Crop Insurance Savings Accounts

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Crop Insurance Savings Account

Crop insurance is a critical risk management tool for farmers to protect against yield and revenue losses, smooth income over time, and remain a viable operation after catastrophic events. However, designing crop insurance instruments that achieve broad participation among farmers at a low cost to the Federal government has proven to be a formidable challenge. Because agricultural production and prices are highly volatile, it is very difficult for both the insurer and the farmer to accurately assess yield and revenue risk at the farm-level. The correlation between historic and future outcomes is quite limited due to weather variability, unforeseen pest problems, frequent changes in technology and market globalization. As a consequence, there is often a disconnect between the insurer and the producer perception/measure of the level of yield and revenue risk associated with a particular farm operation, which results in ineffective insurance pricing and the need for substantial subsidies to induce farmer participation.

In other words, as exemplified by Ramirez and Carpio (2011), the inability of either party to ascertain what the actuarially fair premium is within a reasonable margin of error substantially limits farmer participation unless the overall premium levels are highly subsidized. As a result, achieving broad participation in crop insurance programs has proven costly to the Federal government. In 2010, between 83% and 91% of total plantings for each of the four major US field crops (corn, cotton, soybeans and wheat), which account for three-quarters of the total 255 million acres enrolled, were insured by farmers. To achieve these high levels of participation, however, the government has had to subsidize approximately 60% of the effective premiums at a cost of $4.7 billion just in 2010. In addition, that year, the government paid a $1.4 billion reimbursement of administrative and operating (A&O) expenses to the private companies in charge of implementing the program. As shown in table 1, for fiscal year 2011, the premium subsidy surged to $7.4 billion plus another $1.4 billion in A&O costs paid by the government.

[Insert Table 1 about Here]

During the last 20 years, numerous studies have been conducted with the objective of improving the actuarial performance of the Federal crop insurance program through several different avenues. Some have considered alternative forms of area yield insurance (e.g., Miranda, 1991; Skees, Black, and Barnett, 1997; Goodwin and Ker, 1998; Mahul, 1999; Ker and Goodwin, 2000) and revenue insurance (Gray, Richardson and McClaskey, 1995; Hennessy, Babcock, and Hayes, 1997; Stokes, 2000; Wang et al., 1998; and Coble, Heifner, and Zuniga, 2000). Others have focused on developing improved methods for the Risk Management Agency (RMA) to more accurately assess and price yield and revenue risks (e.g., Barry, Goodwin and Ker, 1998; Moss and Shonkwiler, 1993; Ramirez, 1997, 2000; Ramirez, Misra, and Field, 2003; Ramirez, Misra, and Nelson, 2003; Ramirez, Carpio, and Rejesus, 2009; and Ramirez and Carpio, 2011). In spite of those studies, as previously noted, the need for high government subsidies remains and in fact appears to be increasing. In addition, the most recent work by Ramirez and Carpio (2011) suggests that only marginal improvements are possible even under optimal conditions.

Given the massive and escalating Federal budget deficit and the pressing need to bring it under control over the next decade, it might be unrealistic to expect that the government will continue providing such large subsidies to sustain the crop insurance program as currently structured. In fact, President Obama's budget proposal of February 13, 2012 reduces total farm subsidies to $32 billion by ending direct payments, idling less land, and reducing Federal support to the crop insurance program. And on March 20, 2012, the House of Representatives Budget

Committee proposed to reduce U.S. farm and crop insurance subsidies by $30 billion over the next 10 years and urged for reforms to control the soaring cost of the program. The proposed cuts equal 19 percent of projected spending through fiscal year 2022.

In short, after 20 years of serious but unfortunately unsuccessful efforts to reduce the heavy dependence of the US crop insurance program on external subsidies, it is perhaps time to consider alternatives that can provide an effective safety net for agricultural producers at a much lower cost to the government. The goal of this research is thus to explore a different insurance design that could be an effective risk management tool for farmers, achieve broad participation, minimize the well-known adverse selection and moral hazard problems inherent in insurance markets without perfect information and monitoring, and drastically reduce the need for government subsidization.

Specifically, we reconsider one of the more controversial approaches that has in various forms been proposed in US Farm Bill debates dating back to 1996 - a system based upon farmer owned savings accounts. Surprisingly, despite a plethora of savings account based proposals, few analyses of the viability of such systems have been conducted. Reports such as Dismukes and Durst (2006), Enahoro and Gloy (2006), and Gloy and Cheng (2006) using tax records to analyze Farm and Ranch Risk Management (FARRM) and counter cyclical (CC) savings accounts have presented a mixed picture on the potential of such approaches. Building upon this earlier work, this study proposes a related alternative design based on the establishment of what we refer to as crop insurance savings accounts (CISAs). Our proposed CISA system, which has similarities to programs for health insurance (Health Savings Accounts) and unemployment insurance (Unemployment Insurance Savings Accounts)[1] is designed to closely mimic current revenue insurance policies that have been widely adopted by farmers, but using a personal savings account approach. The system enables farmers to annually deposit pre-tax income in an interest-bearing personal savings account and draw an indemnity from their accounts when there is a qualified loss. If in a given year a farmer's account is exhausted, the government lends money to the account to cover the indemnity. The proposed design reduces the moral hazard and adverse selection problems inherent to the current program. As well, under the CISA system, farm-level risk no longer has to be priced, thus eliminating the premium rating difficulties that weaken actuarial soundness. In addition, administrative costs are likely to be substantially lower.

The remainder of the article is organized as follows. A detailed design of the proposed CISA system is presented in the following section. The next three sections describe the empirical methodology, present results assessing the viability of the CISA system for the specific case of corn producers in the State of Illinois, and discuss the outcomes of a sensitivity analysis. The final section provides some key conclusions and recommendations.

CISA Program Design

In this section we formalize the basic framework of our proposed crop insurance savings account system. For simplicity of exposition, we present the CISA in language analogous to current revenue insurance instruments, which, on a premium basis, accounts for three-quarters of all policies (Shields, 2010). Under the proposed system farmers are allowed to annually save a specified fraction of their historic farm revenue in an individually owned crop insurance savings

[1] See Feldstein and Altman (1998).

account that earns an interest rate r.[2] We denote the contribution made to a farmer's CISA in period t as $\alpha f(R_1, R_2, \dots, R_{t-1})$ where R_t denotes farm revenue, $f(\cdot)$ is some function of past revenue levels (e.g., a simple average of the farmer's previous five years of revenue), and $\alpha \in [0,1]$ is the proportion of $f(\cdot)$ contributed to the farmer's CISA. These investments are assumed to be with pre-tax income.

