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Crop Insurance Savings Accounts: A Viable Alternative to Crop Insurance?

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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. Agricultural production and prices are highly volatile and 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, it is difficult for both the insurer and the producer to accurately assess the level of yield and revenue risk associated with a particular farm operation. 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 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 the total plantings for each of the four major US field crops (corn, cotton, soybeans and wheat) accounting for over 190 million acres were insured by farmers. To achieve these high levels of participation, on average, the government had to subsidize about 50% of the effective premiums at a cost of $36.5 billion during the last ten years. In addition, the government paid nearly $12 billion on administrative and operating (A&O) expenses to the private companies in charge of implementing the program (table 1). For fiscal year 2011, the premium subsidy surged to $7.4 billion plus another $1.4 billion in A&O costs, and it is estimated that subsidy levels in excess of $15 billion will be needed for 2012.

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 (table 1). Given the pressing need to bring the Federal budget deficit under control over the next decade, it is important to explore the viability of less costly alternatives to help farmers manage their yield and revenue risks.

A second unresolved issue that has affected the US crop insurance program for many years has been complaints from farmers, producer organizations and legislators about the rating structure not being fair across crops, cropping systems, and geographical regions. This could also be a result of the insurer's inability to accurately determine what the actuarially correct rates are in each particular situation and the producers themselves not being able to ascertain what they should be paying. Nevertheless, there is discontent about the program supposedly delivering substantial benefits to some participating producers while being ineffective in providing a safety net for others. This debate was exacerbated during the recent Farm Bill negotiations where direct payments are supposed to be replaced by expanding the role and breadth of Crop Insurance.

A less discussed but equally important issue is how the subsidies to the Crop Insurance program are distributed across individual producers. As detailed in Appendix I (to be posted on-line only for interested readers to access), if the producer and/or the insurer are not certain about what the actuarially fair premium is, due to random error on what they perceive or estimate it to be, some will receive more generous subsidies than others. For example, assuming an average premium estimation error of just ±25% and that the government pays for 50% of the effective premium, there is a 15% probability that the subsidized premium paid by the producer is 33% or less of what is actuarially fair and a 15% probability that it is 66% or more of what is actuarially fair. That is, just by chance, it is not unlikely that a producer will receive less than half as much premium payment support from the government as another "identical" operator. Since both face the same yield and revenue risk, this is clearly not an optimal safety net scheme.

In short, given (1) anticipated Federal budget constraints to fund the expansion of Crop Insurance that would be needed to make it effective as the sole source of government income support for all agricultural producers, (2) concerns about whether an expansion of this program as currently structured would meet the risk management needs of all US producers, and (3) the random variations in the allocation of the available Federal support funds due to premium estimation inaccuracies at the farm, county, state and regional levels, it is perhaps time to reconsider alternatives that could provide a reliable and more equitable safety net for at least some agricultural producers at a much lower cost to the government.

The goal of this research is thus to explore the potential viability of a different insurance design that could be an effective risk management tool for many farmers and operate without major government subsidization. Specifically, we formally consider one of the more controversial approaches that has in various forms been discussed 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 explores 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) (Feldstein and Altman 1998), is designed to closely mimic current revenue insurance policies that are now so familiar to farmers, but using a personal savings account approach. The system would enable producers 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 would lend money to the account to cover the indemnity. The proposed design should exhibit minimal moral hazard and adverse selection problems. As well, under the CISA system, farm-level risk would no longer have to be priced, thus eliminating the premium rating difficulties that weaken actuarial soundness and trigger the need for substantial external subsidies. In addition, administrative costs should be relatively small.

CISA Program Design

In this section we formalize the basic framework of our proposed crop insurance savings account system. The design and language of the CISA system we present is analogous in many ways 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 account that earns an interest rate r. We denote the contribution made to a farmer's CISA in period t as $\alpha\overline{R}_t$ where $\overline{R}_t$ is some average of past revenue levels, R_t (e.g., a simple average of the previous five years of revenue), and $\alpha \in [0,1]$ is the proportion of $\overline{R}_t$ contributed to the 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 pre-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) $$B_t = (1+r)B_{t-1} + \alpha\overline{R}_t - max(0, \mathrm{R_t^g} - \mathrm{R_t})$$

(2) $$\pi_t = (1-\tau)[R_t + max(0, \mathrm{R_t^g} - \mathrm{R_t}) - \alpha\overline{R}_t - C_t],$$

where τ is the tax rate and C_t are farm production costs.

To improve upon the contribution scheme presented in equation (1) while maintaining the simplicity and desirable properties of the proposed design, we augment the CISA system with two additional features: capped account balances and catch-up contributions. These additional design elements are included to achieve three primary 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 of 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 who end up with negative terminal balances.

Specifically, in order to prevent some farmers from building up positive account balances in excess of what is needed to insure against statistically likely losses, we impose an upper cap on CISA balances (e.g., 65% of a farmer's 5-year revenue moving average). Once an account reaches this level, no new contributions are permitted until the balance falls below the cap. Additionally, our policy design includes catch-up contributions for individuals with a negative CISA balance. That is, farmers who have a negative balance, and hence have borrowed money from the government, are required to temporarily contribute a higher percentage of their revenue than the pre-specified rate (α). For example, if the contribution rate for a particular guarantee level is set at 3% of past average revenue, individuals with a negative CISA balance would have to contribute an additional share of their future revenues on top of the 3% until they reach a positive balance. In order to ensure that farmers are not unduly burdened by these extraordinary contributions, the catch-up payments only have to be made in years when the actual revenue exceeds their past 5-year moving average. When combined, these two (upper cap and catch-up) features help steer the periodical inflows to the accounts towards what is needed to sustain the selected revenue guarantee level. In other words, they help keep the system actuarially sound even if the pre-specified contribution rate (α) turns out to be too high or two low.

Formally, we propose the following CISA design with capped balances and catch-up contributions. 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 $\overline{B}$ (i.e. when $I\{(1+r)B_{t-1} < \overline{B}\} = 0$) they are not permitted to contribute to their CISA in that year. Alternatively, farmers with balances below the cap ($I\{(1+r)B_{t-1} < \overline{B}\} = 1$) continue to contribute at a constant annual rate α until they reach the cap. Algebraically, this contribution scheme is expressed as $min\left(\alpha\overline{\mathrm{R}}_{\mathrm{t}}, max\,(0, \overline{B} - (1+r)B_{t-1})\right)$. On the other hand, the catch-up payments are only triggered in years when the account has a negative balance and revenue is above the historical average (i.e., when $I\{(1+r)B_{t-1} < 0\} * I\{R_t > \overline{\mathrm{R}}_{\mathrm{t}}\} = 1$). This additional contribution is equal to the lesser of either the outstanding loan balance or the current period revenue in excess of the 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 ($\alpha\overline{R}_t$) if the balance is below the cap and additional catch-up payments if balances are less than zero and revenue in that year is above average, can be expressed as:

(3) $$B_t = (1+r)B_{t-1} + I\{(1+r)B_{t-1} < \overline{B}\} * min\left(\alpha\overline{\mathrm{R}}_{\mathrm{t}}, \max\,(\overline{B} - (1+r)B_{t-1}, 0)\right) + I\{(1+r)B_{t-1} < 0\} * I\{R_t > \overline{\mathrm{R}}_{\mathrm{t}}\} * min(|(1+r)B_{t-1}|, R_t - \overline{\mathrm{R}}_{\mathrm{t}}) - max\left(0, \mathrm{R}_{\mathrm{t}}^{\mathrm{g}} - \mathrm{R}_{\mathrm{t}}\right).$$

To summarize, individuals who have revenues above their pre-specified revenue guarantee withdraw no funds from their account and make the normal contribution as long as they are below the CISA cap threshold. If they have a negative balance, they additionally make a catch-up contribution. Farmers that have revenues below their revenue guarantee make the normal contribution to their CISA and withdraw an indemnity from their account of $\mathrm{R}_{\mathrm{t}}^{\mathrm{g}} - \mathrm{R}_{\mathrm{t}}$ to cover their losses.

