The Economics of Nested Insurance: The Case of SURE

Joseph Cooper*, Thomas Sproul, and David Zilberman

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*Cooper is a senior economist with the Economic Research Service, USDA. Sproul and Zilberman are a graduate and Professor, respectively, in the Department of Agricultural and Resource Economics, University of Califorbnia, Berkeley. The views expressed are the authors' and do not necessarily represent those of the Economic Research Service or the US Department of Agriculture.

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Abstract

Traditionally, disaster assistance was available on an *ad hoc* basis, but the 2008 Farm Act provides a standing disaster assistance program known as Supplemental Revenue Assistance (SURE). This paper introduces a theory of nested insurance to evaluate the impact on of SURE on intensification, acreage and adoption. The results suggest that parameters of a government program like SURE may enhance the adoption and value of crop insurance to the farm sector. A quantitative understanding of the interdependencies between programs like SURE and crop insurance, taking into account the nature of the *ad hoc* alternative, is important in assessing the welfare impacts on farmers, as well as insurance companies. Both our theory and simulation exercise suggest that insurance increases the volume of production and/or leads to increased intensification (substitution into higher value crops). On the other hand, the gains from insurance and from programs like SURE may be lessened by the presence and probability of *ad hoc* disaster assistance.

Key words: Nested insurance, SURE, crops, adoption, ad hoc, disaster assistance

The Economics of Nested Insurance: The Case of SURE

Farming is a risky business. One of the realities of modern life is that farmers need to deal with multiple tools to address risk. Recently, it has been advanced that the risks can be addressed in aggregate by revenue assurance, but since the magnitude of the risk can vary drastically, the same random variable may be targeted by two programs. Historically, farmers could rely on a standardized crop insurance program to deal with moderate to extreme risk, while *ad hoc* disaster assistance programs that dealt with extreme risks. The 2008 Farm Act introduced the Supplemental Revenue Assistance Payments (SURE) program, which is a standing disaster assistance program that explicitly and structurally linked to traditional multi-peril crop insurance. While there is an established literature on the economics of regular insurance, a conceptual understanding of both adoption and impact of nested insurance is lacking, and this paper provides a framework to address this issue.

Two key questions that are addressed by this framework are: under what conditions will farmers adopt insurance which includes a nested disaster program, and what will be the impact of adoption on scale of operations? To answer these questions, we first develop first a conceptual framework where we reduce the farmer's choice problem to be a function of the mean and variance of revenue per acre under a given insurance program. Then, we analyze how changing policy parameters affects participation and farm size through their impacts on the moments of the revenue distribution per acre. Finally, we present a simulation exercise identifying further challenges that the analysis requires.

Background

The USDA operates programs that provide financial support to farmers in the form of payments or low interest loans to compensate them for crop losses due to natural disasters. In addition, despite significant growth in insured acreage under the Federal crop insurance program, Congress has continued to pass legislation providing *ad hoc* disaster assistance payments to producers in response to drought and other adverse events. *Ad hoc* support varies substantially from year to year depending on the weather and whether the *ad hoc* legislation gets passed that covers a disaster(s). For instance, crop disaster outlays including noninsured assistance (NAP) were $75 million in 2008 but $2.5 billion in 2005.

With the 2008 Farm Act, Federal agricultural legislation includes for the first time a formal disaster assistance program, known as the Supplemental Revenue Assistance Payments (SURE) program, which provides producers benefits for 2008 through 2011 crop year farm revenue losses due to natural disasters. SURE is a whole farm program that provides supplemental payments to farmers with Federal crop insurance and NAP in a "disaster county" (a county declared by the Secretary of Agriculture to have suffered weather-related production losses of 50 percent or more, and contiguous counties), subject to other conditions. Essentially, SURE payments would cover a portion of the farmer's insurance deductible, with the payment level increasing with the amount of the farmer's insured coverage. Sign-up for the 2008 SURE began January 2010. Being a free supplement to crop insurance, SURE is likely to impact land use and crop insurance decisions, and to a different extent than would an *ad hoc* disaster regime, particularly in regions where high yield variability could result in frequent disaster declarations. In a deterministic analysis, Smith and Watts (2010) find that SURE has the potential for creating moral hazard conditions on top of those already associated with Federal crop insurance.

Arguably, a key political motivation for SURE is that it has become increasingly difficult over time to pass *ad hoc* payments into law. In principle, one may assume that the SURE program would eliminate the *ad hoc* payments, but this assumption appears to be unrealistic. Indeed, in late 2009 and early 2010, the head of the Senate Agricultural committee pressed for *ad hoc* assistance for farm losses in some regions in 2009 due to bad weather.

Conceptual Model

We consider a risk-averse farmer facing choices about adoption of crop insurance and aggregate land use (e.g., when acreage is variable, the conversion of marginal lands to crops). If the farmer does not adopt crop insurance, he accepts the natural revenue variability associated with his farm size, but for large losses he *may* receive government assistance with some positive probability. If he does adopt crop insurance, disaster assistance is nested in the sense that it provides supplemental coverage. Evaluating these farmer decisions will help to shed some light on the potential effects of the SURE program, which provides supplemental disaster insurance for free – but only to those farmers who purchase crop insurance.[1]

Consider a farmer with a vNM utility function, u, which is everywhere increasing and concave in income. The farmer has a number of acres, A, with identical revenues per acre, Y, so that total revenue is given by AY. Y is a non-negative random variable with continuous, cumulative distribution function, F. The cost of production is a function of acreage, $c(A)$, which is increasing and at least weakly convex in A. In the US, this model of farm size choice is most applicable in regions where in some counties marginal lands are available for inclusion in farming operations at some cost, such as some counties in the Dakotas. The idea of variable acreage would make less sense in the context of corn farming in Illinois, where the supply of

farmland is almost perfectly inelastic. The farmer's profits depend on two choices – whether to participate in the insurance program (a discrete choice, where $i = 1$ denotes participation and $i = 0$ denotes non-participation), and the level of acreage, A. Conditional on the participation choice, we define the profit function as $\pi(A,i) = AY^i - c(A)$. Thus, given the distribution of Y^i, which is impacted by policy/insurance parameters, the farmer maximizes expected utility over acreage as follows:

$$\max_{A,i} E\left[u\left(\pi^i(A)\right)\right] = \max_i v(i)$$
$$where \;\; v(i) = \max_A E\left[u\left(AY^i - c(A)\right)\right]$$

So we assume a backwards inductive approach, where the farmer maximizes the expected utility, *v(i)*, of the adoption choice after selecting the optimal farm size for each policy option. Because the adoption and acreage choice both depend on the distribution of revenue, Y^i, we specify the revenue per acre as a function of policy parameters here.