Withdraws from the account are made when farm revenues in a given year fall below a specified threshold. Using the language of current revenue insurance programs, we call this threshold revenue level the "revenue guarantee" and denote it as R_t^g. Hence, withdraws from the CISA in a given year are equal to $max(0, \mathrm{R_t^g} - \mathrm{R_t})$. In the event that a farmer's CISA balance is insufficient to cover a withdrawal, the required funds are lent to the account by the government at the same interest rate as earned on the savings. Given this structure, the periodic balance of an individual's CISA, B_t, and their periodic after-tax income from farming, π_t, can be expressed as:

(1) $$B_t = (1+r)B_{t-1} + \alpha f(R_1, R_2, \dots, R_{t-1}) - max(0, \mathrm{R_t^g} - \mathrm{R_t})$$

(2) $$\pi_t = (1-\tau)\left[R_t + max(0, \mathrm{R_t^g} - \mathrm{R_t}) - \alpha f(R_1, R_2, \dots, R_{t-1}) - C_t\right],$$

where τ is the tax rate and C_t are farm production costs. Akin to a traditional individual retirement account (IRA), positive balances in CISAs may be withdrawn after retirement from farming or bequeathed to heirs in the event of death. Notice that for farmers who have a positive account balance and expect the account to be positive at retirement, participation in the CISA system does not have a distortionary effect on risk taking activities (i.e., no moral hazard)

[2] Later we will discuss the implications of voluntary vs. mandatory participation in the CISA program. In addition to being a potentially contentious design element, there are implications for program efficacy, adverse selection, and moral hazard.

because the cost is fully internalized. This is a distinct advantage of the CISA system over the current insurance instruments.

For individuals who reach retirement with a negative CISA balance two alternative policy designs are possible, each with their own advantages and disadvantages. One alternative is for the government to simply forgive the debt. This has two clear disadvantages. First, there is a cost to the government in the form of foregone loan repayments and a benefit for those farmers who are more inclined to take risks and thus likely to end with a negative CISA balance. Second, for farmers who at some point begin to expect having a negative terminal period balance, this creates a moral hazard problem in which they do not face the full consequences of taking on greater risk. On the positive side, if upon retirement producers get to withdraw the positive ending balances without paying taxes, any terminal debts are forgiven, and the alternative is no subsidized insurance, it is expected that most rational farmers will voluntarily choose to participate.

The second alternative approach for managing negative balances upon retirement is to require repayment of the debt in the form of an added tax when the land is sold, leased or transferred to heirs. The advantages of this design are two-fold. First, it would result in less financial burden on the government. Second, it would not induce the moral hazard problems described above. The main downside to this approach is that participation would be expected to be lower than in the first alternative where terminal debts are forgiven.

Feasibility of the CISA System

The viability of the proposed crop insurance system rests squarely on one issue - the proportion of farmers that will reach retirement with a negative account balance. If for a given revenue guarantee level, $\mathrm{R}_{\mathrm{t}}^{\mathrm{g}}$, there is a reasonable CISA contribution rate, α, at which most farmers are expected to reach retirement with a positive account balance, then the proposed system could have several obvious advantages relative to the current program. Specifically, the CISA system would likely (a) achieve a high level of voluntary participation because of the tax free savings and final withdrawal benefit, (b) substantially reduce the cost to the government (i.e., no direct subsidies and much lower administrative costs), (c) not distort farmer incentives (i.e., no moral hazard), and (d) eliminate the need for the government to attempt to price farm risk and determine crop insurance premiums, and the resulting adverse selection problems. While the tax free nature of the CISA contributions results in a loss of government revenue, note that in the current program the premiums paid by farmers are tax deductible as well.

While the theoretical motivations for the CISA system are enticing, the question remains whether farmers can themselves finance their own crop insurance benefits via saving a reasonable proportion of their own farm income. Specifically, for a reasonable savings rate, what proportion of farmers would likely fall into the category of having a negative account balance upon retirement? This is the empirical question we focus on in the next sections.

Simulation Methods

Given the procedures to be followed in this research, time series of price and yield realizations that are representative of what farmers might face in future years are needed to evaluate the feasibility of the proposed CISA. Reliable parametric estimates of future price and yield distributions are required to generate those realizations and sufficiently long historical price and yield time series are necessary in order to estimate those distributions. While long time series are available for most major commodity prices, multi-decade farm-level yield records are not as common. Fortunately, the University of Illinois Endowment Farms project has been collecting such records from 26 different "representative" corn producers during the last 50 years. Therefore, the "test-of-concept" analyses presented in this paper are conducted for the specific case of corn producers in the State of Illinois.

Price and Yield Distribution Models

In addition to having access to suitable data, a key to obtaining realistic estimates of the price and yield distributions of interest is to use flexible probability density function (pdf) models that can accommodate a wide range of mean-variance-skewness-kurtosis combinations. One such density function is the Inverse Hyperbolic Sine (IHS), which was first utilized for yield modeling and simulation by Ramirez (1997). Subsequent applications of this model involving both yield and price distributions include Ramirez and Somarriba (2000), Ramirez, Misra and Field (2003), and Ramirez, McDonald and Carpio (2006).

In addition to its flexibility, the IHS distribution model is appealing because each of its first four statistical moments can be independently controlled by a parameter or a parametric function of some exogenous variable(s). Specifically, for both the price and yield distributions, the mean is specified as a linear function of time ($B_1 + B_2 t,\ t = 1,2,\ldots,T$) while the variance, skewness and kurtosis are controlled by constant parameters (B_3, B_4, B_5, respectively). In the single variable case, the IHS density is then given by:

(3) $IHS(Y_t) = G_t (2\pi)^{-\frac{1}{2}} \exp(-0.5 H_t^2)$, where

$$G_t = [B_3^2 (1 + R_t^2)/J]^{-\frac{1}{2}},$$

$$J = [\exp(B_4^2) - 1][\exp(B_4^2)\cosh(-2B_4B_5) + 1]/(2B_4^2),$$

$R_t = J^{\frac{1}{2}} B_4 (Y_t - B_1 - B_2 t)/B_3 + F,$

$F = \exp(0.5 B_4^2) \sinh(B_4 B_5),$

$H_t = \ln\left(R_t + (1 + R_t^2)^{\frac{1}{2}}/B_4\right) - B_5.$

As Ramirez, Misra and Field (2003) point out, as B_4 and B_5 approach zero, this pdf becomes a normal density with mean $B_1 + B_2 t$ and variance B_3^2, which facilitates a test for whether or not prices and yields are normally distributed. In addition, if $B_4 \neq 0$ but $B_5 = 0$, the density is kurtotic but symmetric, while a negative (positive) B_5 induces negative (positive) skewness into the distribution. Specifically, the skewness (S) and kurtosis (K) measures of this pdf are given by:

(4) $S = \frac{1}{4} W^{\frac{1}{2}} (W - 1)^2 [W(W + 2)\sinh(3Q) + 3\sinh(Q)]/(J{B_4}^2)^{1.5}$, and

(5) $K = \frac{\frac{1}{8}(W-1)^2[W^2(W^4+2W^3+3W^2-3)\cosh(4Q)+4W^2(W+2)\cosh(2Q)+3(2W+1)]}{J^2 B_4^4} - 3$, where $W = \exp(B_4^2)$, $Q = -B_4 B_5$.