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. For farmers who have a positive account balance and expect the account to be positive at retirement, participation in the CISA system does not induce a distortionary effect on risk taking activities (i.e., no moral hazard) because the cost of such activities 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 its own advantages and disadvantages. One alternative is for the government to 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 are more 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 risks. 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 farmers would 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 any moral hazard problems. 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, R_t^g, there is a reasonable CISA contribution rate, α, at which a vast majority of 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, automatic access to low-interest government loans to cover burdensome revenue shortfalls, and final withdrawal benefit, (b) substantially reduce the cost to the government through much lower administrative expenses and eliminating or drastically curtailing the need for direct subsidies, (c) alleviate the concerns about the uneven distribution of the government subsidies that are currently provided to agricultural producers through the crop insurance program, and (d) not distort farmer incentives to take risks (i.e., no moral hazard). While the tax free nature of the CISA contributions results in a loss of government revenue, note that under the existing 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 most or all of their revenue risk protection needs via saving a reasonable proportion of their periodical farm income. Specifically, for a reasonable savings rate similar to what they are currently paying for crop insurance, 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 (UIEF) 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 article are conducted for the specific case of corn producers in the State of Illinois.

The specific methods and procedures utilized to obtain suitable parametric estimates of the price and yield distributions and to jointly simulate draws from those distributions are detailed in Appendix II (to be posted on-line only for interested readers to access). Such methods are used to simulate likely time series of prices and yields to be experienced by NF=10,000 hypothetical corn farms in the State of Illinois. Forty-five future yield realizations are simulated for each farm assuming correlations of 0.65 across all yield distributions. In addition, 45 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 sample correlation coefficients observed across the actual UIEF farm-level yield data records. The -0.45 yield-price correlation is based on the average of the sample correlation coefficients observed between those 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 with capped balances and catch-up contributions 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 Appendix II. In the analysis we assume that the regular annual CISA contribution by each farmer is a fraction (α) of his or her average revenue over the previous five years. 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, this is not done in our simulations, in order to deliver a worse case scenario assessment of the proposed CISA system.

Simulations under Baseline Parameters

Using the estimated model parameters and procedures for simulating future yields and prices discussed in Appendix II, table 2 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 five regular contribution rates (α) equal to 1%, 3%, 5%, 7%, or 9% of a farmer's 5-year revenue moving average as well as three different revenue guarantee rates (γ) that are 65%, 75%, or 85% of that moving average ($\overline{R}_t$). The account caps are then set equal to the revenue guarantee level selected by the producer, i.e. $\overline{B} = \gamma\overline{R}_t$. This allows farmers to build up account balances to a level where they can fully cover a CISA withdrawal in a catastrophic year with a 100% crop loss.

Table 2 presents the simulated analysis of the CISA system across the different contribution rates and revenue guarantees. Several performance statistics are reported for each contribution and revenue guarantee rate combination. *Percent Ever have a Negative CISA Balance* denotes the percentage of farmers that are expected to require a loan from the government at least once during their farming lifetime in order to cover a negative CISA balance. *Percent End with Negative CISA Balance* is the percentage of farmers expected to have a negative terminal CISA balance at the end of their farming career. *Average Terminal CISA Balance* is the expected CISA balance for farmers after 40 years of operation. *Average Annual CISA Contribution* is the per acre average annual contribution to a farmer's CISA. *Percent of Revenue Contributed to CISA* is the effective percentage of revenue per acre contributed on average to a farmer's CISA. Note that the latter may differ from the specified annual contribution rate α due to catch-up contributions and capped CISA balances. *Average Annual CISA Withdraw* and *Average # of Withdraws from CISA* are the expected size of withdraws when they occur and the frequency of withdraws from the CISA over the farming lifetime. Finally, table 2 further breaks down the simulation results into two partitions - the subset of farmers that have a positive terminal CISA balance and those with a negative terminal balance. This facilitates comparing the expected terminal balances for these two categories and assessing the potential liabilities of the government when farmers retire.

As expected, the performance of the CISA system varies substantially across the different contribution and revenue guarantee rate combinations. For high contribution rates and low revenue guarantees very few farmers ever require a loan from the government to cover a withdrawal from their account and virtually none end farming with a negative terminal balance. For example, at a 9% contribution rate with a 65% revenue guarantee, the simulations indicate that only 2.85% of farmers would ever have a negative CISA balance and less than 0.005% would end with a negative balance. In the reverse case of a very low contribution rate of 1% and a high revenue guarantee of 85%, nearly all farmers will at some point need a loan from the government and over half would end with a negative balance.

Focusing on the more reasonable combinations of contribution rates and revenue guarantees (3% & 65%, 5% & 75%, and 7% & 85%) the results of the analysis are quite encouraging for the viability of the CISA system. Across each of these combinations less than 1% of farmers are expected to have a negative terminal account balance (0.09%, 0.23%, and 0.85% for the three cases respectively) and participants on average have positive but moderate account balances upon retirement ($427, $461, and $449 per acre respectively). When accounting for the catch-up payments and the limits imposed by the cap on account balances, the effective contribution rates corresponding to the above contribution and revenue guarantee combinations are 2.32%, 3.62%, and 5.92% of average annual revenue ($13.81, $21.60, and $35.25 per acre). 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 revenue coverage levels, were $10.82, $15.43 and $29.27 per acre. Note that, although the effective crop insurance premiums are heavily subsidized by the government, they are not that much lower than the CISA contributions. In fact, if comparable subsidy levels were to be provided for CISA, the required contributions would decline to \$6.90, \$10.80 and \$17.62. In addition, the previous results were obtained without assuming a build-up period prior to initiating the CISA and do not account for the reduction in the amount of yield and price risk that farmers would be willing to take if self-insurance were their only protection against that risk. Finally, for the small percentage of farmers predicted to end with a negative CISA, the terminal balance that would be owed to the government is relatively small (\$85, \$96, \$96 per acre).

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 validity of the results for a typical Midwestern corn farm. However, it is possible that the performance of the proposed CISA system might not be as appealing for farms that are exposed to a substantially higher revenue risk. To test the system under extreme conditions, we focus our sensitivity analysis on a scenario where 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%.