Disasters for the purpose of *ad hoc* assistance are generally determined on the basis of yield losses due to natural causes. For the sake of generality, the theoretical model assumes that the disasters declarations are triggered by revenue losses due to natural causes. From the theoretical perspective, a disaster declaration based on yield losses is a special case that is examined in our empirical section.

First, Y^0 denotes revenue per acre without crop insurance, but with probabilistic *ad hoc* government disaster assistance. Without any intervention, the revenue per acre is simply, *Y*. When revenues fall below a certain level, the *disaster threshold,* $D = F^{-1}(d)$*,* then there is a positive probability, $0 < \varphi \leq 1$, that the government will intervene with disaster payments. For a standing program on the other hand, $\varphi = 1$. The *ad hoc* intervention can be conceptualized as the government declaring a disaster area when revenues are below a certain percentile of the revenue

distribution *and* passing legislation that provides payments. When the government does intervene, the farmer's revenue per-acre is restored to an upper-threshold level of revenues, $T = F^{-1}(t)$, which may be the mean or median of the revenue distribution, for example. Letting I_d be an indicator variable for $Y \leq D$, the expected *profits* with probabilistic *ad hoc* assistance only is given by:

$$E\left[AY^0 - c(A) \mid \varphi, d, t\right] \equiv E\left[AY\left(1 - \varphi \cdot I_d\right)\right] + \varphi \cdot d \cdot AT - c(A)$$

On the other hand, the farmer can buy crop insurance to limit the amount of risk faced in production. To simplify the analysis, we assume the crop insurance uses the same upper threshold, *T*, to calculate the indemnity payment as follows. Whenever $Y \leq T$, to which we assign the indicator variable, I_t, the crop insurance pays reimbursement of $R \cdot (T - Y)$, where *R* is the reimbursement rate. This coverage comes at a premium of *P* per acre. Thus, whenever revenue is below the upper threshold and no disaster assistance is provided, the crop insurance serves to restore revenue to a linear combination of actual revenue, *Y*, and the upper threshold, *T*. Thus, letting $Y_R \equiv TR + (1 - R)Y$, the expected profits when crop insurance is adopted without nested disaster insurance, like SURE:

$$E\left[AY^1 - c(A) \mid R, P, \varphi, d, t\right] = E\left[Y \cdot \left(1 - I_t\right) + Y_R \cdot I_t \cdot \left(1 - \varphi \cdot I_d\right)\right] + \varphi \cdot d \cdot T - c(A) - AP$$

Note that the presence of supplemental disaster insurance within the crop insurance program (i.e., SURE) can simply be represented as a higher level of the reimbursement rate, *R*, conditional on *Y* falling below the disaster threshold. Letting β be the increased reimbursement rate for disasters, the expected profits under crop insurance *with* nested disaster insurance become:

$$E\left[AY^1 - c(A) \mid R,P,\varphi,d,t\right] =$$
$$E\left[Y \cdot (1 - I_t) + Y_R \cdot I_t \cdot (1 - I_d) + Y_\beta \cdot I_d \cdot (1 - \varphi)\right] + \varphi \cdot d \cdot T - c(A) - AP$$
$$\textit{where } Y_\beta \equiv T(R + \beta) + (1 - R - \beta)Y$$

Variances of these two revenue distributions can be derived similarly. This analysis allows us to assess the impacts of changing parameters on the mean and variance of Y^i. Intuitively, increasing the disaster threshold, *D*, decreases the variance of *Y* and increases its mean, because it shifts values upwards toward the mean – and this holds whether or not crop insurance is adopted. The same rationale holds for the partial effects of the *ad hoc* intervention probability, φ, and for the insurance coverage rate, *R*. On the other hand, the insurance premium, *P*, has no effect on the variance of *Y* because it simply shifts all realizations downwards, so only its negative effect on expectation is relevant. The considerations are slightly more complex with respect to the crop insurance threshold, *T*, and the SURE parameter, β, depending on their levels. While increasing *T* always increases the expected revenue (whether or not crop insurance is present), this adjustment only lowers the variance of *Y* if *T* is lower than $\overline{Y}$, because *T* approaching $\overline{Y}$ from below brings values closer to the mean. On the other hand, *T* increasing beyond $\overline{Y}$ can takes values further away from the mean when no crop insurance is present (i.e., *ad hoc* only), and the precise effect depends on specific functional forms when crop insurance is present, so the sign of the comparative static is ambiguous, in general. The same intuition holds for the SURE reimbursement parameter, β.

Now that we have established the effect of key parameters on the revenue distributions, with and without adoption of crop insurance, we can assess the impact of changes in mean and variance on acreage and adoption choice. The approach we take follows a long tradition of using Taylor series approximation of expected utility (e.g., Sandmo, 1971;, Just and Zilberman, 1984;,

Meyer, 1987) as a function of the mean and variance of key parameters, as well as average measures of risk aversion. While the approach is limited by an inability to consider higher moments, if the higher moments do not vary significantly across policy choices, then the impact of approximation error on adoption choice is small. However, it is difficult to derive theoretically meaningful conclusions without these approximations, and simulations are needed to assess the impact of these assumptions on land use choices.

With respect to acreage, A, the first- and second-order conditions for expected utility maximization are given by:

$$\frac{\partial E[u(\pi)]}{\partial A} = E\left[u'(\pi)\cdot\left(Y - c'(A)\right)\right] = 0$$
$$\frac{\partial^2 E[u(\pi)]}{\partial A^2} = E\left[u''(\pi)\cdot\left(Y - c'(A)\right) - u'(\pi)\cdot c''(A)\right] < 0$$

These conditions are sufficient for a unique, interior solution, which will allow us to derive comparative statics for parameters in the standard way. Our next step in drawing inference about behavior based on risk preference is a Taylor expansion of the first order condition about $Y = E[Y] \equiv \overline{Y}$, as follows:

$$E\left[u'(\pi)\pi_A\right] = E\left[\begin{array}{l} u'(\pi)\pi_A + \left(Y - \overline{Y}\right)\left(u''(\pi)\pi_A\pi_Y + u'(\pi)\right) \\ + \dfrac{\left(Y - \overline{Y}^2\right)}{2}\left(u'''(\pi)\pi_A\pi_Y + 2u''(\pi)\pi_Y\right) \end{array}\right]\Bigg|_{Y=\overline{Y}} = 0$$

The second bracketed term is zero by the definition of the mean, since all its multiplicative elements are given numbers when evaluated at $Y = \overline{Y}$. Thus,

$$u'(\overline{\pi})\pi_A + A^* \cdot Var[Y]\left(u'''(\overline{\pi})\pi_A + 2u''(\overline{\pi})\right) = 0$$
$$\Rightarrow 1 + A^* \cdot \frac{Var[Y]}{2}\left(\frac{u'''}{u'} + \frac{2}{\pi_A}\frac{u''}{u'}\right)\Bigg|_{Y=\overline{Y}} = 0$$

where $\pi_A = E[Y] - c'(A) > 0$, which can be easily shown as an implication of risk aversion, following Sandmo (1971).

