Developing a Feasible Whole Farm Insurance product

Keith H. Coble, Lekhnath Chalise
Barry J. Barnett, and J. Corey Miller

Department of Agricultural Economics, Mississippi State University
Corresponding Author: Keith H. Coble coble@agecon.msstate.edu

Submission to the Second International Agricultural Risk, Finance, and Insurance Conference (IARFIC) to be held at the Four Seasons Hotel, Vancouver, British Columbia, Canada, on June 16-18, 2013.

Abstract

Whole-farm insurance is frequently suggested as a conceptually attractive alternative to commodity specific insurance. However, attempts to deliver farm-level whole-farm insurance have been fraught with underwriting and actuarial challenges. This study develops and analyzes customizable area whole farm insurance (CAWFI) as a possible alternative that overcomes some of the major impediments to existing designs. An optimal CAWFI design is tested against scenarios with no insurance program, 90% farm-level whole farm insurance (90% FWFI), and a restricted CAWFI with scale and coverage restricted as in the existing U.S. Group Risk Plan (GRP) and Group Risk Income Protection (GRIP) insurance programs. All insurance scenarios are actuarially-fair by construction. Certainty equivalents are generated for representative farms in Kansas, North Dakota, Illinois, and Mississippi. The study finds that an optimal CAWFI design generates higher certainty equivalents than the alternative scenarios while restrictions on scale and coverage can greatly reduce the effectiveness of the proposed CAWFI product.

Key words: Whole-Farm Crop Insurance, Risk, Certainty Equivalents

Developing a Feasible Whole Farm Insurance Product

Farmers simultaneously face multiple sources of risk including yield risk and price risk. Yield risk can result from adverse weather, disease, and poor management practices. Events that affect global markets can drive variations in price. To stabilize farm revenue in risky environments, farmers adopt various management approaches including crop insurance, forward pricing, and participation in government income support programs. In the United States, crop insurance is widely available and a primary component of the farm safety net for crop producers. With crop insurance the insured exchanges a sure premium to receive an indemnity in the event of a negative outcome.

U.S. producers may purchase a number of different types of crop insurance through programs established by the U.S. Department of Agriculture's Risk Management Agency (RMA). Among these are farm-level yield insurance, farm-level revenue insurance, area-based yield and revenue insurance, and more recently, farm-level, multi-commodity, whole-farm, insurance products. In the U.S., farm-level crop insurance is widely popular. However, these designs are susceptible to adverse selection and moral hazard both of which violate standard insurability conditions (Quiggin et al. 1993; Smith and Goodwin 1996; Babcock and Hennessy 1996; Coble et al. 1997; and Smith and Glauber, 2012).

Area-based insurance products, such as the Group Risk Plan (GRP) and Group Risk Income Protection (GRIP), provide commodity-specific coverage based on county yield (in the case of GRP) or revenue (in the case of GRIP) shortfalls. Area-based insurance can minimize adverse selection and moral hazard because individual farmers have no better information about expected county yields or revenues than does the insurer nor can the behavior of individual farmers significantly influence county average yields or revenues (Miranda, 1991). However, because farm yields and revenues are not perfectly correlated with county yields and revenues, area-based insurance products are subject to basis risk. Basis risk occurs due to the lack of perfect correlation between farm yields or revenues and county yields or revenues (Skees et al., 1997). Because of this basis risk, a farmer could receive an indemnity that exceeds the loss incurred or an indemnity that does not sufficiently cover the loss incurred. In extreme cases, it is possible to receive an indemnity when no loss has been incurred or to incur a loss and receive no indemnity (Barnett et al, 2005; Deng, Barnett, and Vedenov, 2007). GRP and GRIP have to this point captured a relatively small market share of crop insurance business. In 2012 these two products were purchased on less than 1.4 percent of all acres insured (Risk Management Agency, 2013) in spite of research suggesting that GRP can, in some cases, perform better than farm-level yield insurance (Barnett et. al. 2005). Ultimately, area-based insurance products face basis risks that farm-level products do not, but the latter incur more moral hazard and adverse selection problems.

Multi-crop, whole farm insurance has been proposed as an alternative to commodity-specific policies (O'Hara, 2012). Assuming the goal is to protect against shortfalls in whole farm revenue then an insurance product that subsumes all farm enterprises would specifically protect against the risk of interest. Whole-farm insurance can pool all of the price and yield risks of one farm into a single insurance policy at a lower cost compared to commodity-specific revenue insurance or combinations of forward pricing and farm-level yield insurance products (Stokes, Nayda, and English, 1997; Zhu, Ghosh, and Goodwin, 2008). Because revenues for different commodities are less than perfectly correlated with each other, whole-farm insurance can account for diversification effects that result in lower premium costs than insuring each commodity separately.