Table 3 presents summary statistics for the performance of the CISA system under such "worst-case" scenario. As expected, under the greater price and yield standard deviations farmers would need to rely more heavily upon their CISA to provide funds for more frequent and severe crop revenue losses. However, despite the significantly more risky farming environment considered, the CISA system still performs quite well. Under the previously selected combinations of contribution rates and revenue guarantees (3% & 65%, 5% & 75%, and 7% & 85%) we see that while a significant share of individuals on average would require loans from the government at least once during their farming lifetime (48.67%, 61.19%, and 80.34%, respectively), the percentage who would have a negative balance upon retirement is still relatively minor (1.94%, 3.16%, and 7.92%). Under these contribution rates and revenue guarantees, the farmers with a positive account balance upon retirement would on average have per acre savings of $303, $322, and $263 and those with a negative balance would owe the government $72, $82, and $91 per acre respectively.

If the contribution rates in this more volatile agricultural setting were increased, the potential terminal liability for the government could be drastically curtailed. For example, for contribution and revenue guarantee combinations of 5% & 65%, 7% & 75%, and 9% & 85%, the percentage of farmers estimated to end with a negative balance is reduced to 0.41%, 0.97%, and 2.79% respectively, and their average annual contributions would be 3.44%, 5.37%, and 8.26% of annual revenues which translate to $20.28, $31.66, $48.72 per acre. Under these extreme revenue risk assumptions, such contributions are substantially higher than the $10.82, $15.43 and $29.27 per acre average crop insurance premiums paid by grain corn farmers in the State of Illinois at the same revenue coverage levels, however as previously pointed out, the crop insurance premiums are heavily subsidized and under CISA farmers on average would enjoy positive terminal balances of $400.19, $409.96 and $381.15, respectively.

A final important 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 expected (i.e. estimated) price and yield variability scenario (table 2), an average annual contribution of $21.60 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 3), the 65%

coverage level requires a slightly lower contribution of $20.28 per acre and ensures farmers against adverse revenue events that take place 5.08 out of 40 years. In short, if the objective of CISA is to protect farmers from infrequent losses (e.g., those that occur 5 or 6 out of 40 years), it appears that the required 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 or 15 out of 100 years) the proposed CISA system could provide effective coverage at affordable annual contributions regardless of how volatile a crop's revenues are.

Why would CISA be better than Crop Insurance?

A final obvious question is why would CISA be a more effective safety net than the current crop insurance program? The explanation rests on the previous evidence about the impact that premium estimation inaccuracy has on the actuarial performance of crop insurance. Specifically, Ramirez and Carpio (2012) show that, under rational producer behavior, premium estimation inaccuracy can solely explain the substantial subsidies that have been required to keep the program operating. Because of insurer and producer uncertainty about what the actuarially fair premium is, without subsidies, many farmers would feel that they are being overcharged and thus not participate. Under the simplifying assumption that a producer would only purchase coverage if he or she thinks that the premium quoted by the insurer is fair or better, and moderate levels of uncertainty, substantial subsidies are needed to achieve high participation rates. For example, to reach 95% enrollment, all estimated premiums would have to be proportionally subsidized to the extent that they seem favorable to 95% of the producers. To the last producer entering the program, the premium quoted by the insurer might seem just right. Many others would think they are getting a bargain, and in most cases they would be. In fact, the end result of this scheme is that all but the last individual receive subsidies in excess of what is needed to entice participation.

An additional related problem is the resulting distribution of the subsidies across producers. As detailed in Appendix I (to be posted on-line only for interested readers to access), under moderate levels of uncertainty about the actuarially fair premium value, it is quite likely that a producer receives more than twice as much premium payment support from the government as another "identical" operator. For example, assume that the actuarially fair premium is $20/acre but the insurer estimates it at $14/acre for one and $26/acre for the other. At a 50% level of government subsidization, these two farmers would be offered rates of $7/acre and $13/acre, respectively. Because of the high subsidization, both are likely to conclude that this is a good deal and participate in the program. However, although they have an identical risk profile, one would be receiving a subsidy that is nearly twice as high as the other. Alternatively assume that the actuarially fair premium for one producer is $16/acre and $24/acre for the other, but the insurer estimates them both to be $20/acre and offers a subsidized premium rate of $10/acre. Again one would be receiving a subsidy that is more than twice as high as the other.

In contrast, under the proposed CISA, since the producers would own and be paid interest on the contributions they make to their accounts and those contributions are tax-deductible, they are more likely to participate even if the required contribution rate is substantially higher than what they think it should be for the account to end with a positive balance. In addition, the cap feature would prevent the accumulated contributions from becoming excessive relative to what is necessary for self-insurance. On the other hand, if the required contribution rate turns out to lower than what was needed, the catch-up feature would trigger more often and keep the balance from staying negative for too long.

In short, the reason why CISA could work at rates similar to those offered by crop insurance and without external subsidies is that it eliminates the need for unnecessary random "excess" payments to a substantial percentage of the producers. However, there is always the alternative to provide a similar level of subsidy to the account contributions as to Crop Insurance, which would make CISA extremely appealing to most farmers. The cap feature would prevent the total amount of subsidy provided to any particular account from becoming excessive relative to what is necessary for self-insurance and the distribution of the subsidy across producers would likely be much more homogeneous and need-based than under Crop Insurance.

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, the per acre CISA cost should be a fraction of what the government is currently spending subsidizing crop insurance, more favorable terms (such as matched contributions or subsidizing an initial buildup period) could be consider.

In addition, even if some level of matching to the contributions is provided, the lingering concerns and criticisms about unfair rating and the unequal distribution of the crop insurance benefits and subsidies across crops, cropping systems and geographical regions would likely be alleviated. Because of this, it might make sense to at least establish a CISA system as an optional pilot alternative to crop insurance. Finally, although this is not investigated in the study, it is expected that the administrative complexity and burden associated with implementing the proposed CISA system would also be less than that of the crop insurance program. For instance, a model similar to the health and unemployment insurance savings accounts could be followed and annual revenue levels could be easily audited using tax return information.