This first order condition can mean different things for the farmer's choice, depending on risk preferences. We will examine two types of utility functions in this context, Constant Absolute Risk Aversion (CARA) and Constant Relative Risk Aversion (CRRA), each of which has different implications for the above first-order condition:

$$CARA: -\frac{u''}{u'} = \lambda \;\; \forall\pi \;\; \Rightarrow \frac{\partial}{\partial\pi}\left(-\frac{u''}{u'}\right) = 0 \;\; \Rightarrow u''' = u' \cdot \lambda^2$$

$$CRRA: -\frac{\pi \cdot u''}{u'} = \lambda \;\; \forall\pi \;\; \Rightarrow \frac{\partial}{\partial\pi}\left(-\frac{\pi \cdot u''}{u'}\right) = 0 \;\; \Rightarrow u''' = -u''\left(\frac{1+\lambda}{\pi}\right)$$

For both types of utility functions, note that *prudence* ($u''' > 0$ everywhere) is a necessary condition for the risk preferences described. Thus, the first order condition for A^* can be rewritten as:

$$CARA \Rightarrow FOC_A = 1 + A^* \cdot \frac{Var[Y]}{2}\left(\lambda^2 - \frac{2\lambda}{\pi_A}\right)\Bigg|_{Y=\bar{Y}} = 0$$

$$CRRA \Rightarrow FOC_A = 1 + A^* \cdot \frac{Var[Y]}{2}\left(-\frac{u''}{u'}\left(\frac{1+\lambda}{\pi}\right) + \frac{2}{\pi_A}\frac{u''}{u'}\right)\Bigg|_{Y=\bar{Y}} = 0$$

$$= 1 - A^* \cdot \frac{Var[Y]}{\lambda \cdot \pi}\left(\frac{1}{\pi_A} - \frac{1+\lambda}{2}\right)\Bigg|_{Y=\bar{Y}} = 0$$

We use the first order conditions, as well as the effects of parameters on mean and variance per acre, to derive comparative statics results. First off, the first order condition allows us to take comparative statics of the acreage choice, A^*, as a function of mean and variance per acre, and accordingly, as a function of parameters via the chain rule.

Proposition 1:

CARA utility implies $A^*_D, A^*_\varphi, A^*_R > 0$; $A^*_P < 0$; $A^*_T > 0$ *if* $T < \bar{Y}$; $A^*_\beta > 0$ *if* $\beta < 1 - R$.

Proof: Using the rewritten first order condition for CARA utility obtains,

$$\frac{\partial FOC_A}{\partial x} = \frac{A^*}{2}\left(\lambda^2 - \frac{2\lambda}{\pi_A}\right)\frac{\partial Var[Y]}{\partial x} + \frac{A^*\lambda \cdot Var[Y]}{\pi_A^2}\frac{\partial E[Y]}{\partial x}$$

where the multipliers on the partial effects are negative, and positive, respectively. The remainder of the proof follows directly from the partial effects of parameter increases on E[Y] and Var[Y], as discussed above.

Given certain conditions, CRRA utility can imply comparative statics results with the same signs as implied by CARA utility.

Corollary 1:

CRRA utility implies the same signs for comparative statics results as CARA, if

i) $\lambda > \dfrac{A^*\pi_A \cdot (2+\pi_A)}{2\pi - A^*\pi_A^2}$*; or*

ii) $u = \ln(\pi)$ *(so CRRA* λ*=1) and* $c(A) = c \cdot A$.

Proof: The proof reduces to showing that the multiplier factors are equivalent to the CARA case for $Var[Y]_x$ *and* $E[Y]_x$ *(where subscripts again denote partial derivatives). i) Using the rewritten first order condition for CRRA utility obtains*

$$\frac{\partial FOC_A}{\partial x} = -\frac{A^*}{\lambda^2\pi}\left(\frac{1}{\pi_A} - \frac{1+\lambda}{2}\right)\frac{\partial Var[Y]}{\partial x} + \frac{A^* \cdot Var[Y]}{\lambda\pi}\left(\frac{A^*}{\lambda\pi}\left(\frac{1}{\pi_A} - \frac{1+\lambda}{2}\right) - \frac{1}{\pi_A^2}\right)\frac{\partial E[Y]}{\partial x}$$

which generates comparative statics results with the same signs as those of CARA utility when condition (i) is fulfilled.

ii) Calculating A^* *using these functional forms, after some algebra, obtains*

$$\frac{\partial A^*}{\partial x} = -\left(1 - \frac{\pi_A^2}{Var[Y]}\right)^{-2}\left(\frac{-Var[Y] \cdot 2\pi_A \cdot E[Y]_x + \pi_A^2 \cdot Var[Y]_x}{Var[Y]^2}\right)$$

which generates comparative statics results with the same signs as above.

