preferred liability-premium tradeoff.

Within the limits of the available information, the actuarially fair premium for the farmer is determined by RMA. The farmer is offered this premium, discounted by the government subsidy rate. Premiums vary across farmers based on their yield relative to others in the county and other farm characteristics. Farmers can use RMA's online premium calculator or work with an insurance agent to examine the relationship between the coverage level and the liability and premium. Although the subsidy rate for each available coverage level is visible in the online premium calculator, that information can be glossed over, and the farmer may or may not explicitly recognize the subsidy rate that applies to his or her choice of coverage level. In any event, a change in the subsidy rate would appear to the farmer as an increase or decrease in his or her premium.

## **MODEL**

We argue that marginal changes in premiums brought about by changes in the subsidy rate are most likely to affect demand for crop insurance products at the intensive margin. That is, while major reforms to federal crop insurance programs such as those that occur in Farm Bill legislation may induce farmers to make changes to their overall risk management strategy, risk management is only one element of the complex set of management decisions each farmer must make. Therefore, once a farmer has chosen the role that crop insurance plays in their strategy, they are



more likely to respond to marginal increases in premiums by making adjustments in coverage levels than by shifting their product or participation choice.

We seek to capture a local approximation to the farmer's choice of coverage level using an expected utility framework. Given a farm management strategy – including a risk management strategy – and non-farm household income and wealth, farmer  $i$  chooses to purchase crop insurance at coverage level  $g \in G$ , where  $G$  is discrete and finite, to maximize a concave expected utility function over revenue from farming, subject to a budget constraint. Henceforth, we denote coverage level  $g$  as  $\theta_g$ . In our empirical section we will focus on a revenue insurance product offered in eight evenly-distributed coverage levels from 50 to 85 percent coverage. We make use of this choice set for convenience in presenting the model.

Following Cameron and Trivedi (2010) we assume farmer  $i$ 's expected utility from  $\theta_g$  is the sum of two components  $U_{ig} = V_{ig} + \epsilon_{ig}$ . The first component is specified:

$$V_{ig} = \mathbf{x}'_{ig}\boldsymbol{\beta} + \mathbf{z}'_i\boldsymbol{\gamma}_g$$

where  $\mathbf{x}_{ig}$  is a vector of characteristics describing the out-of-pocket cost of  $\theta_g$  to the farmer and  $\boldsymbol{\beta}$  is a vector of parameters. The vector  $\mathbf{z}_i$  contains observable farm- and farmer-specific variables that characterize farmer  $i$ 's wealth and influence the crop insurance premium. The vector  $\boldsymbol{\gamma}_g$  contains alternative-specific parameters that describe how the effects of  $\mathbf{z}_i$  vary across coverage levels. The second component of expected utility,  $\epsilon_{ig}$  captures the individual farmer's degree of risk aversion and capacity to bear risk as well as factors affecting a farmer's expected income and crop insurance premiums that are known to the farmer but unobservable to the researcher.

We observe the farmer's choice of  $\theta_g$  if it is the expected utility maximizing choice. The probability farmer  $i$  chooses  $\theta_g$  is therefore:

$$P_{ig} = \Pr(U_{ik} - U_{ig} \leq 0) \forall k = \Pr(\epsilon_{ig} - \epsilon_{ik} \leq V_{ig} - V_{ik}) \forall k$$

Assumptions on the distribution of the unobservable component of utility,  $\epsilon_{ig}$  yield different models for the farmer's choice probability. The simplest approach is to assume  $\epsilon_{ig}$  is independently distributed extreme value across alternative coverage levels. This approach is attractive because it yields a simple multinomial logit (MNL) model for choice probability.<sup>3</sup>

While it is straightforward to implement, the MNL model has a significant drawback for policy analysis in this case. Namely, it imposes the independence of irrelevant alternatives (IIA) assumption, which implies that the relative probability of choosing  $\theta_g$  over  $\theta_k$  is independent of the characteristics of all other alternative coverage levels. More prosaically, this boils down to assuming the factors that induce a farmer to choose the maximum coverage level of 85 percent over an intermediate alternative of 65 percent coverage are unrelated to those that induce him or her to choose 85 percent coverage level over 60 percent. That is a very strong assumption.

Imposing that assumption is often innocuous when the objective is to explain demand patterns in the data *ex post*. However, if the model is intended to predict changes in demand in response to a policy change *ex ante* and the IIA assumption does not hold in the data, an MNL model may generate misleading predictions. To see this, note that the MNL model implies a particularly

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<sup>3</sup> Farmer  $i$ 's MNL choice probability for coverage level  $g$  is  $P_{ig} = e^{V_{ig}} / \sum_k e^{V_{ik}}$

inflexible pattern of elasticities. Let  $s_k \in \mathbf{x}_{ik}$  be the subsidy rate on  $\theta_k$ . The elasticity of  $\theta_g$  with respect to  $s_k$  is then:

*Equation 1*

$$E_{\theta_g, s_k} = \begin{cases} (1 - P_{ig}) \times \frac{\partial V_{ig}}{\partial s_k} \times s_k & k = g \\ -P_{ik} \times \frac{\partial V_{ik}}{\partial s_k} \times s_k & k \neq g \end{cases}$$

Equation 1 implies, everything else equal, the model will predict coverage levels with low choice probability have larger magnitude direct elasticities than coverage levels with a high choice probability. We can think of no reason why this should necessarily be the case. Moreover, it implies that the indirect elasticity with respect to coverage level  $k \neq g$  is constant across all alternative coverage levels. That implies, observable characteristics equal, all farmers are equally likely to substitute toward 85 percent coverage when its subsidy rate increases regardless of whether their initial choice was the minimum 50 percent coverage level or 80 percent coverage.<sup>4</sup> That is more plausible the more completely expected utility can be characterized by observable characteristics. However, since innately unobservable risk preferences play a key role in farmer choice of insurance coverage, it is unlikely to hold here.