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

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. Performance of CISA with Capped Balances and Catch-up Contributions (100,000 Simulations)

	$\alpha = 1\%$ $\gamma = 65\%$	$\alpha = 1\%$ $\gamma = 75\%$	$\alpha = 1\%$ $\gamma = 85\%$	$\alpha = 3\%$ $\gamma = 65\%$	$\alpha = 3\%$ $\gamma = 75\%$	$\alpha = 3\%$ $\gamma = 85\%$	$\alpha = 5\%$ $\gamma = 65\%$	$\alpha = 5\%$ $\gamma = 75\%$	$\alpha = 5\%$ $\gamma = 85\%$
All Farmers									
% Ever have a Negative CISA Balance	47.26%	90.16%	99.94%	13.56%	45.77%	92.74%	6.77%	22.66%	66.50%
% End with Negative CISA Balance	3.02%	17.43%	52.63%	0.09%	1.90%	21.76%	0.02%	0.23%	4.78%
Ave. Terminal CISA Balance	$138.67	$27.34	$-82.63	$427.65	$326.55	$58.95	$463.62	$461.32	$301.34
Ave. Annual CISA Contribution (per acre)	$7.39	$11.96	$23.45	$13.81	$18.61	$26.59	$14.61	$21.60	$31.98
% of Revenue Contributed to CISA	1.24%	2.01%	3.94%	2.32%	3.12%	4.47%	2.45%	3.62%	5.37%
Ave. Annual CISA Withdraw (per acre)	$4.31	$11.35	$25.28	$4.31	$11.35	$25.28	$4.31	$11.35	$25.28
Ave. # of Withdraws from CISA (per acre)	2.72	6.15	11.35	2.72	6.15	11.35	2.72	6.15	11.35
Farmers with Positive Terminal CISA Balance									
% Ever have a Negative CISA Balance	46.52%	89.07%	99.87%	13.52%	45.37%	91.74%	6.76%	22.60%	65.89%
Ave. Terminal CISA Balance (per acre)	$142.87	$52.68	$17.21	$427.85	$330.34	$100.89	$463.67	$461.81	$311.48
Farmers with Negative Terminal CISA Balance									
Ave. Terminal CISA Balance (per acre)	$-54.73	$-60.52	$-115.96	$-84.92	$-67.48	$-76.15	$-124.20	$-96.01	$-73.92

	$\alpha = 7\%$ $\gamma = 65\%$	$\alpha = 7\%$ $\gamma = 75\%$	$\alpha = 7\%$ $\gamma = 85\%$	$\alpha = 9\%$ $\gamma = 65\%$	$\alpha = 9\%$ $\gamma = 75\%$	$\alpha = 9\%$ $\gamma = 85\%$
All Farmers						
% Ever have a Negative CISA Balance	4.17%	13.64%	42.61%	2.85%	9.16%	28.66%
% End with Negative CISA Balance	0.01%	0.07%	0.85%	0.00%	0.03%	0.23%
Ave. Terminal CISA Balance	$472.48	$487.88	$448.48	$476.23	$497.98	$495.73
Ave. Annual CISA Contribution (per acre)	$14.81	$22.19	$35.25	$14.89	$22.42	$36.30
% of Revenue Contributed to CISA	2.48%	3.72%	5.92%	2.50%	3.76%	6.09%
Ave. Annual CISA Withdraw (per acre)	$4.31	$11.35	$25.28	$4.31	$11.35	$25.28
Ave. # of Withdraws from CISA (per acre)	2.72	6.15	11.35	2.72	6.15	11.35
Farmers with Positive Terminal CISA Balance						
% Ever have a Negative CISA Balance	4.16%	13.62%	42.46%	2.85%	9.15%	28.61%
Ave. Terminal CISA Balance (per acre)	$472.51	$488.05	$450.35	$476.24	$498.06	$496.25
Farmers with Negative Terminal CISA Balance						
Ave. Terminal CISA Balance (per acre)	$-148.46	$-119.82	$-95.70	$-174.59	$-138.33	$-118.08

Note**:** α denotes the contribution rate and γ denotes the revenue guarantee rate. Account balances are capped at $\gamma\overline{R}_t$ for all simulations.

Table 3. Sensitivity Analysis (50% Increase in Yield Stdev. and 25% Increase in Price Stdev.) of CISA with Capped Balances and Catch-up Contributions

	$\alpha = 1\%$ $\gamma = 65\%$	$\alpha = 1\%$ $\gamma = 75\%$	$\alpha = 1\%$ $\gamma = 85\%$	$\alpha = 3\%$ $\gamma = 65\%$	$\alpha = 3\%$ $\gamma = 75\%$	$\alpha = 3\%$ $\gamma = 85\%$	$\alpha = 5\%$ $\gamma = 65\%$	$\alpha = 5\%$ $\gamma = 75\%$	$\alpha = 5\%$ $\gamma = 85\%$
All Farmers									
% Ever have a Negative CISA Balance	87.56%	99.42%	100.00%	48.67%	85.98%	99.64%	28.26%	61.19%	94.39%
% End with Negative CISA Balance	12.81%	34.23%	65.97%	1.94%	12.69%	42.90%	0.41%	3.16%	21.26%
Ave. Terminal CISA Balance	$42.65	$-39.79	$-161.50	$303.22	$124.59	$-57.18	$400.19	$322.06	$86.92
Ave. Annual CISA Contribution (per acre)	$12.34	$21.66	$36.66	$18.15	$25.30	$38.99	$20.28	$29.70	$42.19
% of Revenue Contributed to CISA	2.10%	3.69%	6.23%	3.08%	4.29%	6.62%	3.44%	5.03%	7.16%
Ave. Annual CISA Withdraw (per acre)	$11.39	$22.55	$40.25	$11.41	$22.54	$40.26	$11.39	$22.55	$40.25
Ave. # of Withdraws from CISA (per acre)	5.08	8.74	13.32	5.09	8.74	13.33	5.08	8.74	13.32
Farmers with Positive Terminal CISA Balance									
% Ever have a Negative CISA Balance	86.49%	99.18%	100.00%	48.16%	84.91%	99.43%	28.12%	60.67%	93.56%
Ave. Terminal CISA Balance (per acre)	$63.85	$25.87	$13.79	$307.72	$152.20	$50.48	$401.28	$330.19	$140.86
Farmers with Negative Terminal CISA Balance									
Ave. Terminal CISA Balance (per acre)	$-69.87	$-101.41	$-192.86	$-72.22	$-80.77	$-134.96	$-83.37	$-81.98	$-100.71

	$\alpha = 7\%$ $\gamma = 65\%$	$\alpha = 7\%$ $\gamma = 75\%$	$\alpha = 7\%$ $\gamma = 85\%$	$\alpha = 9\%$ $\gamma = 65\%$	$\alpha = 9\%$ $\gamma = 75\%$	$\alpha = 9\%$ $\gamma = 85\%$
All Farmers						
% Ever have a Negative CISA Balance	18.75%	42.73%	80.34%	13.45%	31.14%	64.26%
% End with Negative CISA Balance	0.15%	0.97%	7.92%	0.07%	0.42%	2.79%
Ave. Terminal CISA Balance	$426.39	$409.96	$262.57	$437.49	$444.15	$381.15
Ave. Annual CISA Contribution (per acre)	$20.86	$31.66	$46.09	$21.11	$32.42	$48.72
% of Revenue Contributed to CISA	3.54%	5.37%	7.81%	3.58%	5.49%	8.26%
Ave. Annual CISA Withdraw (per acre)	$11.39	$22.55	$40.25	$11.39	$22.55	$40.25
Ave. # of Withdraws from CISA (per acre)	5.08	8.74	13.32	5.08	8.74	13.32
Farmers with Positive Terminal CISA Balance						
% Ever have a Negative CISA Balance	18.69%	42.53%	79.62%	13.42%	31.04%	63.87%
Ave. Terminal CISA Balance (per acre)	$426.85	$412.59	$283.89	$437.75	$445.36	$388.91
Farmers with Negative Terminal CISA Balance						
Ave. Terminal CISA Balance (per acre)	$-91.58	$-91.75	$-91.10	$-100.04	$-98.38	$-97.74

Note: α denotes the contribution rate and γ denotes the revenue guarantee rate. Account balances are capped at $\gamma\overline{R}_t$ for all simulations.