Thus far, we have established the impacts of parameter changes on acreage *within* the adoption choice, but not inclusive of it. Recall that *v(i)* is the expected utility of adoption or non-adoption, given that acreage will be optimized. Once the optimal acreages are determined, the farmer simply selects the expected utility maximizing policy, i.e., he adopts insurance if $\Delta v \equiv v(1) - v(0) > 0$. To further investigate the effects of insurance policy on this choice, we evaluate it explicitly:

$$\Delta v = \frac{\partial v}{\partial E[Y]} \Delta E[Y] + \frac{\partial v}{\partial Var[Y]} \Delta Var[Y] + \frac{\partial^2 v}{\partial E[Y] \partial Var[Y]} \Delta E[Y] \cdot \Delta Var[Y]$$

To get conclusive results, we need to approximate $v(i)$ as a function of the first two moments of the distribution of Y^i. As before, we use a second-order Taylor approximation about $\overline{Y}$ to obtain:

$$v(i) = u(\pi(\overline{Y})) + A_i^* \cdot \frac{Var[Y]}{2} \cdot u''(\pi(\overline{Y}))$$

By the approximation above, it is clear that higher mean is "good" and higher variance is "bad", so any mean-variance bundle (defined over *Y*) which decreases variance and increases expectation will enhance adoption. In particular, using CARA and CRRA utility as above, we can show conditions for adoption of crop insurance. Under CARA utility, adoption occurs if:

$$1 - \frac{\lambda}{2} \frac{\Delta Var[Y]}{\Delta E[Y]} + \frac{\lambda^2}{2} Var[Y^1] > 0$$

Under CRRA utility, the adoption is triggered when:

$$1 - \frac{\lambda}{2\pi} \frac{\Delta Var[Y]}{\Delta E[Y]} + \frac{\lambda(1+\lambda)}{2\pi^2} Var[Y^1] > 0$$

Simply put, crop insurance will be adopted if its mean-variance bundle improves over that of *ad hoc* only. By our above results, acreage responds to changes in mean and variance with the same sign as the value function, v. Thus, adoption is more likely under higher reimbursement rate, R, lower premium, P, lower probability of *ad hoc* assistance, φ, and higher disaster threshold, D. As before, the marginal effects of changing the upper threshold, T, and the SURE extra reimbursement rate, β, will depend on their pre-existing levels. Thus, increasing either of these two variables may even increase adoption and reduce acreage simultaneously, or vice versa.

Two further points are apparent; any distribution offered with higher mean and/or lower variance will be adopted and result in higher acreage, and as a special case, actuarially fair insurance (which preserves the mean and lowers the variance) will always be adopted and lead to more acres farmed.[2] However, questions of actuarial fairness of insurance and exposure to baseline risk are affected by the probability of government intervention, because actuarial fairness for the insurance company is different than actuarial fairness for the consumer (the farmer). This is because actuarial fairness from the insurance consumer's perspective means that the expected cost to the insurer is less than the premium.

While our conceptual analysis could identify some of the directional effects of policy choices on adoption and land-use, a simulation, accounting for the fine points of the policy, is required to get a more detailed understanding of the impacts of a program like SURE. The empirical simulations cover a representative farmer planting two crops in a county in South Dakota, a regional with high yield relative to the Corn Belt, and facing joint price and farm level yield densities. The farmer is assumed to be moderately risk averse and maximizes the expected utility of wealth using acreage in each crop and the crop insurance coverage levels as choice variables. While a variety of simplifying assumptions are necessary to make the theoretical

model tractable, our empirical implementation has a richer, "real life" model specifying farmers' alternatives including diversifying crops (as opposed to size expansion). Furthermore, the simulation uses bootstrap procedures to solve problems that do not have closed form solutions to integrals, so we are not confined to approximations in the estimation section.

Policy Background: Federal Crop Insurance and SURE

By law, USDA must try to devise actuarially fair premium rates, where the fair premium is defined as the full cost of the premium, and not just the farmer paid portion. [3]Hence, a key source of producer return to crop insurance purchase is the premium subsidy. At 70 percent coverage, 59 percent of the full premium is paid by the Federal government. If premiums are actuarially fair, the net return to producers would equal 59 percent of expected indemnities.[4] The expected indemnity, based on historical price/yield observations, is denoted as $I(\theta, \bar{y}_{it}, p_{it}^b)$ for coverage level θ (=.70), i indexes the crop, t indexes time, $\bar{y}_{it}$ is the producer's actual production history (APH) yield, and p_{it}^b is the base price for the crop.

While a variety of Federal crop insurance products are available, we focus on Revenue Assurance (RA). Under the base price option, an RA indemnity is paid when realized revenue falls below the guarantee, which equals the RA base price multiplied by the producer's APH yield and the coverage level. The per-acre indemnity is:

$$I(\theta, \bar{y}_{it}, p_{it}^b) = \max\left(0, \theta p_{it}^b \bar{y}_{it} - p_{it} y_{it}\right)$$

where p_{it}^b is the RA base price, p_{it} is the RA realized price (both prices defined by futures markets), and y_{it} is the actual yield. To clarify notation and unite the concepts of our theoretical model with the actual policy parameters, note that Y in the theoretical model would be equal to $p_{it} y_{it}$ in the empirical specification. It is important to remember that the empirical model

explicitly models sources of randomness to be variation over space and time, whereas the theoretical model leaves the source of randomness unspecified. The emphasis on variation over time in the empirical model allows us to incorporate historical data for simulation.

SURE payments. This section presents the details of calculating SURE payments which are essential to a realistic computation of the tradeoffs faced by farmers, and interpretation of the policy parameters. This exact analysis is crucial for the simulation, but may not be of interest to a reader emphasizing the conceptual understanding. Supplemental Revenue Assistance (SURE) is a whole farm program that provides supplemental payments to farmers who purchase crop insurance either through the Federal crop insurance program or through the Noninsured Crop Disaster Assistance Program (NAP). As most crop acreage in the regions we examine is insurable through the former, we focus on SURE as it applies to crops eligible for Federal crop insurance. SURE is analytically described in Carriazo, Claassen and Cooper (2009) and Smith and Watts (2010), but our description is updated to account for the SURE regulations released in December 2009.

SURE payments can be made only to producers who are located in counties where a disaster has been declared (the Secretary of Agriculture determines that there has been a weather-related production loss of 50 percent or more), counties contiguous to disaster counties, or to any producer who experiences production 50 percent or more below normal levels. In addition, producers must suffer a 10 percent production loss to at least one crop of economic significance on their farm in order to be eligible for SURE. The level of the SURE payment is:

$$D_t = \Omega_t * \Psi_t * \max(0.60(G_t - R_t^T),0),$$

where G_t is the SURE guarantee and R_t^T is total farm revenue, and where:

Ω_t is an indicator function equal to 1 if either a disaster is declared in the farmer's county or in a contiguous county or if actual production on the farm is 50 percent or less than normal production, as measured by overall revenue, and 0 otherwise. The normal production on the farm is the sum of the expected revenue for each crop on the farm, or $\sum_i (p_{it}^b \bar{y}_{it})$. The actual production on the farm is the sum of the value of the production produced, $\sum_i (p_{it}^b y_{it})$. Note that both values of the production are based on the price election for the insured commodity.