A large class of models pioneered by McFadden (1978), known as generalized extreme value (GEV) models, weaken the IIA assumption by permitting a more flexible correlation structure among alternatives. These models are also consistent with utility maximizing behavior (McFadden 1978, Train 2009). Perhaps the most straightforward GEV approach to weaken the IIA is to use a nested logit model. In a nested logit model, the researcher divides alternatives into subsets or

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<sup>4</sup> A substitution towards 85 percent coverage when the subsidy rate increases assumes that  $\partial V_{ik} / \partial s_k$  is positive, which we will show to be true.

“nests” of like choices. Unobservable characteristics are allowed to be correlated across alternatives within the same nest, but are restricted to be uncorrelated across nests.

If we believe a farmer’s high tolerance for risk makes him or her more likely to choose all of the lower coverage levels we may specify the model as a nested logit, defining separate nests for low versus high coverage levels. In this case, while there is a clear ordering of coverage levels from low to high, it is not obvious where the line between low and high coverage levels should be drawn. Moreover, the perceived threshold between low and high coverage likely varies across farmers.

Instead, we specify the choice of crop insurance coverage level as an ordered generalized extreme value (OGEV) model, first introduced in Small (1987). In the OGEV model, the unobservable portion of expected utility exhibits what Small refers to as proximate covariance. That is,  $\epsilon_{ig}$  is more correlated among alternatives the nearer they are on the ordering from low to high coverage levels. The model thus allows, e.g., a farmer’s unobserved high tolerance for risk to imply a higher probability of choosing all low coverage levels, but it does not require the researcher to impose his or her beliefs about which coverage rates a farmer will consider high versus low.

The OGEV model is similar to the nested logit in that alternatives are allocated across nests within which unobservable characteristics may be correlated. Unlike the nested logit model, alternatives may belong to multiple nests. We follow Small (1987) and Wen and Koppleman (2001) and derive the OGEV model from the following GEV function:

$$G(y_1, y_2, \dots, y_n) = \sum_{m=1}^{J+M} \left( \sum_{j \in B_m} \alpha_{m-j} y_j^{\frac{1}{\mu_m}} \right)^{\mu_m}$$

which leads to the choice probability:

$$P_j = \sum_m P_{j|m} P_m$$

where:

$$P_m = \frac{\left( \sum_{j \in B_m} (\alpha_{m-j} \exp(V_j))^{1/\mu_m} \right)^{\mu_m}}{\sum_l^{J+M} \left( \sum_{i \in B_l} (\alpha_{l-i} \exp(V_i))^{1/\mu_l} \right)^{\mu_l}}$$

and:

$$P_{j|m} = \frac{(\alpha_{m-j} \exp(V_j))^{1/\mu_m}}{\sum_{i \in B_m} (\alpha_{m-i} \exp(V_i))^{1/\mu_m}}$$

where  $\alpha_{m-j}$  is a parameter describing the weight of coverage choice  $j$  allocated to nest  $m$  such that  $\sum_m \alpha_{m-j} = 1$  and  $\mu_m$  is an inverse measure of the correlation among alternatives in the nest referred to as the “dissimilarity parameter”. Higher values of the dissimilarity parameter imply alternatives within nest  $m$  are more independent and less correlated. Small (1987) shows that the OGEV model reduces to the MNL model when  $\mu_m = 1$  for all  $m$ .

The OGEV model nesting structure specifies a total of  $M + G$  nests, where  $G$  is the total number of alternatives and  $M + 1$  is the maximum number of alternatives in each nest. Each alternative belongs to  $M + 1$  total nests that span the choice set, gradually incorporating the alternatives nearest  $g$  on the ordering. Small (1987) demonstrates that the more nests alternatives  $g$  and  $k$  have in common, the more highly correlated their unobservable characteristics will tend to be. Unobservable factors affecting decisions between alternatives that have no common nests are assumed to be independent. Table 1 presents the OGEV nesting structure for  $M = 4$ .

Table 1: OGEV nesting structure,  $M+1=5$

Nest	Coverage Choice
1	50
2	50,55
3	50,55,60
4	50,55,60,65
5	50,55,60,65,70
6	55,60,65,70,75
7	60,65,70,75,80
8	65,70,75,80,85
9	70,75,80,85
10	75,80,85
11	80,85
12	85

Equation 2 presents elasticities for the OGEV model corresponding to those in Equation 1, as derived in Wen and Koppleman (2001).

Equation 2

$$E_{\theta_g, x_k} = \begin{cases} \frac{\sum_m P_{im} P_{ik|m} \left[ (1 - P_{ik}) + \left( \frac{1}{\mu_k} - 1 \right) (1 - P_{ik|m}) \right]}{P_k} \times \frac{\partial V_{ig}}{\partial x_{s_k}} \times x_{s_k} & k = g \\ - \left( P_{ik} + \frac{\sum_m \left( \frac{1}{\mu_m} - 1 \right) P_{im} P_{ik|m} P_{ig|m}}{P_{ig}} \right) \times \frac{\partial V_{ik}}{\partial x_{s_k}} \times x_{s_k} & k \neq g \end{cases}$$

Equation 2 demonstrates that the OGEV model will deliver fundamentally different predictions for the effect of changes in the subsidy rate on choice probability. Notably, the indirect elasticity with respect to  $s_k$  is no longer constant across alternative coverage levels. The magnitude of the elasticity of  $\theta_g$  with respect to  $s_k$  now depends on the degree to which farmers consider alternatives  $k$  and  $g$  to be close substitutes. By construction, the magnitude of the elasticity of  $\theta_g$  will tend to be relatively larger with respect to the subsidy rates of nearby coverage levels on the ordering.

## DATA

We estimate demand for revenue insurance coverage level using data on individual farmer contracts for corn enterprise units in 2008 and 2009 obtained from RMA. Enterprise units refer to policies covering the entirety of a farmer's corn acreage within a single county. Our data include the coverage level choice and the premium associated with each coverage level whether or not it was chosen by the farmer for every farmer who chose this policy in 2008 and 2009. The data also contain total acreage, APH, and the state and county where the farm is located. Increased subsidy rates in 2009 reflect an effort in the 2008 Farm Bill to incentivize the choice of enterprise unit policies over policies that insure a subset of the farmer's acreage. Table 2 presents the subsidy rates that applied to each coverage level in 2008 and 2009.