In short, the IHS model allows for a wide range of skewness-kurtosis combinations (according to the two equations above which only depend on B_4 and B_5) while its mean and variance are determined by $B_1 + B_2 t$ and B_3 only. In addition, Ramirez, Misra and Nelson (2003) show how the IHS density (equation 1) can be modified to allow for autocorrelation. Specifically, all is needed is to let $R_t = \left(J^{\frac{1}{2}} B_4 P_t (Y_t - B_1 - B_2 t)/B_3\right) + F$ where P_t is the t^{th} row of a T by T transformation matrix P such that $P'P = \Psi^{-1}$ and Ψ is the error term correlation matrix[3]. Using standard procedures, the concentrated log-likelihood function needed for estimating the parameters of this model can be derived from equation (3):

$$(6)\ \sum_{t=1}^{T} \ln\left(G_t\right) - 0.5 \sum_{t=1}^{T} H_t^2$$

The above function is then maximized in order to obtain estimates for the parameters of a price distribution model with a time-varying mean, constant variance, skewness and kurtosis coefficients, and a suitable autocorrelation process. Maximum likelihood estimation is accomplished using the CML procedure of Gauss 9. The data utilized includes the real (inflation-adjusted[4]) corn prices received by Illinois farmers during the last 70 years (USDA, National Agricultural Statistics Service, 2011). As customary, the price series is first tested and confirmed to be stationary according to both the Dickey-Fuller and the Phillips-Peron tests.

The maximum-likelihood parameter estimates and related statistics for this first model are presented in table 2. First note that real prices have been decreasing over time at a rate of 3.22 cents/year, putting them at a predicted average of $4.085/bushel in 2011. The estimate for the standard deviation of the price distribution stands at $0.618/bushel. A White test is conducted to make sure that the model's variance is constant, i.e. that price variability has not been changing over time. A test statistic of 3.37 does not allow for the rejection of the null hypothesis of homoscedasticity (p-value= 0.185).

[Insert Table 2 about Here]

The maximum value of the concentrated log-likelihood function corresponding to the non-normal price model is -60.37 versus -64.92 for the analogous normal model where B_4 and

[3] For a derivation of P in the case of first and second order autoregressive processes please see Judge et al. (1985, p 285 and 294).
[4] Inflation adjusted by the Producer Price Index for farm products (BLS, 2011).

B_5 are set to zero. As a result, the likelihood ratio test statistic (Ramirez, Misra and Field, 2003) easily allows for rejection of the null hypothesis of normality (p-value=0.01). That is, since both B_4 and B_5 are positive, the distribution of corn prices received by farmers in the state of Illinois is in fact positively kurtotic and significantly right-skewed. Finally it is evident that, over time, prices follow a second order autoregressive process as both parameters in this process (B_6 and B_7 in the transformation matrix P) are highly significant while the Box-Pierce test cannot reject the null hypothesis that the transformed model residuals $\{P_t(Y_t - B_1 - B_2 t)\}$ are independently distributed (p-value=0.978). As described in the next section, this model can be used to obtain draws from the current and future price distributions for the purposes of the CISA analyses.

Farm-level yield models are also estimated using the previously described procedures, assuming that there is no autocorrelation. The data in this case is obtained from the University of Illinois Endowment Farms project. Specifically, their ten farms with the largest sample sizes (40 to 45 years) are selected for inclusion in the analyses. The maximum-likelihood parameter estimates and related statistics for these 10 yield distribution models are presented in table 3.

[Insert Table 3 about Here]

First note that all yields are increasing over time, with the rate of increase averaging about 1.4 bushels/acre per year. The predicted yields for 2011, presented in the first row of the table, average a little over 170 bushels/acre versus about 115 bushels/acre in the early 1970's. The standard deviation parameters of the yield distributions range from 18 to 30 bushels/acre and, as with prices, the White tests statistics (also reported in table 3) suggest that yield variability has generally remained constant over the last 40 years. The null hypothesis of yield normality is strongly rejected (p-value<0.025) in four cases, rejected (p-value<0.10) in two cases, and cannot be rejected in the remaining four. In contrast to prices, the prevailing negativity in the B_5 estimates suggests that the yield distributions tend to be left-skewed. Two of the non-rejection instances might be explained by the fact that, in both cases, observations were missing for the year 1983 which was characterized by extremely low yields in most other farms. In the other two, it appears that somehow farmers managed to avoid an extremely low yield event during the observation period, which is needed to trigger rejection.

Price and Yield Simulation

The process of simulating draws from an estimated IHS pdf is simplified by the fact that the IHS random variable is actually defined as a function of a normal (Ramirez, 1997). Specifically, if Z_t is a standard normal, then:

$$(7)\ IHS_t = mean_t\{sig\big(sinh\big(\theta(Z_t + \mu)\big) - F\big)/\big(\theta J^{1/2}\big)\},$$

where F and J are as defined in equation (3) and, in reference to the models in the previous section, $mean_t = B_1 + B_2 t$, $sig = B_3$, $\theta = B_4$, and $\mu = B_5$. Thus, once an IHS distribution model parameters have been estimated, random draws from the implied distribution can be easily obtained on the basis of standard normal draws. In addition, contemporaneously correlated draws from several (S) IHS variables can be generated by simply correlating the (1 by S) Z_t vectors used to generate them by the Cholesky decomposition of the desired (S by S) correlation matrix (Ramirez, 1997). Finally, when the estimated IHS model involves autocorrelation, any T draws can be made to follow that process by multiplying a (T by 1) vector of IHS errors ($\{IHS_t - mean_t\} = \{sig\big(sinh\big(\theta(Z_t + \mu)\big) - F\big)/\big(\theta J^{1/2}\big)\}$; t=1,…,T) by the Cholesky decomposition of the appropriate correlation matrix $\Psi = (\mathrm{P}'\mathrm{P})^{-1}$ and then adding back the systematic component of the model ($mean_t$).