Ψ_t is indicator function equal to 1 if the 10 percent yield loss trigger is met for any of the eligible crops, or 0 otherwise.

The SURE guarantee depends on the level of crop insurance coverage selected by the producer, expected prices, and the producer's APH yield, but is limited to no more than 90 percent of typical or expected revenue:

$$G_t = \min\left(1.2\sum_i (a_{it}\theta p_{it}^b \bar{y}_{it}),\ 0.90\sum_i a_{ti} p_{it}^b \max(\bar{y}_{it}, y_{it}^C)\right)$$

where a_{it} is planted acreage of crop *i* (or acreage where planting was prevented) and y_{it}^C is the producer's counter-cyclical payment program yield or an "adjusted yield". Total farm revenue includes market revenue, commodity program payments, and net crop insurance indemnities:

$$R_t^T = \left(\sum_i a_{it} p_{it}^N y_{it}\right) + \left(\sum_i a_{it} * \max\left[0, I(\theta, \bar{y}_{it}) - PREM(\theta, \bar{y}_{it}, p_{it}^b)\right]\right) + MLB_{it} + 0.15DP_t + \left(CCP_t \ or\ ACRE_t\right)$$

where $PREM(\theta, \bar{y}_{it}, p_{it}^b)$ is the producer paid insurance premium per acre, MLB_{it} is the producer's (farm-level) total marketing loan benefits, DP_t is the producer's total direct payment, CCP_t is the producer's total counter-cyclical payment, and $ACRE_t$ is the farmer's total revenue payments

under the Average Crop Revenue Election program, where CCP_t and $ACRE_t$ are mutually exclusive.[5] The price p_{it}^N is the "National Average Market Price" as determined by the Deputy Administrator of USDA, which for the simulation we assume to be the national average cash price at harvest.

For the proposes of our simulation, we assume that the Secretary makes a disaster declaration with probability φ for a county when county yield for any crop (corn, spring or winter wheat, and soybeans in our model) falls below 65 percent of expected county yield, as was the standard for the 2001 and 2002 *ad hoc* disaster programs.

Empirical Simulation

Modeling the Distribution of Yields and Prices. While the theoretical model assumed an abstract distribution of revenue per acre, the empirical analysis, as well as any computation involving actuarial fairness, must derive actual distributions as a basis for work. The theoretical model collapses the risk profile onto revenue per acre, but empirical estimation must build revenue per acre from the distributions of yield and price, taking account of correlations between the two. The remainder of this subsection is dedicated to estimating the joint distribution of per-acre yield and price faced by farmers. We model the joint distribution of yields and prices for corn, soybeans, and spring wheat —the three major crops in Central South Dakota where most of our farms are located—using a method based on generating correlated within-season price and yield deviates in Cooper (2009a, 2009b).

Under this approach, national average yields are re-expressed as within-season yield deviations in year *s* as $\Delta Y_{is} = \left(Y_{is} - E(Y_{is})\right) / E(Y_{is})$, where expected yields, $E(Y_{is})$, are estimated by regressing average yields on a linear trend using data for *s* = 1975-2008. Yields are detrended to

base year 2008, where $Y_{is}^{d} = E(Y_{i,2008})(\Delta Y_{is} + 1)$. County yields are detrended and transformed to deviation form (denoted as ΔY_{is}^{c}) using the same methods. National average and county average yield data used in the analysis are obtained from National Agricultural Statistics Service (NASS).

Realized harvest prices, P_{is}, are also transformed into deviation form: $\Delta P_{is} = (P_{is} - E(P_{is})) / E(P_{is})$ where $E(P_{is})$ is pre-season expect price. For each crop, we follow Risk Management Agency (RMA) definitions of the expected and realized prices. For the realized price of corn, for example, we use the average of the daily October prices of the December Chicago Board of Trade corn future in period *t*. For the expected price we use the average of the daily February prices of the December CBOT corn future. We also use the February and October prices for the December CBOT soybean contracts to represent expected and realized prices, respectively. For hard red spring wheat, the expected and realized prices are obtained by averaging the closing prices March and August, respectively, for the Minneapolis Grain Exchange (MGE) September contract.

Next, the relationship between ΔP_{is} and ΔY_{is} is econometrically estimated. We assume that ΔP_{is} can only be partially explained by ΔY_{is}, and that the uncertainty in this relationship can be incorporated into the empirical distribution as

$$\Delta P_{is} = g(\Delta Y_{is}, z_i) + \varepsilon_{is}$$

where z_{is} is a vector of other variables that may explain the price deviation and ε_{is} is the error term. We expect that $d\Delta P_i / d\Delta Y_i < 0$, i.e., the greater the realization of national average yield over the expected level, the more likely harvest time price will be lower than the expected price. See

Cooper (*ibid.*) for further model description and for the regression results that we use to simulate price deviations.

We jointly estimate the distributions of price and yield deviations by repeated estimation of the equation above using a bootstrap procedure. Specifically, a pairs bootstrap approach is used in a joint resampling methodology that involves drawing *i.i.d.* observations with replacement from the original data set (e.g., Yatchew). Variation in estimates results from the fact that upon selection, each data point is replaced within the population. The bootstrap procedure creates M sets of coefficient vectors representing uncertainty in the yield-price relationship. That is, for each draw of a yield deviation, there exists a distribution of estimated price deviations.

Next, simulated yield vectors for ΔY_i and ΔY_i^c, i = 1,..,3, are generated using a version of the block-bootstrap approach (e.g., Lahiri) in which the pair-wise (defined over time) relationship between yield values is maintained across each crop and yield aggregation. We draw N times with replacement rows of ΔY_{is} and ΔY_{is}^c, i = 1,..,3, from the actual yield data to generate the simulated yield data, where N =1000. The simulated yield data maintains the underlying historical Pearson and rank correlation – as well as any other relationship between the variables – between county and national yield data, both within crops and across crops.

Finally, for each value simulated ΔY_{in} value, we generate $m = 1,\ldots,M$ simulated price deviations $\Delta\hat{P}_{inm}$ based on the M coefficient vectors from the regression bootstrap. This process results in NM = 1,000,000 simulated values of $\Delta\hat{P}_{inm}$ with pair-wise relationships maintained between simulated prices, ΔY_{in}, and ΔY_{in}^c across the 3 crops.