*Table 2: Subsidy rates for enterprise units (percent)*

Coverage Level								
Crop Year	50%	55%	60%	65%	70%	75%	80%	85%
2008	67	64	64	59	59	55	48	38
2009	80	80	80	80	80	77	68	53

Figure 1 illustrates the breakdown of coverage level choice in our sample by crop year. In both years, relatively high coverage levels are considerably more common than low coverage levels. As subsidies were increased on enterprise unit policies in 2009, higher coverage levels gained market share, particularly the 80 and 85 percent coverage levels.

Figure 1: Coverage level choice

Relative frequency in data by year

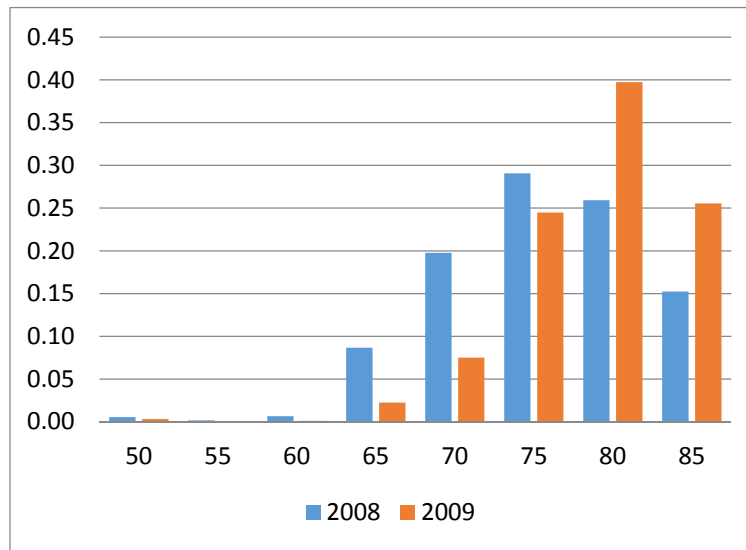


Table 3 is a matrix that describes the change in choices of coverage level for farmers enrolled in both years.<sup>5</sup> The value in each cell represents the share of farmers choosing the coverage level listed at the start of the row in 2008 who chose the coverage level listed at the start of the column 2009. For example, 45 percent of the farmers that chose 55 percent coverage in 2008 maintained that level of coverage in 2009, five percent lowered their coverage level to 50 percent and 10 percent increased coverage to 60 percent. Very few farmers choosing coverage levels of 65 percent or greater in 2008 choose to decrease their coverage in 2009. None reduced their coverage below 70 percent. The vast majority of the farmers that chose a coverage level more than three increments chose minimal coverage (50 or 55 percent) in 2008.

We cannot entirely attribute the shifts in coverage depicted in Table 3 to changes in the structure of subsidies across coverage levels between 2008 and 2009. Many other changes in the crop

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<sup>5</sup> 35.7 percent of the sample is comprised of farmers that purchased the policy in both years, 29.6 percent purchased the policy in 2008, but not 2009 and 34.7 percent purchased the policy in 2009 but not 2008.



insurance program, as well as other farm programs changed between 2008 and 2009 as part of the 2008 Farm Bill. However, it is notable that most farmers that enrolled in both years did not change coverage level. For all but 60 and 70 percent coverage, the largest value in the matrix is on the diagonal. Moreover, most farmers that did change their coverage level chose a 2009 level that was near their 2008 choice on the ordering. For each 2008 coverage level, 85 percent of the 2009 choices are within the three nearest alternatives and 95 percent are within four. This suggests that there are factors that systematically induce farmers to choose a low, intermediate or high coverage level and thus neighboring coverage levels that keep the farmer within these categories are closer substitutes than those more distant in the ordering.

*Table 3: Changes in choice of coverage level 2008-09 (Percent of farmers choosing row in 2008 that chose column in 2009)*

Coverage Level 2008	Coverage level 2009							
	50	55	60	65	70	75	80	85
50	45	0	7	10	19	10	7	0
55	5	45	10	20	10	10	0	0
60	1	0	18	8	39	24	8	2
65	0	0	0	39	24	29	7	1
70	0	0	0	0	37	43	17	2
75	0	0	0	0	1	47	46	6
80	0	0	0	0	0	3	65	31
85	0	0	0	0	0	1	11	88

## RESULTS

We estimate MNL and OGEV models of farmers choice of coverage level as a function of the subsidy rate and premium per-acre paid by the producer. Note that the premium paid by the producer is equal to the total premium per acre times one minus the subsidy rate.<sup>6</sup> The subsidy rate captures the variation in premiums across coverage levels due to government policy and is the

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<sup>6</sup> Recall that the farmer may or may not have paid explicit attention to the subsidy rate.

same for all farmers in the sample.<sup>7</sup> The remainder of the variation in premiums across coverage levels also varies across individual farmers and reflects of farm-specific risk. We also include farm size in acres, expected yield as measured by APH and a dummy variable equal to one if the observation is in crop year 2009.

Based on our observation of farmers change in coverage level between 2008 and 2009 described in Table 3, we define the nesting structure for the OGEV model by setting  $M = 4$  (see Table 1). We follow the standard OGEV model defined in Small (1987) and set  $\alpha_{m-g} = \frac{1}{M+1} = 0.2$  for all nests that include coverage level  $g$ . Unlike the standard OGEV model, we estimate  $\mu_m$  for all nests that include more than one alternative.<sup>8</sup> We estimate both the MNL and OGEV models with simulated maximum likelihood using the SOLVOPT optimization algorithm in the Biogeme software (Bierlaire 2003).

Table 4 contains parameter estimates for the coverage level-varying characteristics  $\beta$  and the dissimilarity parameter  $\mu_m$  for the MNL and OGEV models. A positive coefficient confirms our expectation that, everything else equal, raising the subsidy rate associated with  $\theta_g$  increases the probability it is selected. Negative coefficients on producer-paid premium per acre confirm that a higher premium on  $\theta_g$  decreases the probability it is selected.