Appendix I

This appendix is comprised of two sections. The first section entitled “Yield Variability and Premium Estimation Error” establishes a range of plausible levels of crop insurance premium estimation error corresponding to typical corn production scenarios in the Midwestern US. The second section entitled “Distribution of Crop Insurance Subsidies” assesses the potential impact of such levels of premium estimation error on the distribution of the Crop Insurance subsidies across participating corn producers.

Yield Variability and Premium Estimation Error

The yield simulation scenarios are designed to resemble the case of corn production in the Midwestern US. Specifically, prototypical farms yields with a mean of 180 bushels/acre and standard deviations ranging from 30 to 50 bushels/acre are simulated. In the first part of the analysis (Scenario A), yields are assumed to be normally distributed. At the lowest standard deviation of 30 bushels/acre the probability of a yield value under 130 bushels/acre or over 230 bushels/acre is only 10% (5% under and 5% over). This would have to be a superior farmer with limited downside and substantial upside yield potential. At the highest standard deviation of 50 bushels/acre the 5% probability bounds are 97.5 and 262.5 bushels/acre. This could be farmer with a fair downside but an unrealistically high upside yield potential.

In the second part of the analysis (Scenario B), yields are assumed to follow a substantially left skewed SU distribution (Ramirez, Carpio and Rejesus 2011). At the lowest standard deviation of 30 bushels/acre and skewness and kurtosis values of -3.25 and 23.5, the 5% probability boundaries are 125 and 207 bushels/acre (Figure 1). These expand to 88.5 and 225 bushels/acre at the highest standard deviation of 50 bushels/acre (Figure 2). In other words, the upside yield potential from the mean of 180 bushels/acre less than half as much as the downside potential. It is believed that these distributions are more consistent with the likely behavior of farm-level corn yields in the Midwestern US.

The actuarially fair premiums (AFP) corresponding to each of the above yield distributions for the Actual Production History (APH) farm-level yield insurance program under a price guarantee of $5/bushel and 60, 65, 70, 75 and 80% coverage levels are then computed using standard simulation methods. Specifically, 10 million random yield observations (Y_i) are simulated from the appropriate distribution (normal or SU) given the assumed parameter values (for a description of the procedure to simulate draws from an SU distribution see Ramirez, Misra and Field 2003). Each of those values is compared with CL times the known mean of the distribution (M=180), where CL is the coverage level (0.60, 0.65, 0.70, 0.75 or 0.80). If the simulated yield value is lower than CL*x*M the difference (CL*x*M-Y_i) is multiplied by the assumed price guarantee ($5/bushel), otherwise the observation is discarded. The sum of all the non-discarded values divided by 10 million is thus the expected indemnity associated with that specific yield distribution and, therefore, the actuarially fair premium that needs to be charged.

In the case of the normal distributions (Table 1), at the most common 65% coverage level, the AFP range from $0.97/acre when the standard deviation is 30 bushels/acre to $12.37/acre when the standard deviation is 50 bushels/acre. At the mid-point of 40 bushels/acre the AFP is $4.93/acre. This begins to illustrate the problem faced by the RMA. If the correct standard deviation of a farmer's yield distribution was 40 bushels/acre but the insurer estimated it at 45 bushels/acre, the premium estimate for 65% coverage would be $8.26/acre instead of $4.93/acre. Unfortunately, as shown later because the limited amount of data available for rating, an estimation error of that magnitude might not be uncommon. Alternatively, the insurer could choose to charge all farmers the average premium for the most likely standard deviation value (e.g. 40 bushels/acre). In this case, however, farmers with only slightly lower or higher than average levels of yield variability (e.g. 35 or 45 bushels/acre) would pay quite more ($4.93 versus $2.50/acre) or less ($4.93 versus $8.26/acre) than what they actually should.

The situation is not much different when the yield distribution is assumed to be left-skewed (Table 1). Under this distributional assumption, at the 65% coverage level a producer who is able to maintain a 5% lower bound of 125 bushels/acre (Figure 1) should only pay a $7.14/acre premium. In contrast, a farmer whose 5% lower-bound is 88.5 bushels/acre (Figure 2) should be charged $21.17/acre. Unfortunately again, because of the limited amount of yield data available for participating producers, it is impossible to reliably estimate the correct location of the far left tail of the yield distribution and, as shown in the next section, errors of this magnitude might not be uncommon.

The distribution of the estimated premiums under any given yield distribution can be obtained by simulation methods as well. Specifically, 10,000 small samples of size n=20 are drawn from the underlying distribution and the distributional parameters are estimated based on each sample. In the case of a normal, the usual estimates for the mean and standard deviation are utilized. In the case of an SU, Maximum Likelihood methods are used to estimate the four distributional parameters (Ramirez, Misra and Field 2003). Once the parameter estimates corresponding to each of the 10,000 samples are available, the same procedure utilized to compute the actuarially fair premiums (AFP) is applied to obtain premium estimates. Those 10,000 premium estimates represent (i.e. are draws from) the statistical distribution of the estimated premiums associated with that particular yield distribution.

Key summary statistics describing the distribution of the premium estimates corresponding to each the 10 assumed yield distributions are presented in Tables 1 and 2. In the case of an underlying normal with a mean of 180 and a standard deviation of 40 bushels/acre, the average of the 10,000 premium estimates (labeled as APE in Table 1) at 65% coverage is $5.71/acre versus the AFP of $4.93/acre. In other words, the premium estimates exhibit a 16% upward bias in this particular instance. In addition, the average of the absolute differences between the estimated premiums and the AFP (labeled as MAD in Table 1) is $3.08/acre. This means that premium estimates that are several dollars apart from the AFP of $4.93/acre are fairly common, with a strong tendency for the estimates to be higher rather than lower than the AFP.

When the underlying yield distribution is an SU with the same mean (180 bushels/acre) and standard deviation (40 bushels/acre), the APE is $14.70/acre versus the AFP of $13.70/acre, and the MAD stands at $8.02/acre. This means that premium estimates that are more than 50% lower or higher than the AFP are fairly common. The column labeled PMAD (percentage MAD) in Table 1 is obtained by multiplying the MAD by 100 and dividing by the AFP, which expresses it as a percentage of the AFP. Note that, in all cases, the PMAD decreases with the coverage level and when the yield distribution has a higher standard deviation. Generally on a relative basis the MAD is lower at higher AFP. At the most common 65% coverage level, the PMAD ranges from 98.5 to 48.1 percent for the normal and 78.1 to 46.9 percent for the SU distributions.

While the yield distributions underlying the previously discussed bias and PMAD statistics are hypothetical in nature, they are by no means unrealistic representations of possible corn production scenarios in the Midwest. Nevertheless, more conservative (25 to 50 percent) PMAD values are assumed for the following analyses.