To represent farm-level conditions, we inflate the standard deviation of county-level yields as per Carriazo, Claassen, and Cooper (2009). Starting with county yields in deviation form, we select the inflation factor, α_{ci} (c indexes the county), such that the APH indemnity calculated from our yield distribution is equal to the APH premium:

$$\underset{\alpha_{ci}}{MIN}\left[\omega-(MN)^{-1}\sum_{m}\sum_{n}\max\left\{\left(\theta p_i^{APH}E(y_{i,2008})-p_i^{APH}y_{in}\right),0\right\}\right]^2$$

where $y_{in}=Y_{in}^c+z_{in}\left\{\left[\alpha_{ci}\cdot\sigma\left(Y_i^c\right)\right]^2-\left[\sigma\left(Y_i^c\right)\right]^2\right\}^{0.5}$ is from Cooper *et al.* (2009a), $Y_{in}^c=E(y_{i,2008})(1+\alpha_c\Delta Y_{in}^c)$, z_{in} is a $N(0,1)$ random variable, and ω_i is the RMA premium rate calculated from RMA actuarial data (excluding the fixed rate load to avoid premium charges associated with disaster reserves and other factors not necessarily associated with farm-specific loss risk), p_i^{APH} is the APH price, and the coverage rate, θ, is 0.65.

Description of the representative farmer and SURE payments. For our numerical simulation of famer decision-making in the presence of SURE, we use a representative farmer in Hyde County, South Dakota. Production in this county is relatively risky compared to the Corn Belt, and as such, is a region where disaster assistance is likely to be particularly relevant. The farm is representative of the county in that its mean yield is the same as county yield, but its farm level yield variance is inflated over the county level using the approach discussed in the previous section. We assume that the county level SURE trigger is based on losses in corn, soybeans, or spring wheat. However, to reduce the potential for multiple optimal solutions to the farm level expected utility maximization exercise, we assume that the farmers intends to only grow corn and spring wheat in 2009. We chose this crop combination not to imply an agronomically desirable crop rotation, but simply to make the simulation more interesting as our farmer is relatively indifferent between soybean and spring wheat production. We assume that the farmer

has maintained enrollment in the traditional commodity support programs rather than enrolling in the new ACRE program. Under current expected prices, this means that the farmer receives fixed direct payments, but no marketing loan benefits or counter-cyclical payments.

Table 1 presents various parameters and statistics relating to the representative farm. The first few rows present the mean, standard deviation, and correlation matrix of the yield density function that are estimated for the representative farmer in Hyde County. The last row gives the 2009 crop year planting time output prices around which the estimated price density functions are centered. Where necessary in the simulations, the harvest time futures prices are converted national season average cash price based on the average of the previous five years basis difference between these two prices.

Table 2 presents summary statistics for simulation results for 2009 for gross farm revenue, net indemnities for RA insurance, SURE payments, and total gross farm revenue (which includes the net indemnities and the SURE payments) for the farm with the yield densities summarized in Table 1, with the assumption that the farmer purchases 70% coverage for each crop. Since revenue, insurance payments, and SURE payments are not distributed normally, we also present 90% empirical confidence intervals using the approach discussed in Efron (1987). The table presents three acreage scenarios. The acreage allocation in Scenario I mimics the actual acreage allocation for the three crops in Hyde County, SD. Scenario II drops soybeans and Scenario III drops corn and soybeans. These simulations portray the heterogeneity of returns that may be faced by farmers in the same region.

In Table 2, at around $3 to $5.5/acre, mean SURE payments are small relative to gross farm revenue and even relative to RA net indemnities. However, the 90% upper tail on SURE payments is approximately $30/acre, suggesting that they can become a relatively significant

share of revenue per acre in years with substantial revenue losses. The combination net indemnities and the SURE payments reduces the coefficient of variation of farm revenue by 28 to 29%, but perhaps more importantly, it results in a substantial increase in the 90% lower bound, which is $0 for gross income in two of the three scenarios, but at least $158 with the insurance and SURE. While we present these results for a representative farmer in one county, we have also estimated these payment and revenue figures for other counties in North and South Dakota and find the results to be similar to those in the table.

The results in Table 2 show mean SURE payment increasing as the farmer's crop diversity shrinks moving from Scenario I to III. This payment increase is due to revenue risk increasing the lower the number of unique crops grown. However, the scope for moral hazard of SURE in reducing crop diversity may be minimized by the percentage decrease in the coefficient of variation of revenue being relatively constant across the three scenarios.

Farmer Choices: Maximizing Expected Utility under CARA. Given the joint price and yield densities functions described above, we now turn to the simulation of EU maximizing behavior by the farmer. We assume that the farmer has constant absolute risk aversion (CARA) and chooses acreage and insurance coverage to maximize the expected value of a negative exponential utility function over $N{\cdot}M$ = 1,000,000 simulated price and yield, and insurance combinations as

$$\underset{a_1,a_2,\theta}{Max}\, EU(w) = \frac{1}{N \cdot M} \sum_{j=1}^{N \cdot M} \left[1 - e^{-\lambda w_j}\right],$$

where λ is the absolute risk aversion coefficient and w is wealth. Wealth w is w_o plus net returns under four scenarios: 1) no insurance coverage; 2) insurance coverage; 3) insurance coverage and ad hoc payments; and 4) insurance coverage and SURE payments. Wealth w_j under each

scenario includes direct payments for corn, soybeans, and wheat, with the share of payments for each crop based on the number of base acres in each crop for Hyde county, valued at the base yield rates for that county, with the total value of these payment for being DP = \$6.86 per acre. Note that these are annual fixed payments not requiring production of the crops, and hence, we include the soybean direct payments regardless of whether or not farmer grows soybeans.

Wealth w_j for each price-yield realization j is defined as

$$w_j = w_o + DP + \left(\sum_i a_i p_{ij}^N y_{ij}\right) - \sum_i C_i + D_{ij} + \left(\sum_i a_i I_{ij}(\theta)\right) - \left(\sum_i a_i PREM_{ij}(\theta)\right),$$

where C_i is the production cost for each crop (i = 1,2), D_{ij} is the total SURE payment (if applicable to the scenario), $I_{ij}(\theta)$ is the per acre insurance indemnity, and $PREM_{ij}(\theta)$ is the insurance premium. To reduce the parameter space, we assume that the farmer choose a single insurance coverage rate for each θ crop. Note that under current expected prices, the probability of marketing loan benefits and counter-cyclical payments being issued are zero for the crops in question, and as such, are not included in w_j.