As immediate evidence against the IIA assumption imposed by the MNL model, estimates of  $\mu_m$  in the OGEV models are significantly different from one for all nests except 4 through 6. This implies that the unobservable component of expected utility is independent across these coverage

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<sup>7</sup> The highest levels of coverage is not an available choice for farmers in a few counties. In 2008 about 10 percent of corn insured acres were in counties where 80 and 85 percent coverage was not offered.

<sup>8</sup> We restrict  $\mu_m = 1$  for nests with a single alternative.

levels, but correlated across coverage levels within all other nests. More formally, the MNL model is rejected by a likelihood ratio test statistic of 416, which is statistically significant for any reasonable significant level and results of the standard Hausman (1978) test also reject the IIA assumption for our data.

Notice that the nests for which  $\hat{\mu}_m$  is significantly different from one are those containing coverage levels that are either entirely above or entirely below 60 percent coverage. In contrast,  $\hat{\mu}_m$  is not significantly different from one for nests that encompass coverage rates on either side of 60 percent. This suggests farmers tend to decide on a risk management strategy that includes either high or low coverage levels, and choose a coverage level from within one of those two categories. The particularly low values for  $\hat{\mu}_2$  of around 0.10 suggest that farmers consider coverage levels of 50 and 55 percent to be highly substitutable. Likewise, estimates of  $\hat{\mu}_m$  of around 0.20 for nests 8 through 11 suggests that farmers substitute among coverage levels higher than 65 percent.

Table 4: Selected parameter estimates and measures of fit (variables with alternative-specific properties)

Parameter / Measure of Fit	MNL		CNL	
	Value	t-stat	Value	t-stat <sup>a</sup>
Subsidy Rate	10.9	12.21***	5.30	11.51***
Producer Premium	-0.08	- 28.83***	-0.04	-18.75***
$\mu_1: 50$	1.00	--	1.00	--
$\mu_2: 50 - 55$	1.00	--	0.11	4.19***
$\mu_3: 50 - 60$	1.00	--	0.11	1.48*
$\mu_4: 50 - 65$	1.00	--	0.06	0.29
$\mu_5: 50 - 70$	1.00	--	1.00	0.00
$\mu_6: 55 - 75$	1.00	--	1.00	0.00
$\mu_7: 60 - 80$	1.00	--	0.42	2.06**
$\mu_8: 65 - 85$	1.00	--	0.19	8.77***
$\mu_9: 70 - 85$	1.00	--	0.21	11.16***
$\mu_{10}: 75 - 85$	1.00	--	0.19	9.47***
$\mu_{11}: 80 - 85$	1.00	--	0.19	4.13***
$\mu_{12}: 85$	1.00	--	1.00	--

Final LL	-39975.885	-39767.989
Adj. $\rho^2$	0.314	0.317
Sample Size	28,042	28,042

<sup>a</sup>The t-stats for  $\mu$  reflect  $H_0: \hat{\mu}_n = 1$ .

Appendix Table A contains coefficient estimates for the alternative-invariant farm characteristics and year dummy variables for both models. Our results suggest farmers insuring larger enterprise units and farmers with higher expected yields are likely to select higher coverage levels. Note especially that the coefficients on APH are economically significant and monotonically increasing. This suggests that farmers with land that is highly suitable for corn production will tend to choose higher coverage levels.

Table 5 compares the observed share of farmers choosing each coverage level in the data set with the predicted shares<sup>9</sup> for the MNL and OGEV models. Both models replicate observed market shares well. However, the two models deliver very different predictions for the effect of changes in subsidy rates on farmers' choice of coverage level. This can be seen in Table 6 which compares the matrices of MNL and OGEV market elasticities with respect to the subsidy rate for each specification. We use Equation 1 and Equation 2 to calculate elasticities for each coverage level for each farmer in our data set. Note that  $\frac{\partial v_{ig}}{\partial \text{subrate}} = (\beta_{\text{subrate}} - \beta_{\text{pprema}} \text{tprema}_g)$ , where  $\beta_{\text{pprema}}$  is the coefficient on producer paid premium per acre and  $\text{tprema}_g$  denotes the total premium per acre for coverage-level  $g$ , exclusive of the government subsidy. Market elasticities are calculated using sample enumeration and represent the average elasticity for a given coverage level.

Table 5: Observed vs. predicted market shares

	Coverage Rate (percent)							
	50	55	60	65	70	75	80	85
Observed Share of farmer choices								

<sup>9</sup> Predicted shares are calculated using sample enumeration.

	0.004	0.001	0.004	0.053	0.134	0.267	0.331	0.206
Predicted: MNL Model								
Model 1	0.005	0.002	0.004	0.055	0.133	0.264	0.329	0.208
Model 2	0.005	0.002	0.004	0.055	0.133	0.264	0.329	0.208
Predicted: OGEV Model								
Model 1	0.005	0.001	0.004	0.054	0.133	0.266	0.330	0.208
Model 2	0.005	0.001	0.004	0.055	0.133	0.266	0.329	0.208

Direct and indirect elasticity estimates are presented in Table 6. As expected, own elasticities are positive, implying that an increase the subsidy rate leads to increasing take-up of the associated coverage rate. In contrast, cross elasticities are negative. The direct elasticity of 7.838 for 50 percent coverage in the OGEV model is interpreted as a prediction that, all else equal, a one percent increase in the subsidy rate on 50 percent coverage will increase the share of farmers choosing 50 percent coverage by 7.838 percent. Indirect elasticities suggest, for example, that a one percent increase in the subsidy on 50 percent coverage will decrease the share of farmers choosing 55 percent coverage by 0.025 percent.

To see the fundamental differences in the predictions of OGEV and MNL models, first compare the direct elasticities on the diagonal of each matrix. In the MNL model the least popular coverage levels are the most elastic, while most popular coverage levels are least elastic. This result is by construction: Recall from equation 1 that the direct elasticity in the MNL model is inversely proportional to the choice probability. This implies that, all else equal, the share of farmers choosing the less common, high subsidy, low coverage alternatives will decline more in response to declines in their own subsidy rate than will popular high-coverage and lower subsidy alternatives.