The Risk Management Agency already offers whole-farm insurance products known as Adjusted Gross Revenue (AGR) and AGR-Lite.[1] However, these two products have proven to be unpopular with farmers accounting for less than one-half of one percent of total federal crop insurance liability in 2013 (Risk Management Agency, 2013). AGR and AGR-Lite make payments based on shortfalls in income as reported on the Schedule F federal income tax form. Since most farms use cash accounting, AGR and AGR-Lite require a number of adjustments to the Schedule F information. Additional adjustments are required if significant changes are made from one year to the next in the agricultural commodities produced on the farm. As a result, the AGR and AGR-Lite products have very stringent underwriting rules to prevent fraud and abuse. While these products are conceptually simple, they are operationally quite complex and highly prone to moral hazard problems. For example, crop seasons for commodities may vary and evidence of losses on an early crop may be difficult to measure months after the occurrence.

Another issue with whole-farm insurance involves the need to understand price variability, yield variability, and price-yield interactions for all commodities grown on a farm. These factors complicate developing insurance programs and create the potential for adverse selection due to inaccurate rating assumptions (Dismukes and Coble, 2006). Consider a farm with three crops and both price and yield risk for a total of six random variables. An appropriate rating model would need to somehow reflect a six-by-six correlation matrix. In particular one would need within-farm crop yield correlations which to this point have been poorly documented.

[1] In addition, for some Midwestern counties farmers may choose a farm level revenue insurance unit structure that insures the combined total of corn and soybean revenues.

Consequently, we consider a hybrid product that allows a producer to customize multi-crop area insurance to a specific farm. Our approach uses area revenue as a trigger to preclude many of the fraud and recordkeeping challenges of the current AGR and AGR-Lite programs. However, whole-farm insurance based on a county revenue trigger cannot cover some farm revenue shortfalls because of the lack of perfect correlation between aggregate revenue and farm revenue. As a result, selecting the appropriate weighting scheme becomes an important consideration. Simply using the sum of aggregated commodity revenue by county implicitly weights all commodities by the crop mix of the county, and a farm producing a different crop mix may receive poor risk protection due to the lack of correlation between the farm and county revenue measures.

This study introduces the concept of whole farm area revenue insurance and also estimates optimal scale and coverage levels along with an appropriate weighting mechanism to customize the area crop mix to the farm crop mix for both single-crop and multi-crop designs. The goal of the proposed customizable area whole-farm insurance (CAWFI) product is to incorporate the risk-reducing properties of whole-farm insurance into an area-based product to minimize adverse selection and moral hazard problems. Additional benefits of the design include mitigating the complexities of the premium rating and indemnity calculations associated with whole-farm products.

The Proposed Customizable Area Whole Farm Insurance Model

In any given year t the gross revenue received from producing crop i on farm f is

(1) $$R_{ift} = A_{ift} \times Y_{ift} \times P_{it}$$

where A is acres, Y is the realized yield, and P is the price received for the commodity.[2] Yield and price are both stochastic, so realized gross revenue is also stochastic. The expected gross revenue from crop i is

(2) $$E(R_{ift}) = A_{ift} \times \left(\left(E(Y_{ift}) \times E(P_{it})\right) + Cov(Y_{ift}, P_{it})\right)$$

where $E(\cdot)$ designates the expectations operator.

If one or more of the crops is insured, the realized gross revenue net of insurance premium is

(3) $$R^S_{ift} = (A_{ift} \times Y_{ift} \times P_{it}) + \pi^S_{ift} - n^S_{ift}$$

where π is the insurance premium, n is any indemnity received, and the superscript S indicates a particular insurance scenario. If "no insurance" is included as one of the possible insurance scenarios (in which case both π and n would equal zero), equation 3 is generalized to incorporate equation 1. Realized "whole farm" gross revenue net of insurance premium for farm f in year t is then calculated as

(4) $$R^S_{ft} = \sum_i R^S_{ift}.$$

The proposed CAWFI indemnity function extends that currently used for the GRIP product. As with GRIP, CAWFI indemnities are based on realized revenue calculated using the National Agricultural Statistics Service (NASS) county-level yield rather than the farm-level yield. Unlike GRIP, CAWFI insures against shortfalls in whole farm revenue. Thus,

(5) $$CAWFI\_R_{ift} = A_{ift} \times Y_{ict} \times P_{it}$$

where $CAWFI\_R$ designates the CAWFI calculation of realized revenue and the subscript c indicates the county in which farm f is located. Notice that for each crop i the farm acreage is multiplied by the county level yield to estimate realized production in year t.

[2] For simplicity, price is assumed to be fully systemic (rather than farm-specific).