Table 1 provides the parameters – fertilizer and all other costs – used for the cost functions C_i, and are based on ERS/USDA cost estimates for the region that includes South Dakota. To reflect increasing marginal costs as additional acreage is brought into production, and to reduce the probability of corner solutions in the simulations, we assume quadratic cost functions (e.g., Howitt, 1995) for each crop i, $C_i = \nu_0 a_i + \nu_1 (a_i)^2$, where ν_0 is the parameter on the constant marginal costs and ν_1 the parameter on the increasing marginal costs. We assume that marginal costs is increasing in fertilizer.

We normalize our farm to one acre. Initial wealth w_o is derived from USDA data as discussed in Carriazo, Claassen, and Cooper (2009) and is $833.54 for the one acre farm. We use two scenarios for the supply of land: 1) supply is completely inelastic and $\sum_i a_i \leq 1$; and 2) supply is completely elastic. In either case, to restrict the feasible parameter space in estimation, the EU maximization is subject to the budget constraint $\sum_i C_i + \left(\sum_i a_i I_{ij}(\theta) \right) \leq w_o + DP$.

We assume the farmer has a moderate risk aversion premium of 20 percent (e.g., Hurley, Mitchell, and Rice, 2004; Mitchell, Gray, Steffey, 2004). The associated absolute risk aversion coefficient λ is scaled to the standard version of net revenue for the one acre farm using the approach in Babcock, Choi, and Feinerman (1993). For our baseline standard deviation of $103.09 evaluated over our *N*x*M* simulated price and yield combinations, we assumed 0.27 acres of corn and 0.73 acres of wheat, θ =0.7, quadratic cost functions, and no SURE payments. The resulting λ = 0.003988. Note that as the coefficient of variation was similar across the two crops, for the simulation we raised the standard deviation of corn by 25 percent to make the analysis more interesting.

We let the insurance coverage rate vary between 0 and 100 percent. The actual range for RA coverage is 55 to 85 percent. However, the simulation approach allows us to find the farmer's optimal coverage level, which can provide additional insights over staying within the range of actual program parameters. Table 3 provides the simulation results for a farmer whose crop insurance premium is actuarially fair *before* the government insurance subsidy is applied. Hence, the final premium is advantageous to the farmer from an actuarial perspective. For the analysis in Table 4, the farmer's actuarially fair premium is multiplied by 1/(1-0.59) *before* the the government insurance subsidy is applied. Hence, the farmer's actual premium is actuarially

fair at a 70% coverage level, but fairness at other coverage rates depends on the RMA subsidy schedule.[5]

Finally, expected utility is maximized with respect to planted acres and insurance coverage level subject to the one or two constraints (depending on the land supply scenario) as a Lagrangean function using the Newton method with a STEPBT line search. The budget constraint was not binding in any of the scenarios, indicated the estimated shadow price on the budget constraint being zero in each case.

Simulation Results. While in the simulation we have fixed acreage, there is a choice between corn and wheat. Corn is a high-risk, high-reward crop, so if insurance increases the acreage of corn, this is equivalent to intensification or increasing acreage, in the theoretical model. In the world of real policy options, the farmer faces a large menu of combinations of coverage rates and premiums. Looking at Table 3, and as expected from the theoretical model, the simulation where the insurance premiums are more than actuarially fair for the farmer, the farmer chooses a relatively high level of coverage (in gravitating towards more highly subsidized policies).

In the case where land is constrained to 1, allowing the farmer to choose insurance causes a shift towards corn, which has a higher coefficient of variation than wheat for this farmer. However, adding *ad hoc* payments as well causes the farmer to shift acreage to spring wheat, which also happens when land supply is completely elastic in both the Table 3 and Table 4 scenarios. Disaster payments in the county are invoked 14.4% of the time for corn and 18% of the time for spring wheat, which likely accounting for increased production of the latter when ad hoc payments are available.

In the land constrained scenarios in Tables 3 and 4, adding *ad hoc* payments to the farmer's revenue lowers the farmer's optimal level of insurance coverage, which confirms the predictions of the theoretical section and results directly from constant absolute risk aversion. Also, as suggested by the theory, in the unconstrained land scenarios in both Tables, adding *ad hoc* payments to the farmer's revenue leaves the farmer's optimal level of insurance coverage unchanged; the farmer increases acreage instead.

In both the Table 3 (advantageous insurance premiums) and Table 4 (approximately actuarially fair insurance premiums post subsidy) scenarios, adding SURE to insurance induces insurance coverage to increase for the former, but not for the latter. In fact, when land is constrained in table 4, SURE even induces a decrease in coverage. The results show the importance of subsidies in inducing adoption.

Interestingly, in table 3 where land supply is elastic, the farmer's optimal insurance coverage is greater than the actual 0.85 limit on θ, and binds up against the model's upper limit of 1.0. This occurs in spite of the SURE guarantee G_t not being allowed to exceed 0.90 of expected revenue. On the other hand, SURE total gross farm income R_t is a function of net indemnities, which receive a floor of zero in the calculation of R_t, and hence, the interactions between SURE and θ are relatively complex.[65] However, it is clear that subsidies of insurance premiums may lead to "corner solutions" characterized by full or maximal insurance.

In either the Table 3 or Table 4 scenarios, adding the SURE payments do not induce acreage expansion relative to the scenarios with insurance only. In fact, in the table 4 scenario, adding SURE actually induces acreage to shrink relative to the case with insurance, although acreage under SURE is still higher than with no insurance. Adding *ad hoc* assistance to the insurance scenario does cause acreage expansion, and especially in the case in Table 4, where the

insurance is less desirable to the farmer than in the Table 3 scenarios. The key point here is the relative costs and benefits of insurance coverage vis-à-vis acreage. When the level of insurance coverage is chosen by the farmer, he may choose higher coverage rates and lower acreage depending on the parameters of the insurance and the resulting relative costs. Altogether, we find that the introduction of nested insurance leads to intensification and/or increased acreage.

Conclusion

Farmers may face a multitude of possible insurance arrangements for related risks, and this paper introduces a theory of nested insurance to evaluate the impact on intensification, acreage and adoption. The results suggest that parameters of a government program like SURE may enhance the adoption and value of crop insurance to the farm sector. A quantitative understanding of the interdependencies between programs like SURE and crop insurance, taking into account the nature of the *ad hoc* alternative, is important in assessing the welfare impacts on farmers, as well as insurance companies. Both our theory and simulation exercise suggest that insurance increases the volume of production and/or leads to increased intensification (higher value crops). On the other hand, the gains from insurance and from programs like SURE may be lessened by the presence and probability of *ad hoc* disaster assistance. Hence, a big challenge in designing and implementing a program like SURE is to limit alternative *ad hoc* arrangements.