Distribution of Crop Insurance Subsidies

While it is not claimed that the previously discussed PMAD and bias magnitudes are characteristic of the RMA premium estimates for corn production in the Midwestern US, in this section they will be used to explore the potential impacts of such levels of premium estimation inaccuracy on the distribution of crop insurance subsidies across farmers who produce the same crop and (unknown to the insurer) exhibit identical yield risk profiles. Specifically, it is assumed that both the farmer and the insurer do not know what the AFP is and thus have to estimate it with various degrees of error (PMAD and bias). The producer and insurer premium estimates are denoted by PPE and IPE, respectively, and producers may be willing to pay a risk-protection premium (RPP) in excess of their PPE. A farmer's decision rule for participating in the program, thus, is PPE+RPP≥IPE, i.e. that his/her own premium estimate plus any risk protection premium he/she is willing to pay is greater than the insurer's quote.

For each scenario in the analysis, it is assumed that 10,000 identical producers are eligible to participate in the program. Alternatively, this could be interpreted as conducting repeated outcome draws for a single producer. Each outcome (i) is characterized by a set of two premium estimates, one by the producer (PPE_i) and one by the insurer (IPE_i), which are randomly drawn as follows:

1) $PPE_i=AFP+PPB+U_{iP}$
2) $IPE_i=AFP+IPB+U_{iI}$

where AFP=10 in all cases, PPB and IPB are the biases in the producer and insurer premium estimates, respectively, and U_{iP} and U_{iI} are draws from uncorrelated uniform distributions with zero mean and whatever range is necessary to achieve the desired PMAD for PPE and IPE.

In the first scenario (S1a) presented in Table 2 it is assumed that IPB, PPB and RPP are all zero and that both the PPE and the IPE exhibit a relatively low PMAD of 30%. Thus, both U_{iP} and U_{iI} are set range between -6 and 6 which means that the premium estimates will range from 4 to 16 in both cases. Since the estimated premiums are not subsidized (Government Subsidy Rate=GSR=0 in Table 2) in this scenario, as expected, $PPE_i \geq IPE_i$ in just about 50% of the 10,000 simulated outcomes, which means that only half of the eligible producers would voluntarily participate (Producer Participation Rate= PPR=0.50). A more interesting question, however, is: what is the distribution of the premiums paid by the participating producers relative to the AFP, i.e. to what they should in fact be paying?

This question can be answered by comparing their IPE_i (i.e. what they ended up paying) with the AFP. As detailed in Table 2, in this scenario, over 25% of participating producers end up paying more than the AFP (i.e. what they should pay) while 16% pays less than half of the AFP. In addition, because only farmers for whom $PPE_i \geq IPE_i$ participate in the program and there is no RPP or any positive bias on the producer's premium estimate, the sum of their IPE_i (i.e. what they actually pay) is only 80.0% of the sum of their AFP, which means that this particular scheme could not operate without a substantial external subsidy. Thus, PPG (the Percentage Paid by Government) equals 0.20 in Table 2.

In practice, the RMA provides subsidized premiums to promote higher levels of participation. Mathematically, this alters the participation rule to $PPE_i \geq (1\text{-}GSR) x IPE_i$ where GSR is the government subsidy rate. For instance, if GSR=0.50 (50 percent), the insurer's quote would be 0.50x IPE_i. The second scenario (S1b) presented in Table 2 maintains the baseline assumptions of S1a (IPB=0, PPB=0, RPP=0, and PMAD=30%) but assumes a GSR of 52% which is roughly in line with what has been observed in recent years. In this case

$PPE_i \geq 0.50xIPE_i$ in 9,020 of the 10,000 cases, i.e. the producer participation rate (PPR) is 90.2 percent. The sum of $0.50xIPE_i$ for the participating producers is only 46.2% of the sum of their AFP, which means that 53.8% of the total indemnity payments would have to be externally subsidized. Thus, PPG=0.538 in Table 2.

In addition note that, because of the high overall subsidy level, all participating producers now pay less than 80% of what is actuarially fair. However, while over 20% are charged 30% or less, on the other extreme, nearly 25% pay 60% or more of the AFP. That is, just by chance, two producers with identical yield risk profiles would often end up paying very different crop insurance premiums and thus receiving vastly disproportionate shares of the intended government subsidy. Table 2 presents several other scenarios involving various plausible combinations of premium estimate biases, PMADs and risk protection premiums, as well as the possibility of a substantial correlation (CORR) between the insurance and producer premium estimates. At least some degree of correlation should be expected since the RMA considers the farm's recent yield history on its rating protocol and the farmer could give some weight to the insurer's quote when determining what he/she thinks the actuarially fair premium might be. The scenarios are designed to approximately resemble the current program outcomes, specifically a 90% producer participation rate (PPR) given a 50% external premium subsidy (PPG).

Note that, in all the 90% participation (i.e. "b") scenarios, the 25% of the producers paying the highest premiums pay at least twice as much as the 25% paying the lowest premiums. In S6b, for example, 26.1% pay less than 30% of the AFP while 24.5% pay more than 70% of the AFP. In other words, just by chance, 26.1% of the farmers end up receiving a subsidy of at least 70% while 24.5% get a rate subsidy of 30% or less. Further, 14.8% receive a subsidy of at least 80% while 11.0% get 20% or less.

Numerous other scenarios are explored involving exhaustive combinations of producer and insurer PMADs, bias, RRP and CC. From these scenarios it is concluded that while some such combinations result in a high percentage of producers participating at relatively low levels of external subsidy (GSR and PPG), as long as a non-negligible PMAD (≥2.0) is assumed to be associated with the insurer's estimate for the AFP, the dispersion of the premiums to be paid by "identical" farmers remains high. It can thus be argued that this is an unavoidable disadvantage of crop insurance. While, through substantial external subsidies, it is possible to avoid a situation where too many farmers end up paying more than the AFP, it appears that the distribution of those subsidies across participating farmers will always be highly and randomly uneven. Just by chance, some producers will receive a large share of the subsidy while others get very little or possibly even none at all.

In order to facilitate comparisons, the previous analysis focus on the case of a set producers with identical risk profiles. However, a logical extrapolation of the above results is that an individual with a low-risk operation (i.e. whose AFP is relatively low) could very well end up paying a similar or even larger premium than another high-risk farmer. An alternative, of course, would be for the insurer to charge the same "average" premium to all producers whose operations appear to face about the same yield risk. The problem with this is that, because of the previously illustrated difficulties with accurately assessing farm-level risk (i.e. estimating the AFP), producers with substantially different risk exposure (i.e. AFP) could end up paying the same "average" premium.

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Table 1: Actuarially Fair Premium (AFP), Average of Premium Estimates (APE), Mean Absolute Deviation of the Premium Estimates from the AFP (MAD), Percentage Bias (PBIAS) and Percentage MAD (PMAD) for two alternative underlying corn yield distributions with 5 different standard deviations (STD).