The true expected value of $CAWFI\_R$ is

(6) $$E(CAWFI\_R_{ift}) = A_{ift} \times \Big(\big(E(Y_{ict}) \times E(P_{it}) \big) + Cov(Y_{ict}, P_{it}) \Big)$$

however, consistent with procedures currently used for GRIP, we ignore the covariance term when calculating the expected revenue for CAWFI.

The whole farm estimate of realized revenue used for CAWFI indemnity calculations is

(7) $$CAWFI\_R_{ft} = \sum_i CAWFI\_R_{ift}$$

and the whole farm estimate of expected revenue is

(8) $$E(CAWFI\_R_{ft}) = \sum_i E(CAWFI\_R_{ift})$$

where again, the covariance term is ignored.

If the superscripts NI and $CAWFI$ are used to designate no insurance and CAWFI insurance scenarios respectively, then CAWFI indemnities are calculated as

(9) $$n_t^{CAWFI} = max\left(\left(\frac{Trigger^{CAWFI} - CAWFI\_R_{ft}}{Trigger^{CAWFI}} \right), 0 \right) \times \left(E\left(R_{ft}^{NI}\right) \right) (scale)$$

where

(10) $$Trigger^{CAWFI} = E(CAWFI\_R_{ft}) \times coverage.$$

$Coverage$ and $scale$ are choice variables (denominated in percentages) that are selected by the insured. Identical variables exist for GRIP and GRP (see Skees, Black, and Barnett, 1997 or Deng, Barnett, and Vedenov, 2007). For most insurance products, $coverage$ is less than 100% with the difference being the percentage deductible. For example, the maximum $coverage$ for GRIP and GRP is currently 90% (10% deductible). However, since area-based products are not subject to moral hazard there is no compelling conceptual reason for restricting $coverage$ to be less than 100%. The variable $scale$ adjusts indemnities to allow for differences in how shortfalls in county-level whole farm revenues translate into shortfalls in farm-level whole farm revenues.

Note also that the indemnity function in equation 9 has a disappearing deductible because of the percentage trigger inside the first set of brackets. To see this, consider a complete loss with $CAWFI\_R$ equal to zero. The ratio becomes 1.0 and the insured would receive an indemnity equal to the total value of the crop liability (i.e. the deductible disappeared). However for a small loss of say 12 percent the deductible remains. In effect the deeper the loss, the more the deductible disappears. This is an attribute used in the current area- triggered GRP and GRIP designs.

Assessing Risk Reduction

To evaluate the welfare effects of insurance, consider a basic two period model of wealth dynamics for farm f with non-stochastic beginning wealth W_f^0. Ignoring production costs, ending wealth W_f^1 is

(11) $$W_f^1 = W_f^0 + R_{ft}^S.$$

If production costs are assumed to be non-stochastic, as they frequently are, their exclusion from equation 11 is effectively the same as reducing the level of W_f^0 and will not affect the ordinal ranking of W_f^1 values across different insurance scenarios.

Insurance scenarios are evaluated for each farm using the constant relative risk aversion (CRRA) utility function (See Lusk and Coble 2005 or Holt and Laury, 2002)

(12) $$U = \begin{cases} \frac{\left(W_f^1\right)^{1-\emptyset}}{1-\emptyset} & if\ \emptyset \neq 1 \\ \ln W_f^1 & if\ \emptyset = 1 \end{cases}$$

where $\emptyset$ is the relative risk aversion coefficient. If there are j possible outcomes for W_f^1 then

(13) $$E(U) = \begin{cases} \sum_j \tau_j \frac{\left(W_{fj}^1\right)^{1-\emptyset}}{1-\emptyset} & if\ \emptyset \neq 1 \\ \sum_j \tau_j \ln W_{fj}^1 & if\ \emptyset = 1 \end{cases}$$

where τ_j is the probability weight associated with outcome W_{fj}^1. Certainty equivalents are calculated as

$$(14) \quad CE = \begin{cases} \left(E(U)(1-\emptyset)\right)^{\left(\frac{1}{1-\emptyset}\right)} & if\ \emptyset \neq 1 \\ e^{E(U)} & if\ \emptyset = 1 \end{cases}.$$

Ultimately there are three parameters that may be varied to maximize risk reduction in the CAWFI design – (1) commodity weights, (2) coverage level, and (3) the scale parameter. These all could be choice variables for the producer in a completely flexible program or potentially may be restricted to a reasonable range to simplify the program. For this paper, we focus on maximizing risk reduction through the CAWFI design. Thus we assume an unsubsidized premium rate for the product. Subsidies would complicate the analysis by altering the mean of ending wealth in addition to reducing risk.