Table 6: Elasticity of row coverage with respect to subsidy rate of column coverage

<b>MNL Elasticities</b>

Coverage rate	For subsidy associated with coverage rate in the column							
	cov=50	cov=55	cov=60	cov=65	cov=70	cov=75	cov=80	cov=85
cov=50	8.71	-0.01	-0.04	-0.48	-1.22	-2.51	-2.98	-1.54
cov=55	-0.05	8.79	-0.04	-0.48	-1.22	-2.51	-2.98	-1.54
cov=60	-0.05	-0.01	9.04	-0.48	-1.22	-2.51	-2.98	-1.54
cov=65	-0.05	-0.01	-0.02	8.61	-1.22	-2.51	-2.98	-1.54
cov=70	-0.05	-0.01	-0.04	-0.48	8.30	-2.51	-2.98	-1.54
cov=75	-0.05	-0.01	-0.04	-0.48	-1.22	7.02	-2.98	-1.54
cov=80	-0.05	-0.01	-0.04	-0.48	-1.22	-2.51	5.90	-1.54
cov=85	-0.05	-0.01	-0.04	-0.48	-1.22	-2.51	-2.98	5.90
<b>OGEV Elasticities</b>								
	cov=50	cov=55	cov=60	cov=65	cov=70	cov=75	cov=80	cov=85
cov=50	7.838	-0.008	-0.473	-0.195	-0.604	-1.261	-1.467	-0.744
cov=55	-0.025	4.195	-0.018	-0.193	-0.604	-1.261	-1.467	-0.744
cov=60	-0.403	-0.006	5.535	-0.194	-0.607	-1.264	-1.469	-0.744
cov=65	-0.023	-0.006	-0.018	6.327	-0.652	-1.351	-1.541	-0.744
cov=70	-0.020	-0.006	-0.019	-0.212	5.242	-1.931	-1.956	-0.793
cov=75	-0.020	-0.006	-0.019	-0.214	-1.044	8.665	-5.002	-1.587
cov=80	-0.020	-0.006	-0.019	-0.213	-0.966	-4.501	9.124	-3.180
cov=85	-0.020	-0.006	-0.018	-0.193	-0.685	-2.554	-5.842	7.548

In contrast to the MNL model, in the OGEV model, the highest coverage levels tend to be more elastic than the lowest coverage levels. The coverage level that is the most sensitive to changes in its own subsidy rate in the OGEV model is the second highest, 80 percent coverage. Instead of being determined by market share, in the OGEV model the elasticity of a given coverage level depends on the degree to which farmers perceive them as having close substitutes among other coverage levels. Interestingly, direct elasticities are larger in the MNL model than the OGEV model for coverage levels less than 75 percent and smaller in the MNL model for the higher coverage levels. This suggests that the MNL model will tend to over-estimate the market response to changing subsidies on low coverage rates and under-estimate the response to changing subsidies on high coverage rates.

Table 6 also illustrates the difference between the MNL and OGEV models for indirect elasticities. In the MNL model, indirect elasticity with respect to the subsidy rate for a given coverage level (column) is constant across alternatives (rows). This means, everything else equal, an increase in the subsidy rate on 80 percent coverage is expected to decrease the share of farmers choosing 50 percent coverage level by the same proportion as the share of farmers choosing 85 percent coverage: 2.98 percent. This is a direct consequence of the IIA assumption. Elasticity with respect to the subsidy rate on 85 percent coverage is independent of all unobserved factors that influence the initial coverage choice.

In contrast, in the OGEV model low coverage levels are disproportionately more elastic to subsidies on other low coverage levels than they are to subsidies on high coverage levels and vice versa. Consider the elasticity of each coverage level with respect to the subsidy on 80 percent coverage (column 8). A one percent cut in the subsidy on 80 percent coverage is predicted to decrease the share of farmers choosing 75 percent coverage by 5.002 percent, but it is predicted to decrease the share of farmers choosing 55 percent coverage by only 1.467 percent – less than one-third as much. Interestingly, unlike in the MNL model OGEV model results systematically suggest that farmers choosing 65 percent coverage or higher are more responsive to changes in the subsidy rate on the coverage levels immediately above them than the coverage levels immediately below them. The reverse holds for those choosing 60 percent coverage or less. This is further evidence that crop insurance plays a fundamentally different role in the risk management strategy of farmers choosing low coverage levels than it does for farmers choosing high coverage levels.

## **POLICY SIMULATIONS**

In the previous section we demonstrated that the OGEV model distinguishes between the behavior of farmers that choose low levels of crop insurance as part of their risk management strategy and

those who choose high levels of coverage. In this section we use our results to estimate the cost savings available from subsidy reform and the tradeoffs these savings imply in terms of farmer coverage. We simulate four reform scenarios using the BIOSIM software (Bierlaire 2003), restricting our sample to the 2009 observations since we base our simulations on changes to the subsidy rates prevailing in 2009.

Table 6 lists the structure of subsidy rates used in each simulation. In scenario A, we simulate a cut in the 2009 subsidy rates by 5 percent across-the-board. In this scenario, the relative prices of policies are unchanged. In scenario B we simulate a 5 percent cut in the subsidy rate on the highest coverage levels only, which lowers the cost of low coverage levels relative to high coverage. In scenario C we lower the maximum subsidy rate to 75 percent. This lowers the cost to farmers of high relative to low coverage levels. In scenario D we simulate a flat subsidy rate of 50 percent for all coverage levels.