The above procedures are used in conjunction with the estimated model parameters to simulate random realizations of prices and yields to be experienced by NF=10,000 hypothetical corn farms in the State of Illinois. It is assumed that the population of 10,000 farms is equally divided into 10 groups, each of which is characterized by one of the 10 yield distributions models detailed in table 3 (six non-normal and four normal). Forty-five future years of random yields are simulated for each farm assuming correlations of 0.65 across all yield distributions. In addition, 40 years of future state-wide price realizations are simulated assuming correlations of -0.45 with each of the 10,000 sets of yield draws. The 0.65 yield-yield correlation is selected on the basis of the average of the 45 sample correlation coefficients observed across the 10 farm-level yield series underlying the analyses. The -0.45 yield-price correlation is based on the average of the 10 sample correlation coefficients observed between the 10 yield series and the state-wide price data during the period those yields were observed.

CISA Performance Analysis

This section assesses the potential performance of the proposed CISA system for the particular case of corn producers in the State of Illinois, with a focus on three key measures: (1) The proportion of farmers who require loans from the government at some point in time ($B_t < 0$), (2) the proportion of farmers who have a negative terminal balance ($B_T < 0$), and (3) the cost of the program to the government. In each simulation the periodic revenue of a population of 10,000 farmers over 45 years is generated using the draws from the yield and price simulation algorithm described in the previous section. We begin our analysis by considering a simple scheme where it is assumed that the annual CISA contribution by each farmer is a fraction (α) of his/her average revenue over the previous five years. In the next section we will consider a more sophisticated contribution scheme with several distinct advantages over this simple specification. Similarly, we assume that the revenue guarantee (R_t^g) is a fraction (γ) of the farmer's average revenue over the past five years. Hence, the periodic balance a farmer's CISA (individual subscripts omitted) is given by:

(7) $$B_t = (1 + r)B_{t-1} + \alpha\overline{R}_t - max(0, \gamma\overline{R}_t - R_t);\ t = 6, \ldots, 45.$$

where $\overline{R}_t = \frac{1}{5}\sum_{t-5}^{t-1} R_t$ denotes a five year moving average of farm revenue. While in practice it may be beneficial to allow farmers to build up an initial balance in their CISA account before transitioning from a traditional crop insurance program to a CISA system[5], we do not in our simulations (i.e., we assume that the balance at t=5 is zero) in order to deliver a fair assessment of the cost of CISAs to the government and farmers. This absence of a buildup period, as we will elaborate on later, has a number of implications.

Simulations under Baseline Parameters

Using the estimated model parameters and procedures for simulating future yields and prices discussed in the previous section, table 4 presents summary statistics for the performance of the CISA system over a range of contribution rates and revenue guarantees. All numbers presented are averages over 100,000 simulated populations of 10,000 farmers each. We consider contribution rates of 3%, 5%, and 7% and revenue guarantees of 65%, 75%, and 85% of the farmers' past five year revenue moving averages. The CISA borrowing and saving interest rate is assumed to be a constant 3%. In terms of performance measures we focus on (1) the percentage

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[5] For example, some employers provide employees with seed money to build up new health savings accounts.

of farmers that ever experience a negative CISA balance in at least one year over the 40 years of operation, (2) the percentage of farmers that have a negative terminal CISA balance after 40 years, and (3) the average terminal CISA balance of farmers.

[Insert Table 4 about Here]

As expected, the performance of the CISA system varies substantially across different contribution rates and revenue guarantees (table 4). For the most logical combinations of contribution rates and revenue guarantees (3% & 65%, 5% & 75%, and 7% and 85%), the percentage of individuals who ever have a negative account balance over the 40 year time horizon is relatively low. For example, at a 5% contribution rate and a 75% revenue guarantee, across the 100,000 simulations on average only 18.82% of farmers experience a negative CISA balance and require a loan from the government in at least one year.

As discussed earlier, the most critical factor for the viability of the proposed CISA system when farmer participation is voluntary and negative end-balances are to be repaid to the government is the percentage of farmers that would expect to reach retirement with a negative account balance, as this might be a disincentive to participate. For the lower contribution rate (3%) and revenue guarantee (65%), the simulation results are tremendously positive on this metric: on average, only 0.84% of the farmers end with a negative account balance after 40 years of operation. The average terminal CISA balance for all farmers is $1208.61 per farmer per acre, and the average terminal balance for the 0.84% of farmers retiring with a negative balance is just -$199.32 per acre, which could be easily managed given land values in the Midwest. In addition, note that if higher percentage contributions are required from farmers who desire higher revenue guarantees (i.e. one has to pay 5% for 75% coverage and 7% for 85% coverage), the terminal balance statistics are similarly favorable. Also note that these results are obtained without assuming a build-up period prior to initiating the CISA system and do not account for the reduction in the amount of yield and price risk that farmers are willing to take if self-insurance is their only protection against that risk.

Capped Balances with Catch-up Contributions

While the results presented in table 4 suggest that by saving a small percentage of their annual average revenue farmers can self-insure against unacceptable revenue losses with a very low default rate, there are two drawbacks of this simple design. First, by having a constant contribution rate over time regardless of whether a farmer has a large or small positive or negative balance in his/her CISA, there is no differentiation of contribution rates among farmers who at any given time are at a higher or lower risk of ending up with a negative balance. This inevitably results in some farmers building up substantial positive account balances far in excess of what is required to insure against statistically remote deficits. As well, farmers who suffer unusually severe or frequent crop losses and thus accumulate large negative balances, but only replenish their account at a constant rate, α, are at a much higher risk of having to retire owing money to the government.

Given these undesirable consequences of the constant contribution rate scheme, we propose an alternative design that strives to achieve three objectives: (1) minimize the periodical contribution rate (given the desired coverage level) for farmers who are carrying adequate balances in their accounts, (2) prevent the buildup of balances in excess what is needed to provide sufficient funds in the event of catastrophic losses, and (3) more rapidly replenish accounts that are in a deficit to minimize the percentage of farmers ending up with negative terminal balances.