A straightforward but enormously important component of CAWFI is the choice of commodity weights. Crop mixes on a particular farm are likely to deviate dramatically within a county. Thus, it is not at all implausible to envision a farm with a mix of 25 percent corn and 75 percent soybeans in a county the has an aggregate mix of 50 percent corn, 25 percent soybeans, and 25 percent other crops. Given that county price and yield data are available, one can construct an infinite set of revenue indices in the county by varying the commodity weights. Given risk reduction as a goal, then the same set of readily observable aggregate data can be used to tailor a whole farm design to widely differing farms by optimizing the weights used for each farm. As shown in equation 1 it is intuitive to use the acreage mix of the farm to weight commodities in the CAWFI index. This matches the weights used in the farm's whole farm revenue distribution. However we conduct sensitivity analysis of this issue.

The coverage level is a common crop insurance choice variable and can reflect non-participation if allowed to take a value of zero. Typically, individual crop insurance coverage levels are limited to less than 100% to reduce the incentive for moral hazard. This also is imposed on area products such as GRP and GRIP. However the moral hazard concern is essentially negated by removing the yield used for indemnification from the farmer's control. Deng Barnett and Vedenov (2007) show that coverage levels for an area yield product can optimally exceed 100 percent of expected yield.

Given that scale is a choice variable in the model proposed above, a question arises regarding the appropriate scale value that a risk averse producer would prefer. This issue has been addressed previously in the context of GRP insurance. Miranda (1991) adapted a framework commonly used in optimal hedge ratio and capital asset pricing models to decompose farm yield deviation from expectation into systemic and idiosyncratic components. Specifically,

(15) $$Y_{ift} - E(Y_{ift}) = \beta_f(Y_{ict} - E(Y_{ict})) + \varepsilon_{ift}$$

where β_f is the responsiveness of farm yield deviations from expectation to county yield deviations from expectation. In this construction $\beta_f(Y_{ict} - E(Y_{ict}))$ represents the systemic component of farm yield deviations from expectation and ε_{ift} is the idiosyncratic component.

Miranda (1991) went on to show that if the indemnity function for an area yield insurance product is constructed as

(16) $$n_{it} = max((Trigger_{ict} - Actual\ Yield_{ict}), 0) \times \left(E\left(Y_{ift}^{NI}\right)\right)(scale)$$

then the optimal value for $scale$ is equal to β_f. The scale parameter that provides the greatest risk protection to the producer exactly matches the parameter that reflects the marginal change in farm yield deviations when a systemic deviation in yield occurs. Note first that β_f can take values greater and less than 1.0, but Miranda showed that the acre-weighted average of all farms in a county must equal 1.0 due to county yield being an aggregate of the individual yields. This does not imply that on average the total variability of farms in a county equals the county yield variability because it excludes the additional idiosyncratic risk of the individual farms.

Secondly, contrary to the common suggestion that a scale parameter is needed to adjust for differences in mean yield, the scale parameter actually is optimal when it scales deviations from the mean. Thus, it may be thought of as an adjustment to the county yield deviation to best match the systemic portion of farm risk that can be mitigated by the area insurance product.

The actual indemnity function used for GRP is

$$(17)\qquad n_{it} = max\left(\left(\frac{Trigger_{ict} - Actual\ Yield_{ict}}{Trigger_{ict}}\right), 0\right) \times \left(E\left(Y_{ift}^{NI}\right)\right)(scale).$$

In this case, the optimal $scale$ is equal to β_f only if Miranda's decomposition is converted to percentage terms such that

$$(18)\qquad \frac{Y_{ift} - E(Y_{ift})}{E(Y_{ift})} = \beta_f\left(\frac{Y_{ict} - E(Y_{ict})}{E(Y_{ict})}\right) + \varepsilon_{ift}.$$

Similarly, for GRIP the optimal $scale$ is equal to β_f if

$$(19)\qquad \frac{R_{ift} - E(R_{ift})}{E(R_{ift})} = \beta_f\left(\frac{R_{ict} - E(R_{ict})}{E(R_{ict})}\right) + \varepsilon_{ift}.$$

For the proposed whole farm CAWFI indemnity function, the optimal $scale$ is equal to β_f when

$$(20)\qquad \frac{R_{ft} - E(R_{ft})}{E(R_{ft})} = \beta_f\left(\frac{CAWFI\_R_{ft} - E(CAWFI\_R_{ft})}{E(CAWFI\_R_{ft})}\right) + \varepsilon_{ft}.$$

Data and Empirical Application

This study focuses on four representative farms from four different states to reflect varied crop/geographical regions. These farms are: a Yazoo County, Mississippi corn-soybean farm, a

McLean County, Illinois corn-soybean farm, a Sheridan County, Kansas corn-wheat farm, and a Barnes County, North Dakota corn-wheat farm.