**Table 6. Subsidy rates for reform scenarios (percent)**

Scenario	Coverage Level							
	50%	55%	60%	65%	70%	75%	80%	85%
Base	80	80	80	80	80	77	68	53
A	76	76	76	76	76	73.15	64.6	50.35
B	80	80	80	80	76	73.15	64.6	50.35
C	75	75	75	75	75	75	68	53
D	50	50	50	50	50	50	50	50

We examine substitution across coverage levels resulting from reforms by calculating the predicted distribution of farmer choice across coverage levels in each scenario using sample enumeration from the simulation, and comparing it to the base model predictions. The average coverage level under scenario  $k$ ,  $E[\theta_k]$  is obtained from this distribution. We obtain the expected premium per-acre paid by farmers under each scenario by calculating:



$$E[pprem_k] = \frac{1}{N} \sum_{i=1}^N \left( \sum_{g=1}^8 \hat{p}_{igk} \times tprem_{ig} \times (1 - s_{gk}) \right)$$

where  $\hat{p}_{igk}$  is farmer  $i$ 's simulated probability of choosing  $\theta_g$  under scenario  $k$ ,  $tprem_{ig}$  is farmer  $i$ 's total premium for coverage level  $g$  in 2009, and  $s_{gk}$  is the subsidy rate on  $\theta_g$  under scenario  $k$ . We calculate the expected dollar subsidy per-acre,  $E[suba_k]$  similarly. We calculate the total expected cost to the government,  $E[TC_k]$  by multiplying each individual's expected dollar subsidy per acre by the number of acres enrolled, and then summing over individuals. Table 7 summarizes the results from each scenario. It includes predictions for the expected premium paid by farmers, the expected cost to the government and the average coverage level under each subsidy rate reform scenario, as well as the percent change in each from the Base model predictions, which align very closely to the data.

*Table 7: Summary of reform scenario results*

	$E[pprem_k]$	% Change	$E[suba_k]$	$E[TC_k]$	$E[\theta_k]$	% Change
Base	14.99	NA	29.72	1.67	78.82	NA
Scenario A	16.86	12.5	28.26	1.59	79.03	0.3
Scenario B	16.73	11.6	28.18	1.59	78.91	0.1
Scenario C	16.09	7.3	29.84	1.68	79.46	0.8
Scenario D	27.38	82.7	27.38	1.54	83.55	6.0

*Scenario A: 5 percent subsidy cut across-the-board*

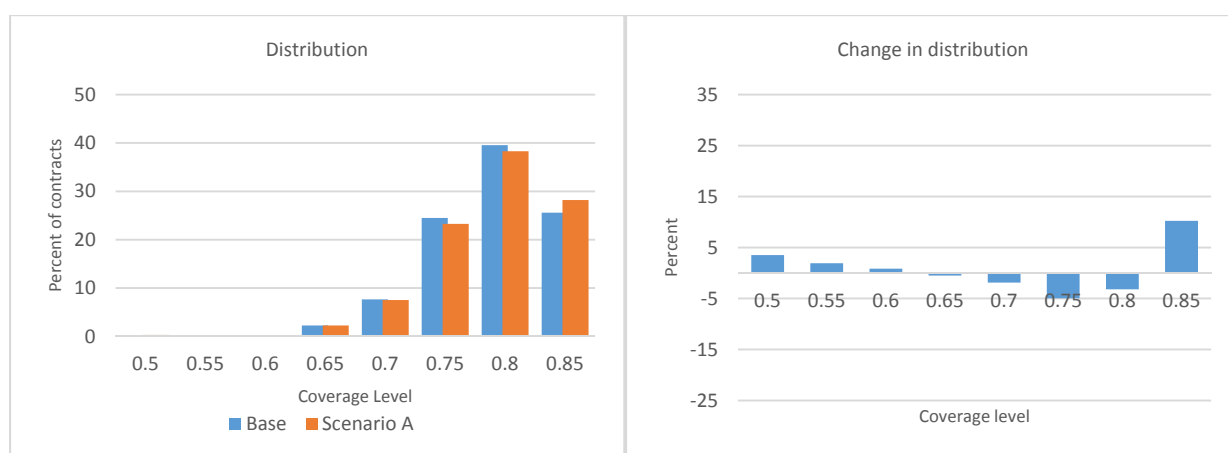
Figure 2 depicts the distribution of farmer choice of coverage level and the percent change in the predicted market share of each coverage level under Scenario A relative to the base model. On net, this reform induces farmers to substitute toward the extremes of the ordering: the 85 and 50 percent coverage levels had the largest percent increase in market share. The share of farmers choosing all other high coverage levels falls. The largest declines, both in terms of share and level,

are in the choice of 75 and 80 percent coverage, which Table 6 implies are close substitutes for 85 percent coverage.

The average coverage level increases slightly to 79.0 percent in this scenario, compared to the base model average of 78.8 percent. The average premium per acre increases from \$14.99 in the base model to \$16.86, reflecting both the larger out-of-pocket cost from lower subsidies and the increase in average coverage level. Even with these relatively small changes, the reform brings about expected cost savings to the government of roughly \$80 million.

**Figure 2: Change in coverage level distribution: Scenario A**

**5% cut across-the-board**



**Scenario B: 5 percent cut in subsidies on high coverage levels**

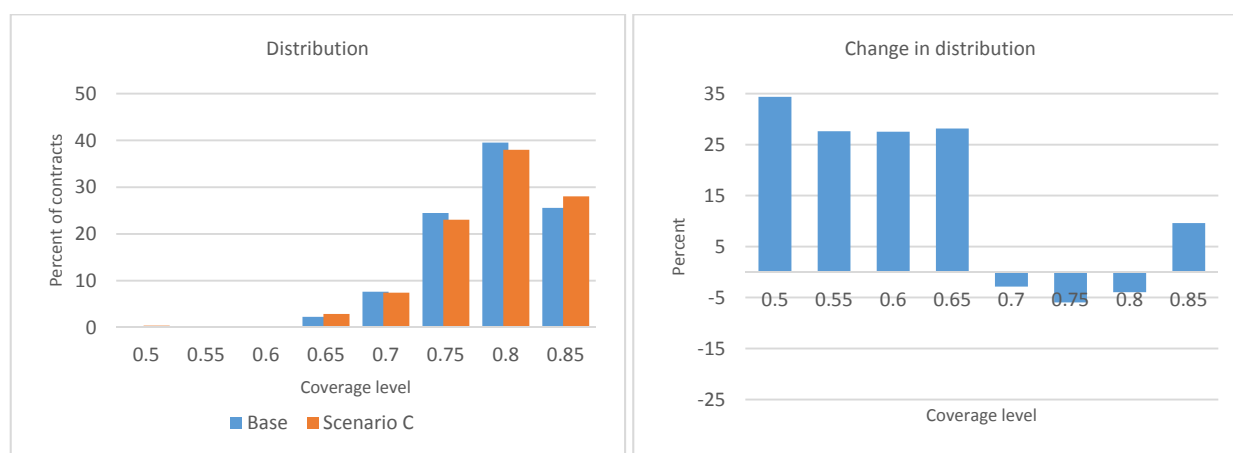
In this scenario, the 5 percent subsidy cut applies only to coverage levels greater than 70 percent. This implies that out of pocket costs of high coverage levels increase relative to low coverage levels. Figure 3 depicts the change in the distribution of coverage level choice under Scenario B relative to the base model. This reform induces movement toward lower coverage levels with the largest market share increase in the minimal coverage level of 50 percent. This suggests that the