Specifically, we propose the following improvements to our original design. Letting $I\{\cdot\}$ denote an indicator function that equals 1 if it is true and 0 otherwise, when farmers reach or exceed an account balance cap of θ percent of their average revenue (i.e. when $I\{(1+r)B_{t-1} < \theta\overline{\mathrm{R}}_{\mathrm{t}}\} = 0$) they are not permitted to contribute to their CISA in that year. Alternatively, farmers with balances below the cap ($I\{(1+r)B_{t-1} < \theta\overline{\mathrm{R}}_{\mathrm{t}}\} = 1$) continue to contribute at a constant annual rate (α) up until they reach it. Algebraically, this contribution is expressed as $min(\alpha\overline{\mathrm{R}}_{\mathrm{t}}, \max(0, \theta\overline{\mathrm{R}}_{\mathrm{t}} - (1+r)B_{t-1}))$.[6] For farmers with negative balances, we institute "catch-up" payments in addition to their regular contribution, but these are only triggered in years when revenue is above their historical average (i.e., when $I\{(1+r)B_{t-1} < 0\} * I\{R_t > \overline{\mathrm{R}}_{\mathrm{t}}\} = 1$). This contribution is equal to the lesser of either their outstanding loan balance, or the current period revenue in excess of their moving average (i.e. $min(|(1+r)B_{t-1}|, R_t - \overline{\mathrm{R}}_{\mathrm{t}})$). Formally, the evolution of account balances under this specification of a regular contribution (if account balances are below the balance cap) and additional catch-up payments (if balances are less than zero and revenue in that year is above average) can be expressed as:

(8) $$B_t = (1+r)B_{t-1} + I\{(1+r)B_{t-1} < \theta\overline{\mathrm{R}}_{\mathrm{t}}\} * min(\alpha\overline{\mathrm{R}}_{\mathrm{t}}, \max(\theta\overline{\mathrm{R}}_{\mathrm{t}} - (1+r)B_{t-1}, 0)) + I\{(1+r)B_{t-1} < 0\} * I\{R_t > \overline{\mathrm{R}}_{\mathrm{t}}\} * min(|(1+r)B_{t-1}|, R_t - \overline{\mathrm{R}}_{\mathrm{t}}) - max(0, \gamma\overline{\mathrm{R}}_{\mathrm{t}} - \mathrm{R}_{\mathrm{t}}).$$

Table 5 presents simulation results of the CISA performance under the above described contribution scheme with capped balances and catch-up contributions. The simulations are

[6] It is also specified that farmers with balances that grow above their cap due to either interest accumulation or a decrease in their cap from a fall in their 5-year moving average of revenue are not permitted to withdraw funds from their account.

conducted for regular contributions of 1.5%, 3.0%, and 6.0%, revenue guarantees of 65%, 75%, and 85%, and caps of 65%, 75%, and 85% (i.e., $\theta = \gamma$), respectively. The rationale for letting $\theta = \gamma$ is that this allows farmers to build up account balances to a level where they can fully cover a CISA withdrawal in a catastrophic year with 100% crop losses.

As evidenced in table 5, very favorable ending balances are obtained under this design despite the lower annual contribution rates. Across the three revenue guarantee levels (65%, 75%, and 85%), just 0.50%, 0.91%, and 1.03% of farmers are expected to have a negative terminal CISA balance. Due to the inclusion of a contribution cap, the average ending account balances of \$434.14, \$511.30, and \$510.72 per acre are substantially lower than under the previous scheme (table 4). In addition, for the very small percentage of farmers that are expected to retire with a deficit, their outstanding loan balance is small (-\$96.36, -\$118.32, and -\$166.58 per acre) relative to the value of land in the Midwest.

Because of the cap provision, the actual contributions as a percentage of past revenue required under this more sophisticated scheme average just 1.41%, 2.53% and 4.55%, respectively, and the corresponding per acre contributions are \$8.42, \$15.04 and \$27.11 per year. As a point of reference, the 2007-2011 average crop insurance premiums paid by grain corn farmers (crop code 0041) purchasing revenue insurance products in the State of Illinois for the same (65%, 75% and 85%) coverage levels, were \$10.82, \$15.43 and \$29.27 per acre[7]. As noted in table 5, these modest contribution levels are enough to ensure revenue loss protection against

[7] This was obtained by dividing the total premium amount paid by farmers by the number of acres insured at each of the three coverage levels. The selected product is Crop Revenue Coverage (CRC) for 2007-2010 and Revenue Protection (RP) for 2011. From 2007 to 2010, CRC was the top selling revenue insurance plan. Since 2011, CRC and three other revenue-based plans were discontinued and combined into a single uniform RP policy.

events (i.e. withdrawals) that on average occur 2.72, 6.15 and 11.35 times out of 40 years (i.e. 6.8, 15.4 and 28.4 out of 100 years), respectively.

[Insert Table 5 about Here]

Distribution of Outcomes under the CISA System

While the statistics presented in table 5 offer a promising projection on the potential of CISAs to deliver an effective self-insurance system in the case of Illinois corn farmers, it is critical to look beyond average performance and understand the distribution of potential outcomes. In this section we discuss a series of figures illustrating the distribution of the statistics presented in table 5 for a CISA system with capped balances and catch-up contributions.

Figure 1 presents, over the range of contribution rates and revenue guarantee levels, a breakdown of the 100,000 simulation outcomes as a function of the percentage of farmers that ever experience a negative CISA balance. As can be seen, for a significant percentage of the simulations a sizable percentage of farmers at some point will require a loan from the government due to a negative account balance. For example, at the 65% coverage level, in over 20% of the simulations (i.e. there is a greater than 20% probability that) none of the 10,000 farmers will ever need a loan. Alternatively, at the 85% coverage level, in over 15% of the simulations 100% of the farmers will at some point need a loan. Given the absence of an account buildup period before relying on the CISA as the sole source of insurance, this is to be expected. Including a small buildup period would substantially shift the mass of the distribution in Figure 1 to the left. In regard to the more relevant terminal balance statistic, however, as illustrated in figure 2, over a farming lifetime virtually all simulations result in a very low percentage of farmers ending with an account deficit. That is, regardless of the selected coverage level, it is highly unlikely that if CISA was implemented for Illinois corn farmers more than 5% of them would end up with a negative balance.

[Insert Figure 1 about Here]

[Insert Figure 2 about Here]

Figure 3 presents the distribution of the average terminal CISA account balances across the 100,000 simulations. Note that the probability of the average balance for the 10,000 hypothetical farmers ending up being negative is negligible. This suggests that if the government chose to forgive the negative account balances of farmers reaching retirement, even in the event of an extremely unlikely outcome, the cost to the government would be relatively small. From table 5, the expected average cost per acre is $0.48 (0.50% of $96.36), $1.08 (0.91% of $118.32), and $1.72 (1.03% of $166.58), for the 65%, 75%, and 85% coverage levels respectively. So, for example, if farmers were "retiring" 2.3 million acres of corn per year (1/40th of the total number of acres planted in the U.S. in 2011), even at the 85% coverage level, the expected loss in loan re-payments to the government would be less than $4 million/year.