County yield data were obtained from the National Agricultural Statistics Service of the United States Department of Agriculture for the period 1975 to 2009 (NASS, 2010). All yields were adjusted to 2011 technology using a linear trend specification (Coble and Dismukes, 2008). Representative farm-level yields are simulated from the detrended county-level yields according to Miranda's formulation as shown in equation 15. The representative farm yield is set to have a combined idiosyncratic and systemic risk level that matches that implied by the RMA farm-level yield insurance premium rate. To do so, the magnitude of idiosyncratic risk must be obtained. Consistent with Coble and Dismukes (2008) we assume $\varepsilon_{ift} \sim N(0, \sigma^2)$, that is, idiosyncratic risk is assumed to be distributed normally with a mean of zero and variance σ^2. County-level yields are simulated by taking a random draw from the empirical distribution of detrended county yields. Conditional on the simulated county-level yield, a farm-level yield is simulated using equation 15 and a random draw from the distribution of ε_{ift}.

The standard deviation of ε_{ift} is estimated as follows. Given the actual RMA yield insurance rate at 65 percent coverage is known, a grid search is conducted to obtain the standard deviation that most closely matches the crop insurance rate. This is done by simulating with the county yield deviations and various idiosyncratic standard deviation values seeking to find the σ_f value that most closely matches the RMA premium rate.

With the coverage level constant at 65 percent, we obtain estimates of the mean loss costs from a grid search performed across σ_f values ranging from 1 to 10 times σ_c with intervals of 0.1, where σ_c is the standard deviation of a county-level yield for a given crop and location. For each σ_f, 100 random draws are combined with each county yield draw to generate a farm yield $y_{ift.}$ The σ_f selected for the simulation is the one that minimizes the absolute difference between the simulated expected loss cost and the actual RMA rate

(21) $$Min|PR_{65} - ELC_{\sigma}|$$

where ELC_{σ} is the expected loss cost for a given level of σ_f calculated as

(22) $$ELC_{\sigma} = \frac{\sum_{t=1}^{100}\left(\frac{\left(CL\times E\left(y_{ift}\right)\right)-y_{ift}}{CL\times E\left(y_{ift}\right)}\right)}{100}$$

and PR_{65} is the premium rate for farm-level crop yield insurance in the county at 65 percent coverage when the expected farm yield is equal to $E\left(y_{ift}\right)$. In these equations, the subscript t refers to a simulation iteration.

Futures contract price changes over the production season for 1975-2009 were obtained from the Commodity Research Bureau (CRB) database. For each crop the daily closing futures price for the harvest month contract was obtained for all trading days in February and a mean value computed. The same calculation was done for the month prior to expiration for the same contract in the same year. This allows the computation of price changes from planting to harvest time. Also harvest time basis between cash and futures was computed using the CRB harvest month data and NASS reports of harvest cash prices.

Ultimately, a time series of detrended county yields, historical futures price changes and basis risk are obtained along with an estimate of σ_f for each crop and location. These data are then used to parameterize the multivariate parametric simulation. We first estimate the beta distribution for the detrended county yield data assuming a lower bound of zero and an upper bound of 120 percent of the maximum yield. Futures prices and price basis are assumed log-normally distributed and as previously described idiosyncratic farm risk is assumed $\varepsilon_{ift} \sim N\left(0, \sigma_f^2\right)$. We also obtain the marginal probability distributions and correlation matrix from the data and assume idiosyncratic yield risk is uncorrelated with other risks, but impose a 0.7 correlation across the idiosyncratic portion of yield risk within the farm.

Simulation Approach

The Phoon, Quek, and Huang (PQH) (2004) procedure is a multivariate simulation procedure for correlated stochastic variables from mixed marginal distributions based on an Eigen decomposition of a rank correlation matrix. Anderson, Harri and Coble (2009) demonstrate that the primary advantage of the PQH procedure compared to other techniques such as the Iman-Conover procedure is that it is straightforward and distribution-free. Using Eigen values and the decomposition of the correlation matrix, we generate 100,000 sample observations for futures price, basis risk, county yield, and idiosyncratic yield risk for both crops in a county using the PQH simulation technique.

We assume a base case of moderately risk-averse farmers with a risk-aversion coefficient of 2. Certainty equivalents are calculated as shown in equation 14.

Results

Descriptive Statistics

Table 1 presents descriptive statistics for the 100,000 simulated observations used in this study. The Illinois representative farm has a higher mean yield and lower standard deviation than any of the other farms. Relative farm-level yield risk (as measured by the coefficient of variation) is highest for the Kansas and North Dakota representative farms. . The Mississippi and Kansas representative farms have similar mean farm-level corn yields but the Kansas farm has a higher standard deviation and thus higher relative risk. The relative county-level corn yield risk is lowest for the Mississippi county and highest for the North Dakota county. At both the farm- and county-level the Mississippi farm has higher relative yield risk for soybeans than the Illinois farm. Likewise, at both the farm- and county-level the North Dakota farm has higher relative yield risk for wheat than the Kansas farm. The relative risk of ending futures prices and ending marketing year average (MYA) prices is similar across all crops.