	Normal Distribution - Mean = 180					Non-Normal Distribution - Mean = 180				
STD	**AFP**	**APE**	**MAD**	**PBIAS**	**PMAD**	**AFP**	**APE**	**MAD**	**PBIAS**	**PMAD**
30.00	0.97	1.38	0.96	41.58	98.46	7.14	8.73	5.57	22.36	78.07
35.00	2.50	3.12	1.89	24.96	75.70	10.20	11.67	6.82	14.38	66.86
40.00	4.93	5.71	3.08	15.80	62.39	13.70	14.70	8.02	7.27	58.55
45.00	8.26	9.26	4.47	12.18	54.13	17.29	17.84	9.20	3.19	53.22
50.00	12.37	13.52	5.95	9.30	48.06	21.17	21.20	9.92	0.17	46.87

Table 2: Distribution of the premiums paid by participating producers under various combinations of insurer premium bias (IPB), producer risk protection premiums (RPP), insurer and producer PMADs (IPMAD and PPMAD), and correlations between the insurer and the producer premium estimates (CORR).

IPB	0.00		0.00		0.00		0.00		-15%		15%	
RPP	0.00		0.00		10%		15%		15%		15%	
IPMAD	30%		40%		50%		50%		50%		50%	
PPMAD	30%		40%		50%		50%		50%		50%	
CORR	0.00		0.00		0.60		0.60		0.60		0.60	
Scenario	**S1a**	**S1b**	**S2a**	**S2b**	**S3a**	**S3b**	**S4a**	**S4b**	**S5a**	**S5b**	**S6a**	**S6b**
GSR	0.000	0.520	0.000	0.650	0.000	0.570	0.000	0.520	0.000	0.440	0.000	0.590
PPR	0.500	0.902	0.499	0.897	0.560	0.898	0.589	0.900	0.679	0.902	0.499	0.901
PPG	0.200	0.538	0.266	0.665	0.129	0.551	0.123	0.503	0.257	0.515	0.005	0.509
PAFP												
20%	1.000	0.985	1.000	0.742	0.866	0.792	0.866	0.809	0.779	0.756	0.964	0.852
25%	1.000	0.889	0.938	0.644	0.834	0.737	0.834	0.760	0.749	0.712	0.929	0.795
30%	1.000	0.793	0.878	0.550	0.802	0.682	0.803	0.710	0.719	0.669	0.894	0.739
35%	1.000	0.696	0.821	0.457	0.770	0.625	0.772	0.659	0.690	0.624	0.860	0.681
40%	1.000	0.601	0.765	0.369	0.739	0.569	0.741	0.609	0.661	0.580	0.827	0.622
45%	0.919	0.507	0.712	0.283	0.708	0.511	0.711	0.558	0.633	0.535	0.795	0.562
50%	0.840	0.416	0.660	0.200	0.677	0.451	0.681	0.507	0.605	0.491	0.762	0.501
55%	0.765	0.329	0.611	0.120	0.648	0.391	0.651	0.454	0.577	0.446	0.730	0.439
60%	0.694	0.248	0.563	0.045	0.619	0.330	0.623	0.400	0.549	0.401	0.699	0.375
65%	0.626	0.168	0.518	0.000	0.590	0.269	0.594	0.347	0.522	0.356	0.668	0.311
70%	0.562	0.095	0.473	0.000	0.562	0.207	0.566	0.292	0.496	0.311	0.638	0.245
75%	0.501	0.025	0.432	0.000	0.534	0.143	0.538	0.237	0.470	0.266	0.608	0.178
80%	0.444	0.000	0.391	0.000	0.507	0.078	0.511	0.182	0.444	0.220	0.580	0.110
85%	0.391	0.000	0.354	0.000	0.480	0.013	0.485	0.126	0.419	0.174	0.551	0.042
90%	0.341	0.000	0.317	0.000	0.455	0.000	0.460	0.069	0.394	0.127	0.523	0.000
95%	0.295	0.000	0.283	0.000	0.429	0.000	0.434	0.012	0.370	0.080	0.496	0.000
100%	0.252	0.000	0.251	0.000	0.403	0.000	0.409	0.000	0.346	0.033	0.470	0.000

Notes: GSR, PPR, PPG, stand for the Government Subsidy Rate to each individually estimated premium, the Producer Participation Rate in the program, and the Percentage (of the total program indemnities) Paid by the Government. The percentages on the first column under PAFP are the percentages of the AFP. The numbers in the columns next to them are to be interpreted as follows: on the second column, for example, there is a 100% probability that the producer will end up paying more than 40% of the AFP, a 91.9% probability that he/she will pay more than 45% of the AFP, an 84.0% probability that he/she will pay more than 50% of the AFP, and so on.

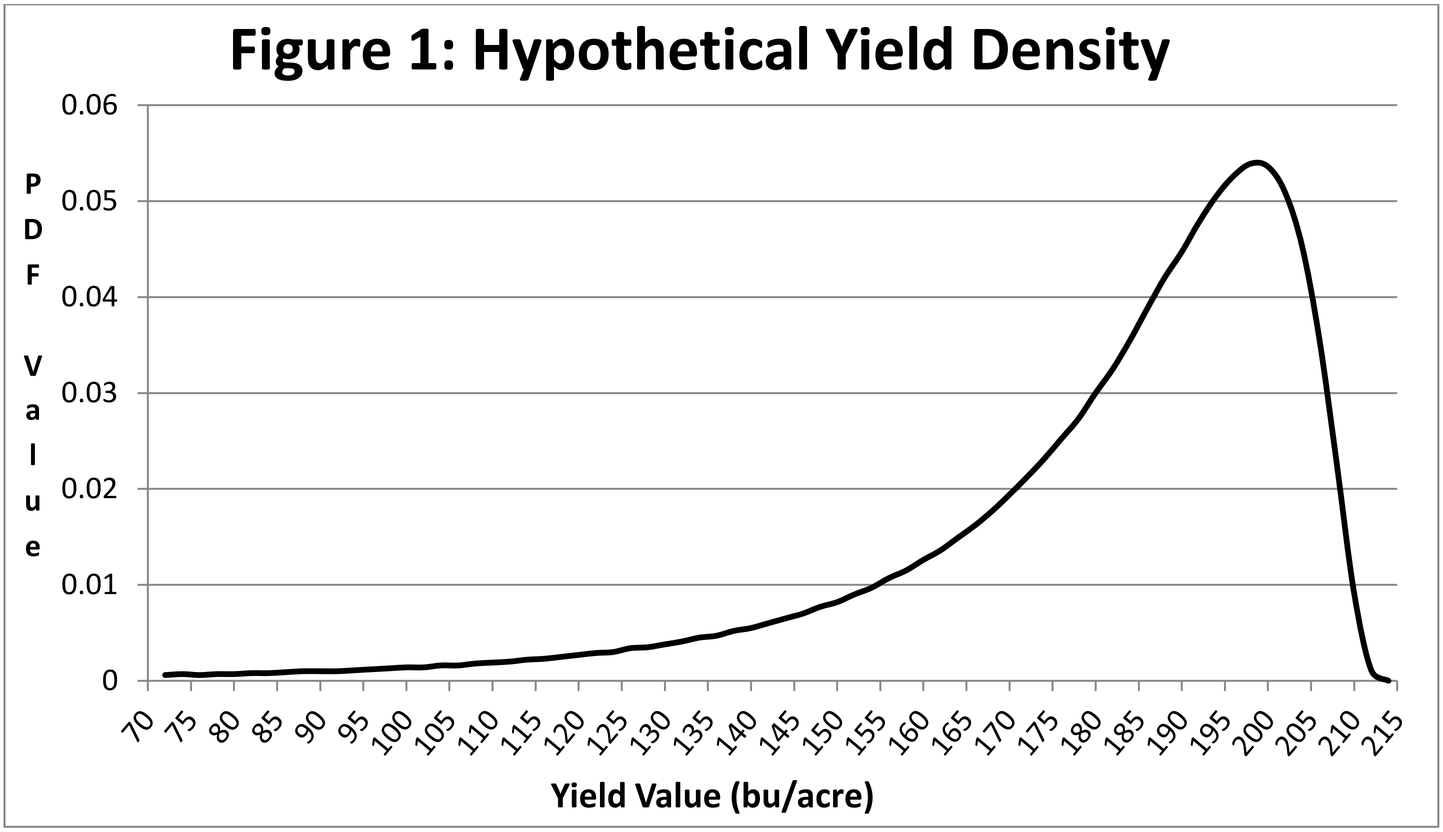
Figure 1: Hypothetical Yield Density
PDF Value
0.06
0.05
0.04
0.03
0.02
0.01
0
70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215
Yield Value (bu/acre)