[Insert Figure 3 about Here]

Sensitivity Analysis

Given the robustness of the datasets and the methods used to estimate the price and yield distributions underpinning the previous analyses, we feel fairly confident of the results for the 10 particular farms being considered. However, it is possible that the performance of the proposed CISA system might not be as strong for farms that are exposed to a substantially higher revenue risk. Considering this possibility, we focus our sensitivity analysis on a scenario where the both price and yield volatility are markedly higher. Specifically, the standard deviation of the price distribution is increased by 25% and the standard deviations of the yield distributions are increased by 50%. In all cases, these increases are the equivalent of adding more than two standard errors to the models' original parameter estimates. Under these extreme assumptions, the average of the standard deviations of the 10 yield distributions stands at 36 bushels per acre.

Table 6 presents summary statistics for the performance of the CISA system under such "worse-case" scenario. Note that, in order to maintain the percentage of farmers ending up with a negative terminal balance under 2%, the prescribed contributions for the 65%, 75% and 85% coverage levels had to be increased to 2.5%, 5% and 9% of past average revenue. However, thanks to the cap provision, actual contributions as a percentage of past revenue required under this more sophisticated scheme are just 2.43%, 4.14% and 6.91%, respectively, and the corresponding annual contributions are \$11.39, \$22.55 and \$40.25 per acre. Although under this extremely pessimistic scenario the necessary contributions would be higher that what Illinois farmers are currently paying for crop insurance (\$10.82, \$15.43 and \$29.27 per acre), note that on average they would benefit from substantial residual balances (\$398.53, \$443.10 and \$443.03 per acre) at the end of the coverage period.

A final observation is that high annual percentage contributions are only required when coverage for events that occur very frequently is desired, which is not really the objective of having insurance. For example, under the scenario where the estimated level of price and yield variability is assumed (table 5), an average annual contribution of \$15.04 per acre is needed for 75% coverage, which protects farmers from low revenue events that occur 6.15 out of every 40 years. In contrast, under the increased price and yield volatility scenario (table 6), the 65% coverage level requires slightly lower annual contributions of \$14.29 per acre and ensures farmers against adverse revenue events that take place 5.08 out of 40 years. So, if the objective is to protect farmers from infrequent losses (e.g. those that occur 5 or 6 out of 40 years), it appears that the contribution level is not much affected by how volatile revenues (i.e. prices and yields) are. This suggests that as long as coverage levels are reasonably defined in terms of the frequency of loss they are designed to protect (e.g. 5, 10 and 15 out of 100 years) the proposed CISA system should provide effective coverage at affordable annual contributions regardless of how volatile a crop's revenues are.

Concluding Remarks

Overall, the results offer a promising outlook on the viability of the proposed CISA system provided that revenue guarantee levels and contribution rates can be appropriately matched to ensure that only a small percentage of the CISA accounts end up with a negative terminal balance and that the farmers can afford the necessary contribution levels. Since, as proposed, CISA's cost should be a very small fraction of what the government is currently spending subsidizing the crop insurance apparatus, more favorable terms (such as matching or allowing for an initial buildup period) could be consider in cases when the required contribution levels seem unaffordable.

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Table 1. Government Cost for Federal Crop Insurance, 2002-2011 (Dollars in millions)

Fiscal Year	Indemnity	Underwriting Losses or (Gains) [a]	Premium Subsidy	Private Company A&O[b] expense reimbursements	Other costs	Total costs
2002	4,114	1,182	1,513	656	115	3,466
2003	3,768	822	1,874	743	149	3,588
2004	2,828	(305)	2,387	900	143	3,125
2005	2,796	(293)	2,070	783	139	2,699
2006	3,585	(32)	2,517	960	125	3,570
2007	3,493	(1,068)	3,544	1,341	123	3,940
2008	5,024	(1,717)	5,301	2,016	137	5,737
2009	8,416	108	5,198	1,602	131	7,039
2010	2,759	(2,523)	4,680	1,371	143	3,671
2011	13,429	2,392	7,376	1,383	144	11,295
Total	50,212	(1,434)	36,460	11,755	1,349	48,130

a. Program underwriting loss (gain if negative) is the amount of claims paid in excess of premium collected and other income.
b. A&O: Administrative and operating

Source: U.S. Department of Agriculture, Risk Management Agent.

Table 2. Maximum-Likelihood Parameter Estimates and Related Statistics for the Non-Normal Price Distribution Model

	P.E.	S.E.E	T.V.	P.V
B_1	6.3412	0.2144	29.5815	0.0000
B_2	-0.0322	0.0052	6.2110	0.0000
B_3	0.6179	0.0745	8.2948	0.0000
B_4	0.3229	NA*	NA*	0.0106
B_5	20.0914	NA*	NA*	0.0106
B_6	0.7605	0.1091	6.9694	0.0000
B_7	-0.3974	0.1228	3.2354	0.0010

Notes: P.E., S.E.E, T.V., and P.V. stand for parameter estimate, standard error estimate, t-value and p-value respectively. The significance (p-value) of the non-normality parameters (B_4 and B_5) is ascertained through a likelihood ratio test. B_6 and B_7 are the first- and second-order autoregressive parameters.