[Insert Table 1 about here]

Table 2 presents the expected percentage of revenue attributable to each crop for different crop mixes on each representative farm. The "half and half" crop mix means that the available acres are divided equally among the two crops. When the scenario refers to a majority crop, the majority crop is assumed to be planted on 70 percent of the available acres while the majority crop is planted on the remaining 30 percent.

[Insert Table 2 about here]

Evaluation of Optimal CAWFI

One of the fundamental issues this study addresses involves finding an optimal scale for the CAWFI model in order to customize area yields into farm-level yields more accurately. The optimal weights obtained as an acreage share of crops on the farm were fixed, and a search was conducted to find the optimal scale for the CAWFI model. The optimal scale is equal to the beta coefficients estimated using Equation 20 for each crop and crop mix. Conditioned on the optimal scale, a grid search was conducted to find the optimal coverage level over the range of 80% to 180%, with intervals of 5%. The optimal level was determined by evaluating the certainty equivalent for each coverage level and choosing the coverage level with the highest certainty equivalent.

We evaluate CAWFI with optimal scale and coverage level for both single and multi-crop revenue scenarios for the four geographical regions. GRIP and GRP use a scale ranging from 0.90 to 1.50 and a coverage level ranging from 70% to 90% in 5% increments. Thus, for the restricted CAWFI model, we impose these restrictions on scale and coverage level. . We estimate the percentage difference in certainty equivalents between optimal and restricted CAWFI models for each crop on the single crop farm and for each crop mix in the multi-crop farm.

We also compare the optimal CAWFI model to a “no-insurance” scenario as well as to a hypothetical customizable farm-level whole farm insurance (FWFI) product at 90 percent coverage. The premium used in all scenarios is actuarially fair (premium equals expected indemnity). The premium does not include transaction costs, administrative costs, reserve loading, an insurer’s return on equity, or government premium subsidies. While the assumption of an actuarially fair premium is inconsistent with current federal crop insurance products, it allows one to focus solely on the certainty equivalent value of any risk reduction provided by the insurance product.

Optimal Scale and Coverage Level

Table 3 presents optimal scale and coverage level for each of the representative farms assuming different crop mixes. Optimal scales vary across regions and crop mixes but always exceed 1.00. In general, the Illinois representative farm has lower optimal scales than the Kansas, North Dakota, or Mississippi farms. Optimal coverage levels also vary across regions and crop mixes but are always at least 120%. . The estimated CAWFI optimal scale values vary across crops and regions. The estimated optimal scale for Kansas corn and wheat are 2.74 and 1.63, respectively. Similarly, the estimated optimal scale for North Dakota corn, North Dakota wheat, Illinois corn, Illinois soybeans, Mississippi corn, and Mississippi soybeans are 2.59, 1.79, 1.45, 1.46, 2.01 and 2.32, respectively (table 3). Optimal scale values in excess of 1.00 for area-based insurance is consistent with the findings of Deng, Barnett, and Vedenov (2007).

[Insert Table 3 about here]

Optimal CAWFI versus Restricted CAWFI

Table 4 compares certainty equivalents for CAWFI with optimal scale and coverage to CAWFI with scale and coverage restricted as in the current GRP program. The optimal scale and coverage levels of Table 3 are included as a point of reference. As expected, restricting scale and coverage level reduces the welfare of an insured farmer. Certainty equivalents are reduced in every scenario. The magnitude of the reduction ranges from 3.12% (for soybeans only in Illinois) to 13.85% (for majority soybeans in Mississippi). In general, the restrictions reduce producer welfare the most in riskier production scenarios.

[Insert Table 4 about here]

Table 5 presents the certainty equivalent estimates expressed as ratios comparing different insurance scenarios. As a baseline, the third column expresses the certainty equivalent of FWFI with a 90% coverage level to the certainty equivalent of no insurance. A 90% coverage level is used because given the susceptibility of farm-level insurance products to moral hazard, it is unlikely that a coverage level higher than 90% would ever be offered (the maximum coverage level for current RMA farm-level insurance products is 85%). As would be expected, all of the ratios are greater than one indicating that a producer with the assumed degree of risk aversion would prefer 90% FWFI to having no insurance. A more specific interpretation can be made by focusing on the example of the Kansas farm with the corn only crop mix. In this case, the certainty equivalent for 90% FWFI is 123% of the certainty equivalent with no insurance. In general, the 90% FWFI policy increases certainty equivalents for the Kansas, North Dakota, and Mississippi representative farms much more than for the Illinois representative farm. The insurance is less beneficial for the Illinois farm because this farm is exposed to relatively less revenue risk. Revenue risk is lower because the Illinois farm has lower yield risk and a larger negative correlation between price and yield.