subsidy on premiums is an important incentive for farmers to purchase policies at the higher coverage levels.

Since the size of the population shifting toward 85 percent is larger than those shifting toward lower coverage levels, the average coverage level increases very slightly from 78.8 to 78.9 percent. The average premium per acre increases to \$16.73. Government savings are roughly the same under this reform as they are under a 5 percent cut in all subsidy rates (\$80 million), however the increase in the average coverage level is much smaller.

**Figure 3: Change in coverage level distribution: Scenario B**

**5% cut on high coverage levels subsidies**



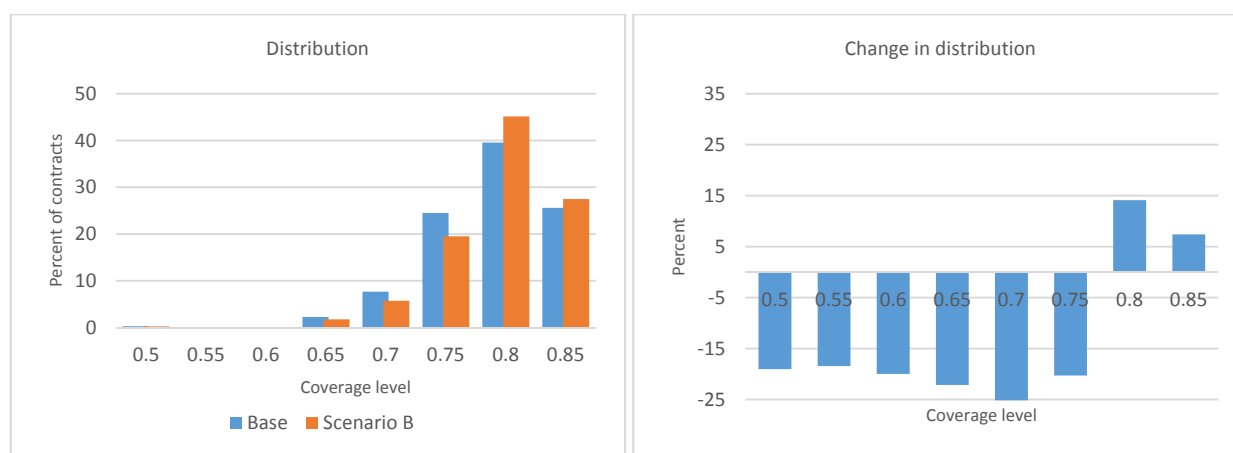
### *Scenario C: 75% maximum subsidy*

Scenario C is the reverse of the previous scenario in the sense that the out of pocket cost of *low* coverage level alternatives increase relative to high coverage levels. The reduction of the maximum subsidy rate to 75 percent represents a 6.25 percent cut on coverage levels less than 75 percent and a 3.75 percent cut on 75 percent coverage. Thus, relative prices among low coverage levels remain the same, whereas the price of 70 and 75 percent coverage have increased relative to their closest substitutes. Figure 4 depicts the change in the distribution of farmer choice under

Scenario C relative to the base model. On net, this reform induces farmers to substitute toward the highest coverage levels. The loss in market share is especially pronounced for the intermediate coverage levels. The average coverage level increases to 79.5 percent, compared to the base average of 78.8 percent. The average premium per acre increases to \$16.09, primarily reflecting the substitution toward higher coverage levels. Notably, this scenario *increases* the expected cost of the program by \$10 million.

**Figure 4: Change in coverage level distribution: Scenario C**

**75% maximum subsidy**



#### *Scenario D: 50% flat subsidy rate*

Finally, Figure 5 depicts the change in the distribution across coverage levels under Scenario D, a flat subsidy rate of 50% for all coverage levels, relative to the base model. This simulation represents a more significant change to the structure of subsidies than the other experiments. Our implicit assumption that farmers do not choose to enter or exit the program is thus stronger in this scenario and as such we will not focus on the predicted changes in program costs.

The results of this experiment are nevertheless interesting from a theoretical perspective. In a standard expected utility model of the insurance coverage level decision such as in Du et al (2014),