Table 3. Maximum-Likelihood Parameter Estimates of Yield Distribution Model

	Farm 1		Farm 2		Farm 3		Farm 4		Farm 5	
	N	**NN**	**N**	**NN**	**N**	**NN**	**N**	**NN**	**N**	**NN**
Mean	182.39	193.58	162.14	161.47	179.00	183.10	174.77	173.44	163.47	163.47
B1	100.69	92.60	85.39	84.98	93.38	89.89	88.06	89.57	99.78	99.78
B2	1.542	1.905	1.448	1.443	1.616	1.759	1.636	1.583	1.202	1.201
B3	20.926	21.236	18.005	20.931	22.695	23.477	18.327	25.820	20.301	20.301
B4	0.000	0.914	0.000	0.808	0.000	0.722	0.000	1.258	0.000	0.000
B5	0.000	-0.436	0.000	-0.683	0.000	-0.787	0.000	-0.041	0.000	0.000
Skew	0.000	-2.405	0.000	-2.251	0.000	-1.808	0.000	-1.147	0.000	0.000
Kurt	0.000	28.144	0.000	17.222	0.000	10.416	0.000	306.377	0.000	0.000
White	2.318	2.227	3.741	3.801	2.635	2.456	2.228	2.409	4.831	4.831
-2MV	392.48	375.48	379.24	377.05	390.53	381.57	372.15	363.85	398.67	398.67
LRTS		16.994		2.191		8.965		8.297		0.000
	Farm 6		**Farm 7**		**Farm 8**		**Farm 9**		**Farm 10**	
	N	**NN**	**N**	**NN**	**N**	**NN**	**N**	**NN**	**N**	**NN**
Mean	168.15	181.43	165.97	169.30	186.07	188.71	165.95	171.69	136.04	140.88
B1	114.63	103.19	89.29	86.20	121.66	118.99	128.67	123.16	84.49	80.77
B2	1.010	1.474	1.447	1.568	1.215	1.315	0.704	0.916	0.973	1.134
B3	25.492	27.087	27.705	29.943	21.424	23.122	24.481	26.618	25.454	25.717
B4	0.000	0.418	0.000	0.735	0.000	0.518	0.000	0.725	0.001	0.273
B5	0.000	-15.000	0.000	-0.775	0.000	-9.451	0.000	-0.723	0.000	-15.000
Skew	0.000	-1.394	0.000	-1.876	0.000	-1.832	0.000	-1.717	0.000	-0.856
Kurt	0.000	3.642	0.000	11.257	0.000	6.509	0.000	10.002	0.000	1.330
White	4.846	4.166	2.579	2.252	4.539	4.558	1.494	1.642	3.290	3.493
-2MV	391.21	385.31	398.21	392.61	358.68	348.59	369.35	365.73	409.71	405.69
LRTS		5.907		5.598		10.089		3.621		4.024

Notes: N and NN stand for normal and non-normal model, respectively. Skew and Kurt are the standard measures of kurtosis and skewness. White is the White test statistic which, under the null hypothesis of homoscedasticity, is distributed as a $\chi^2_{(2)}$ random variable. -2MV is minus two times the maximum value of the log likelihood function and LRTS is the resulting likelihood ratio test statistic which, under the null hypothesis of normality, is also distributed as a $\chi^2_{(2)}$ random variable.

Table 4. Performance of CISA (100,000 Simulations)

	$\alpha = 3\%$ $\gamma = 65\%$	$\alpha = 3\%$ $\gamma = 75\%$	$\alpha = 3\%$ $\gamma = 85\%$	$\alpha = 5\%$ $\gamma = 65\%$	$\alpha = 5\%$ $\gamma = 75\%$	$\alpha = 5\%$ $\gamma = 85\%$	$\alpha = 7\%$ $\gamma = 65\%$	$\alpha = 7\%$ $\gamma = 75\%$	$\alpha = 7\%$ $\gamma = 85\%$
All Farmers									
% Ever have a Negative CISA Balance	11.29%	36.92%	86.43%	5.94%	18.82%	55.84%	3.73%	11.61%	35.04%
% End with Negative CISA Balance	0.84%	11.90%	73.46%	0.02%	0.85%	23.15%	0.00%	0.05%	3.46%
Ave. Terminal CISA Balance (per acre)	$1208.61	$641.61	$-512.63	$2237.53	$1669.09	$515.48	$3267.49	$2699.87	$1546.62
Ave. Annual CISA Contribution	$18.03	$18.03	$18.03	$30.06	$30.05	$30.06	$42.08	$42.08	$42.08
Ave. Annual CISA Withdraw (per acre)	$4.30	$11.34	$25.26	$4.32	$11.36	$25.28	$4.30	$11.34	$25.26
Ave. # of Withdraws from CISA	2.72	6.14	11.35	2.73	6.15	11.35	2.72	6.14	11.35
Farmers with Positive Terminal CISA Balance									
% Ever have a Negative CISA Balance	10.81%	32.65%	64.47%	5.93%	18.51%	49.91%	3.73%	11.60%	34.24%
Ave. Terminal CISA Balance (per acre)	$1217.03	$725.25	$200.67	$2237.87	$1677.47	$708.95	$3267.51	$2700.50	$1578.21
Farmers with Negative Terminal CISA Balance									
Ave. Terminal CISA Balance (per acre)	$-199.32	$-253.76	$-684.75	$-278.82	$-243.21	$-325.57	$-791.36	$-358.82	$-268.03

Table 5. Performance of CISA with Capped Balances and Catch-up Contributions

	$\alpha = 1.5\%$ $\gamma = 65\%$ $\theta = 65\%$	$\alpha = 3.0\%$ $\gamma = 75\%$ $\theta = 75\%$	$\alpha = 6.0\%$ $\gamma = 85\%$ $\theta = 85\%$
All Farmers			
% Ever have a Negative CISA Balance	25.37%	37.53%	45.86%
% End with Negative CISA Balance	0.50%	0.91%	1.03%
Ave. Terminal CISA Balance	$434.14	$511.30	$510.72
Ave. Annual CISA Contribution (per acre)	$8.42	$15.04	$27.11
% of Revenue Contributed to CISA	1.41%	2.53%	4.55%
Ave. Annual CISA Withdraw (per acre)	$4.31	$11.35	$25.28
Ave. # of Withdraws from CISA (per acre)	2.72	6.15	11.35
Farmers with Positive Terminal CISA Balance			
% Ever have a Negative CISA Balance	25.16%	37.30%	45.67%
Ave. Terminal CISA Balance (per acre)	$435.26	$513.55	$513.26
Farmers with Negative Terminal CISA Balance			
Ave. Terminal CISA Balance (per acre)	$-96.36	$-118.32	$-166.58

Table 6. Sensitivity Analysis (50% Increase in Yield Stdev. and 25% Increase in Price Stdev.) of CISA with Capped Balances and Catch-up Contributions

	$\alpha = 2.5\%$ $\gamma = 65\%$ $\theta = 65\%$	$\alpha = 5.0\%$ $\gamma = 75\%$ $\theta = 75\%$	$\alpha = 9.0\%$ $\gamma = 85\%$ $\theta = 85\%$
All Farmers			
% Ever have a Negative CISA Balance	48.01%	53.36%	58.20%
% End with Negative CISA Balance	1.93%	1.98%	1.97%
Ave. Terminal CISA Balance	$398.53	$443.10	$443.03
Ave. Annual CISA Contribution (per acre)	$14.29	$24.37	$40.68
% of Revenue Contributed to CISA	2.43%	4.14%	6.91%
Ave. Annual CISA Withdraw (per acre)	$11.39	$22.55	$40.25
Ave. # of Withdraws from CISA (per acre)	5.08	8.74	13.32
Farmers with Positive Terminal CISA Balance			
% Ever have a Negative CISA Balance	47.44%	52.97%	57.90%
Ave. Terminal CISA Balance (per acre)	$403.75	$448.98	$448.94
Farmers with Negative Terminal CISA Balance			
Ave. Terminal CISA Balance (per acre)	$-98.33	$-130.98	$-168.05