The fourth column presents the certainty equivalent of optimal CAWFI relative to the certainty equivalent of no insurance. Again, as would be expected, all of the ratios are greater than one indicating a preference for optimal CAWFI rather than no insurance. Of more interest is a comparison of columns 3 and 4 for each farm and crop mix. While the ratios of certainty equivalents are similar, optimal CAWFI generally has a higher certainty equivalent relative to the no insurance scenario than does the FWFI with a 90% coverage level. The only notable exception is the Mississippi farm with the soybean only crop mix. In other words, when the farm-level whole farm insurance product has a coverage level restricted to 90% to control for moral hazard, the optimal area-based whole farm insurance product can provide risk protection that is at least as good as that provided by the restricted farm-level product.

The fifth column in table 5 presents the certainty equivalent of CAWFI when scale and coverage level are restricted as in the current GRP product relative to the certainty equivalent of no insurance. While the restricted CAWFI is still preferred to no insurance, in many cases the restrictions greatly reduce CAWFI certainty equivalents relative to CAWFI with optimal scale and coverage level. Again, this finding is consistent with Deng, Barnett, and Vedenov's (2007) findings regarding GRP. The restrictions on CAWFI scale and coverage level reduce certainty equivalents so much that the baseline case of 90% FWFI is almost always preferred to the restricted CAWFI.

Moving Beyond Actuarial Fairness

While the assumption of actuarially fair premiums allows one to focus solely on the risk reduction provided by the various insurance designs, it also imposes a serious limitation in that it ignores transaction costs and administrative costs. This can be seen by focusing on the sixth and seventh columns of table 5. The sixth column shows the expected indemnity of an optimal CAWFI policy as a ratio of the expected indemnity for a 90% FWFI policy. With actuarially fair premiums the premium is equal to the expected indemnity so this column can also be interpreted as the actuarially fair premium of an optimal CAWFI policy as a ratio of the actuarially fair premium for a 90% FWFI policy. The ratio varies between 2.36 and 7.07 implying that the actuarially fair premium for the optimal CAWFI policy is between two and seven times the actuarially fair premium for the baseline 90% FWFI policy. The very high actuarially fair premium for the optimal CAWFI policy is not surprising given the levels of the optimal scale and coverage presented in table 4. This reflects the common insurance notion that assuming no transaction costs or administrative costs, the optimal decision is to fully insure – to protect oneself against the maximum possible loss because there are no costs associated with "swapping money" with the insurer.

But, of course, this isn't very realistic. There are real transaction costs and administrative costs associated with selling and servicing insurance policies. Insurance companies load premiums to cover these costs along with loading for reserves, rating ambiguity, and return on equity. With a loaded (rather than actuarially fair) premium one cannot afford to routinely swap money with the insurer, so one cannot afford to insure at optimal levels of scale and coverage. The seventh column of table 5 presents the expected indemnity (actuarially fair premium) for a CAWFI policy restricted as in GRP as a ratio of the expected indemnity for a 90% FWFI policy.

The ratios are all less than one indicating that the actuarially fair premium for a restricted CAWFI policy would be less than the actuarially fair premium for a 90% FWFI policy. In most cases, the restricted CAWFI policy would have a much lower premium than the 90% FWFI policy. Since index insurance has significantly lower transaction and administrative costs than farm-level insurance, it is also quite likely that the premium loads on the restricted CAWFI policy would be significantly lower than a 90% FWFI policy.

So in the absence of large premium subsidies a restricted CAWFI policy should cost much less than a 90% FWFI policy. The tradeoff is that the 90% FWFI policy generally offers more risk reduction than the restricted CAWFI policy. However, as we saw earlier, given our assumptions on risk aversion, difference in risk reduction between the 90% FWFI policy and the restricted CAWFI policy varies considerably by region and crop mix. For the Mississippi representative farm producing only soybeans the actuarially fair premium for a restricted CAWFI policy would be only 32% of the actuarially fair premium for a 90% FWFI policy. However, the certainty equivalent of a 90% FWFI policy is 181% of the certainty equivalent with no insurance whereas the certainty equivalent of a restricted CAWFI policy is only 155% of the certainty equivalent with no insurance. So while the premium is lower with the restricted CAWFI policy compared to 90% FWFI, the risk reduction (measured as certainty equivalent) is also considerably lower. In contrast for the Illinois representative farm, the actuarially fair premium for a restricted CAWFI policy varies between 44% and 63% of the actuarially fair premium for a 90% FWFI policy (depending on crop mix). However, there is very little difference in the certainty equivalents between a restricted CAWFI policy and a 90% FWFI policy. Given, the low yield risk and negative price-yield correlation for the Illinois farm, none of the insurance scenarios increase certainty equivalents relative to the no insurance scenario as much as with the representative farms in other regions.