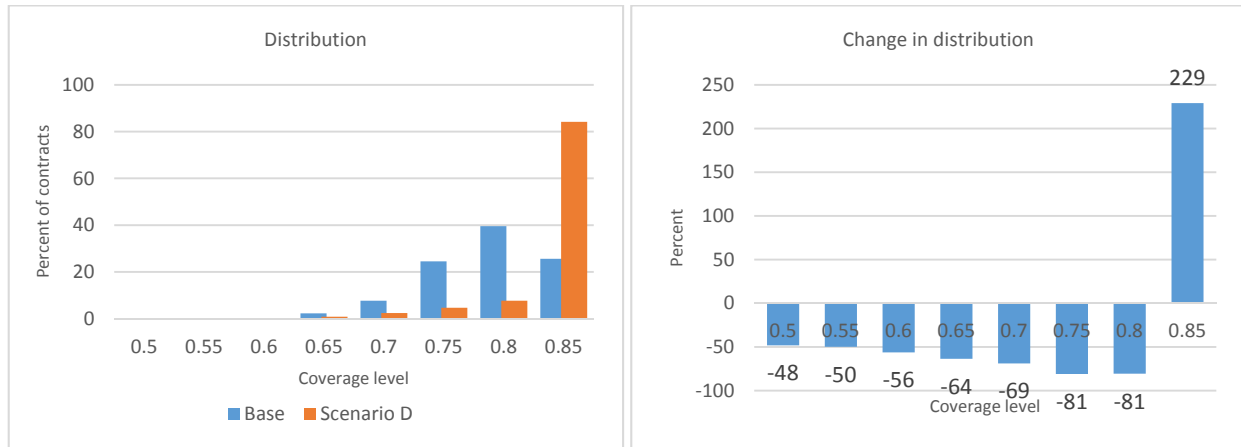
when faced with Federal crop insurance premiums that are statutorily-required to be actuarially fair, a risk-averse farmer should insure at the highest coverage level possible. When premia are subsidized, this holds as long as the dollar amount delivered by the subsidy is at least weakly increasing with coverage level. If not, the farmer should choose the coverage level with the highest dollar subsidy or a higher coverage level. Du et al reject this theory for the case of crop insurance on the basis of observed farmer choices that violate this predicted behavior.

Under the structure of subsidy rates prevailing in 2009, Du et al find that the dollar subsidy amount may decrease at higher coverage levels. When subsidy rates are flattened out, this is no longer the case by definition. Figure 5 reveals a very large shift toward the highest coverage level when subsidy rates flatten out. Other high coverage levels, which are close substitutes for the maximum 85 percent coverage, become particularly unattractive to farmers under this scenario – the 75 and 80 percent coverage levels each lose 81 percent of their market share whereas 50 and 55 percent coverage only lose about half their market share.

Nevertheless, the model does not predict that all farmers choose the highest coverage level as the standard theory would suggest. We do not seek to explain farmer behavior in this paper, however our model results suggest that farmers choosing lower coverage levels tend to value crop insurance in a fundamentally different way. We interpret the results of Scenario D as suggesting that Federal crop insurance plays a more central role in the risk management strategy of a considerable share of farmers that choose higher coverage levels, and as such, these farmers behave more like rational expected utility maximizers under the standard model of insurance coverage choice.

**Figure 5: Change in coverage level distribution: Scenario D**

**50% subsidy on all coverage levels**



## CONCLUSIONS

We introduce a new discrete choice method to the analysis of crop insurance choice, focusing on the choice of coverage level within federal crop revenue insurance for corn enterprise units. Unlike previous research, our OGEV model explicitly accounts for the ordered nature of the choice set. This allows us to account for unobservable factors that systematically influence the role of crop insurance coverage within a farmer's overall risk management strategy.

Our results suggest farmers place their decision within an overall risk management strategy characterized either by low or high levels of crop insurance coverage. Farmers may generally prefer low over high coverage levels for many reasons. Possible factors include farmland characteristics, such as whether or not the land is irrigated; farmer characteristics, such as the individual's degree of risk aversion; or even the personal preferences of the insurance agent with whom the farmer interacts. Our data do not include variables that capture these characteristics – the latter are not generally observable or even quantifiable. Nevertheless, they play a systematic and important role in determining a farmer's choice of coverage level and, importantly, his or her

response to changes in the incentives offered by the government. By accounting for the influence of these unobserved factors, our approach provides more precise estimates of the expected cost savings associated with policy reform and a more nuanced analysis of how change in incentives affect the degree to which farmers are covered by federal crop insurance products.

We use our model to explore three marginal adjustments to the distribution of crop insurance subsidy rates across coverage levels. We find that the largest government savings can be obtained by cutting the relatively lower subsidy rates on higher coverage levels. Cutting the relatively higher subsidy rates on the lower coverage levels while leaving the subsidies on high coverage levels unchanged actually *increases* the cost of the program.

A fourth experiment, which simulates a flattening of the subsidy rate to 50 percent for all coverage levels suggests that the varying subsidy rates on high coverage levels distorts farmers choice of crop insurance. In future work, we plan to explore this result in more depth by developing a model that allows for entry and exit from the revenue insurance policy we examine here. That is, we intend to modify the model to allow changes in incentives to induce new enrollments into the policy or provoke existing enrollees to discontinue their participation in the policy.

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## Appendix

Table 4: Coefficient estimates for alternative-invariant characteristics (OGEV)					
		OGEV		MNL	
Variable	Coverage Rate	Value	t-stat	Value	t-stat
Acreage	50	0.0000	-	0.0000	-
	55	0.0001	0.41	-0.0001	-0.21
	60	-0.0002	-0.7	-0.0005	-1.19
	65	0.0002	1.01	0.0001	0.55
	70	0.0003	2.02**	0.0004	1.58
	75	0.0004	2.09**	0.0004	1.52
	80	0.0005	2.64***	0.0006	2.36**
	85	0.0005	2.90***	0.0007	2.86***
APH	50	0.0000	-	0.0000	-
	55	-0.0059	-3.29***	-0.0051	-2.65***
	60	0.0050	4.59***	0.0068	4.79***
	65	0.0223	24.4***	0.0306	28.26***
	70	0.0283	30.72***	0.0371	34.72***
	75	0.0332	32.84***	0.0457	39.67***
	80	0.0376	32.98***	0.0542	40.54***
	85	0.0426	32.16***	0.0642	38.96***
Year	50	0.0000	-	0.0000	-
	55	-0.6110	-1.58	-0.8350	-2.28**
	60	-1.3800	-4.27***	-1.5200	-4.95***
	65	-0.9180	-4.81***	-1.7300	-9.61***
	70	-0.6660	-3.54***	-1.4200	-8.26***
	75	-0.1250	-0.69	-0.9590	-5.61***
	80	0.0981	0.55	-0.3480	-2.07**
	85	0.3670	2.05**	0.1270	0.73