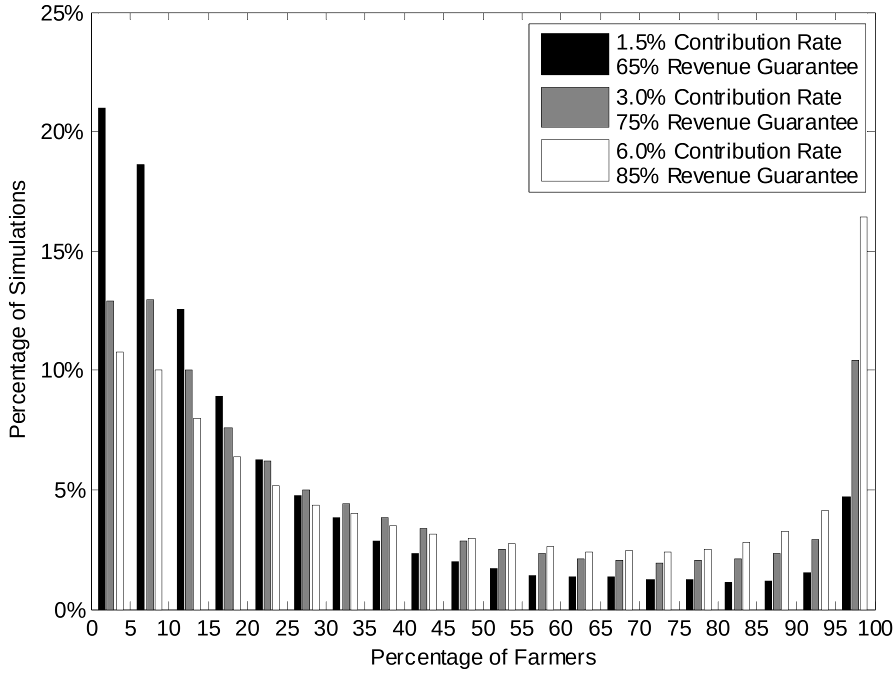

Figure 1. Percentage of Farmers Ever with a Negative CISA Balance

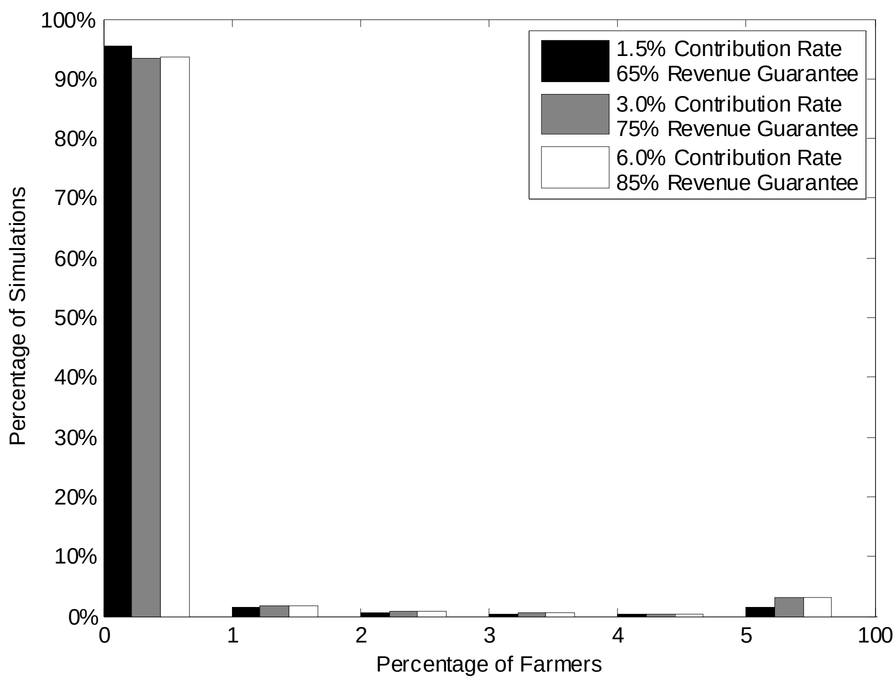

Figure 2. Percentage of Farmers with a Negative Terminal CISA Balance

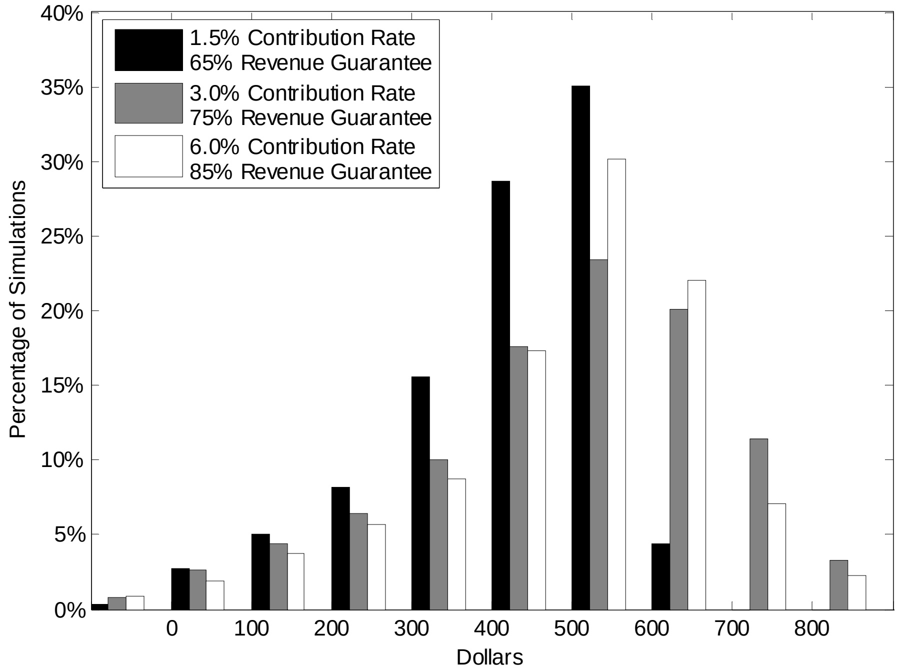

Figure 3. Average CISA Terminal Balance per farmer per acre