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Table 1. Descriptive Statistics for the estimated farm level density functions used for the Simulations

	Corn	Soybeans	Spring wheat
	Yield data (bu./acre)		
Mean	88.55	28.33	37.65
Standard deviation	51.31	14.75	20.00
	Yield correlation matrix		
Corn	1.000	0.082	0.115
Soybeans	0.082	1.000	0.081
S. Wheat	0.115	0.081	1.000
	Cost data ($/acre)		
Fertilizer (ν_1)	$93.31	$11.31	$44.21
All other (ν_0)	$148.03	$94.61	$65.54
	Futures price data at planting, 2009 crop year ($/bu.)		
Output price	$4.05	$8.80	$6.20

Notes: The farm data was generated by scaling up the variance of estimated county level yield densities based on NASS/USDA data for Hyde County, South Dakota. Operating costs per acre are for the region including South Dakota (source: 2008 ERS Commodity Costs and Returns).

Table 2. Gross farm returns, net insurance indemnities, and SURE payments (per acre)

	Mean ($/acre)	Standard Deviation ($/acre)	90% Empirical C.I. ($/acre) Lower	Upper	Coeff. of Variation	(percent change)
I. Corn acres = 0.0258, soy acres = 0.0464, spring wheat acres = 0.6955						
Market revenue	277	114	25	602	0.412	
RA Net indemnities	23.70	36.27	0.00	159.29		
SURE payments	2.98	7.93	0.00	29.59		
Total revenue	304	89	179	602	0.294	-28.78%
II. Corn acres = 0.0271, soy acres = 0.0, spring wheat acres = 0.7294						
Market revenue	277	119	11	613	0.430	
RA Net indemnities	23.68	37.74	0.00	166.87		
SURE payments	3.48	8.75	0.00	29.91		
Total revenue	304	93	175	614	0.305	-29.11%
III. Corn acres = 0.0, soy acres = 0.0, spring wheat acres = 1.0						
Market revenue	260	144	0	666	0.553	
RA Net indemnities	19.78	44.03	0.00	161.87		
SURE payments	5.45	10.33	0.00	26.69		
Total revenue	285	113	158	666	0.40	-28.14%

Notes: Figures are for the farm described in Table 1. We assume the insurance coverage rate is 70%. Total revenue includes direct payments. Revenue values are gross. The acreage allocation in Scenario I mimics the actual acreage allocation for the three crops in Hyde County, SD. Scenario II drops soybeans and Scenario III drops corn and soybeans.

Table 3. Simulation results for the EU maximizing farmer for whom the RA crop insurance is actuarially fair *before* the government subsidy (farmer is moderately risk averse)[b c]

Scenario	Corn Acres	S. Wheat Acres	Insurance Coverage (θ)	Total acres
	I. Land supply is completely inelastic[a]			
No insurance	0.285	0.715	--	1
RA insurance	0.332	0.668	0.85	1
RA insurance and *ad hoc* payments	0.0631	0.937	0.80	1
RA insurance and SURE	0.294	0.707	0.88	1
	II. Land supply is completely elastic			
No insurance	0.718	1.621	--	2.339
RA insurance	1.267	2.758	0.85	4.028
RA insurance and *ad hoc* payments	1.274	2.787	0.85	4.061
RA insurance and SURE	1.184	2.843	1.00	4.027
RA insurance and SURE (upper bound on θ = 0.85)	1.282	2.893	0.85	4.175

Notes: Whereas actual RA crop insurance is bounded over {%55,85%} (although actual bounds vary by region), in the model it is bounded over {0%,100%}, except where noted.

[a]Maximum land availability equals 1.

[b]The farmer's RA crop insurance premium is actuarially fair before the government premium subsidy is applied.

[c]The farmer has a risk premium of 20%.

Table 4. Simulation results for the EU maximizing farmer for whom the RA crop insurance is approximately actuarially fair *after* the government subsidy (farmer is moderately risk averse)[b c]

	Corn Acres	S. Wheat Acres	Insurance Coverage (θ)	Total acres
	I. Land supply is completely inelastic[a]			
No insurance	0.285	0.715	--	1
RA insurance	0.261	0.739	0.80	1
RA insurance and *ad hoc* payments	0.367	0.634	0.65	1
RA insurance and SURE	0.266	0.735	0.75	1
	II. Land supply is completely elastic			
No insurance	0. 718	1.621	--	2.339
RA insurance	0.945	1.931	0.80	2.876
RA insurance and *ad hoc* payments	1.263	2.896	0.80	4.159
RA insurance and SURE	0.724	1.728	0.80	2.453

[a]Maximum land availability equals 1.

[b]The farmer's actuarially fair RA crop insurance premium is multiplied by 1/(1-0.59) before the government premium subsidy is applied.

[c]The farmer has a risk premium of 20%.

Endnotes

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[1] To be eligible for *ad hoc* payments, the farmer generally needs to have at least some minimal level of insurance coverage but the payment levels are not a function of the insurance coverage levels. SURE payments on the other hand are a direct function of insurance coverage levels.

[2] In the discussion in this section, we are abstracting away from the specific provisions of the Federal crop insurance program, in which a subsidy covers a portion of the full crop insurance premium cost.

[3] A number of authors have argued that premium rates are not actuarially fair and that some producers benefit from asymmetric information while others are charged higher than fair premiums (e.g., Just, Calvin, and Quiggen; Makki and Somwaru). At best, as the insurance products are not calculated using individual-specific yield risk measure, they can only be actuarially fair on average.

[4] $s(\theta)$ is the subsidy rate (.59 for 70% coverage).

[5] If the eligible farmer chooses to be in enrolled in the Average Crop Revenue Election program (ACRE) rather than in the traditional commodity program, then the CCP payment in t is replaced by an ACRE revenue payment, DP's are reduced by 20% and the loan rate in the MLB by 30%.

[6] The reason that the second decimal place in the estimated coverage rates tend to be zero or 5 is that for the model, we have converted the discrete RMA subsidy schedule to a continuous schedule covering θ in bands of 0.05 increments over 0.55 to 0.85. For instance, for $0.65 \leq \theta < 0.75$, the premium subsidy is 0.59. For instance, for $0.75 \leq \theta < 0.80$, the premium subsidy is 0.55, etc. The subsidy is zero for $\theta \geq 0.85$.