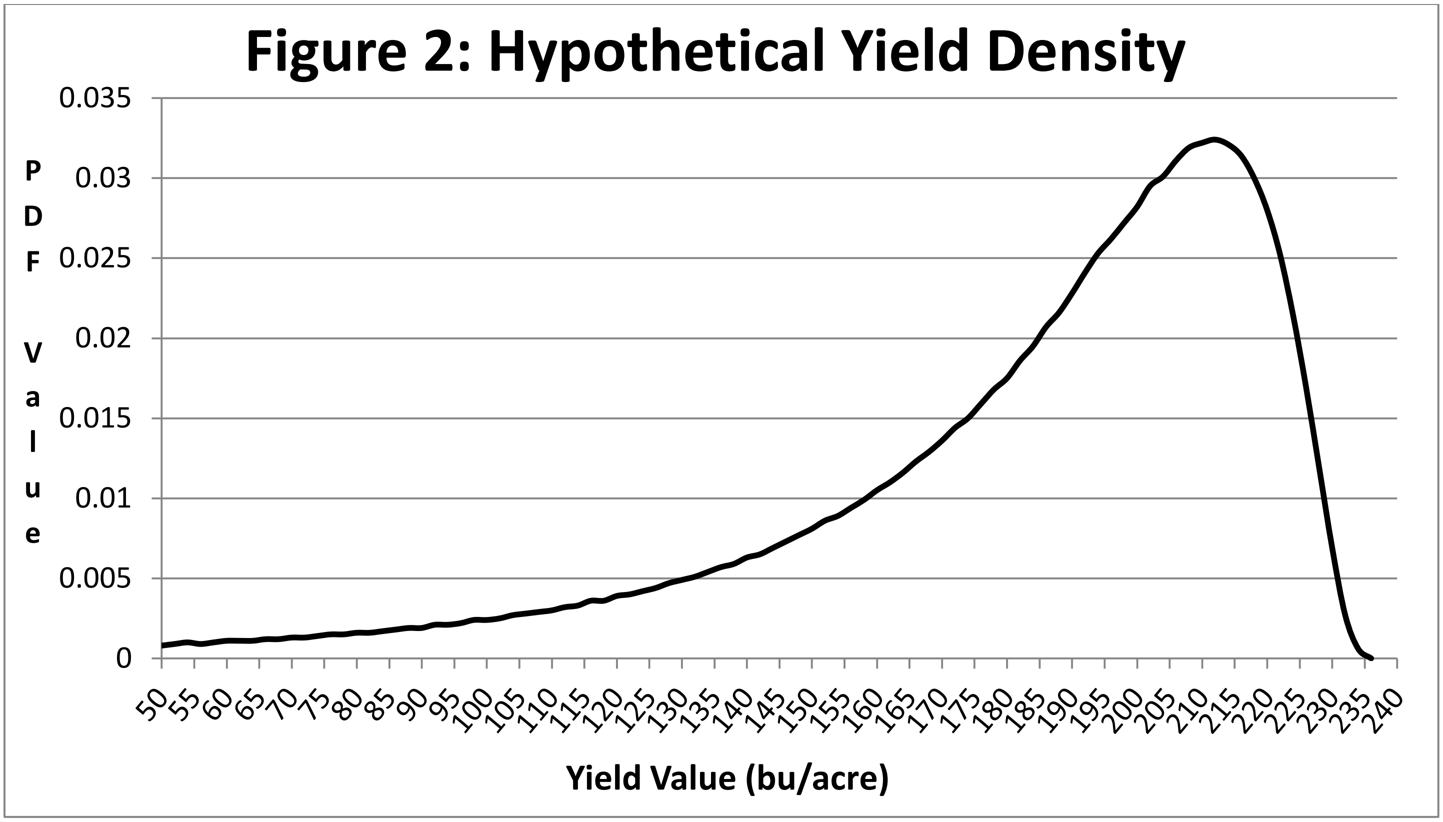
Figure 2: Hypothetical Yield Density
PDF Value
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240
Yield Value (bu/acre)

Appendix II

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 article 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 (2010).

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 ($B_1 + B_2 t,\ t = 1,2,\dots,T$) 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:

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

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

$J = [\exp(B_4^2) - 1][\exp(B_4^2)\cosh(-2B_4 B_5) + 1]/(2B_4^2)$,

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

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

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

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) $K = \{(W - 1)^2 [W^2 (W^4 + 2W^3 + 3W^2 - 3)\cosh(4Q) + 4W^2 (W + 2)\cosh(2Q) +$
$32W+1/8J2B44\}-3$, where

(6) $W = \exp(B_4^2)$ and $Q = -B_4 B_5$.

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 (Judge et al. 1985). Using standard procedures, the concentrated log-likelihood function needed for estimating the parameters of this model can be derived from equation (1):

$$(7) \qquad \sum_{t=1}^{T} \ln{(G_t)} - 0.5 \sum_{t=1}^{T} H_t^2$$

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[2]) 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 1. 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).

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 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 2.

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 1970s. 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 2) 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:

$$(8) \qquad IHS_t = mean_t\{sig\big(sinh\big(\theta(Z_t + \mu)\big) - F\big)/\big(\theta J^{1/2}\big)\},$$

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 vector of IHS errors ($\{IHS_t - mean_t\} =$

$\{sig(sinh(\theta(Z_t + \mu)) - F)/(\theta J^{1/2})\}, t = 1, \ldots, T)$ 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.

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Table 1. 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 2. 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.