[Insert Table 5 about here]

Conclusions

Our study develops a CAWFI model and evaluates the results for four representative farms producing corn, wheat, and soybeans in Illinois, Kansas, Mississippi, and North Dakota. From an operational standpoint it appears relatively straightforward to construct this instrument for crop producers where NASS time series is available for the CAWFI design. While basis risk exists with this product, the onerous record keeping, and data adjustments used to implement AGR are almost entirely avoided. Importantly the concerns of moral hazard are mitigated as county yield is used rather than own-farm yield. Furthermore the adverse selection problem resulting from the not knowing the within farm random variable correlation matrix is precluded as the correlation matrix of interest is the correlation of publically available county data. As anticipated, allowing producers to develop weights across enterprises improves the performance of this design.

We determine the optimal scale and optimal coverage levels for the CAWFI model where farmers are allowed to select these values as needed. The optimal scales for most of the crops in the single-crop context exceed the GRP maximum scale of 1.50 and coverage levels also exceed 100 percent. We also develop a restricted CAWFI model by imposing restrictions on scale and coverage level, and estimate a farm-level FWFI model at 90 percent coverage. Because the certainty equivalents for restricted CAWFI are less than those of optimal CAWFI for all crops and crop mixes across states, relaxing the restrictions on CAWFI can likely increase farmers' expected utility. In the single crop context, optimal CAWFI generates larger certainty equivalents than FWFI for most crop mixes. In multi-crop contexts, optimal CAWFI generates certainty equivalents larger than those for FWFI for all representative farms and all crop mixes. However, expected indemnity payouts for optimal CAWFI are more than three to seven times those of FWFI in multi-crop contexts, and more than four to seven times larger in single crop contexts, depending on geographical regions and crop mixes. Farmers must pay three to seven times more in premiums for optimal CAWFI to obtain the same level of risk protection as with 90 percent FWFI. This result is partially a function of omitting various loads such as delivery cost, credibility loads are not included. If they were, producers would likely not choose such high coverage levels. Conversely we omit subsidies that are included in the current insurance program. While our results suggest relaxing the restrictions imposed on the current GRP and GRIP programs, it appears there is a general perception that it would be inequitable to offer coverages in excess of 100 percent or scale parameters greater than 150 percent.

This study uses whole-farm insurance built on farm-level yields as a baseline model to compare with optimal CAWFI. The results could be extended to compare the optimal CAWFI model with commodity-specific revenue coverage products like Revenue Protection. In practice, insurance products are offered with farm programs, which we do not consider. Another extension could consider all farm support together with optimal CAWFI, which may assist in determining the overlapping effects of optimal CAWFI with other farm-support programs.

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Table 1. Descriptive Statistics of Simulated Data (N=100,000)

Variable	Mean	Std Dev	C.V.	Mean	Std Dev	C.V.
Ending Future Price of Corn	6.19	0.53	0.09			
Ending Future Price of Soybean	13.11	1.54	0.12			
Ending Future Price of Wheat	9.08	0.94	0.10			
Ending MYA price of Corn	6.02	0.49	0.08			
Ending MYA price of Soybean	13.39	1.28	0.10			
Ending MYA price of Wheat	9.02	0.74	0.08			
		Mississippi			**Illinois**	
Corn Farm Yield	145.45	49.53	0.34	182.72	43.2	0.24
Corn County Yield	148.7	12.62	0.08	180.48	22.24	0.12
Soybean Farm Yield	37.53	22.69	0.60	53.29	11.19	0.21
Soybean County Yield	32.76	6.38	0.19	52.56	5.12	0.10
		North Dakota			**Kansas**	
Corn Farm Yield	129.98	76.27	0.59	143.58	77.76	0.54
Corn County Yield	119.75	21.93	0.18	137.95	19.27	0.14
Wheat Farm Yield	46.76	18.25	0.39	32.74	21.6	0.66
Wheat County Yield	45.29	8.14	0.18	35.67	11.09	0.31

Table 2. Share of Revenue by Crop Mix across Representative Farms.

		Revenue Share of Crops		
State	Crop Mix (Acres)	Corn	Soybeans	Wheat
Illinois	Half-and-half	0.618	0.382	–
	Majority corn	0.791	0.209	–
	Majority soybeans	0.410	0.590	–
Kansas	Half-and-half	0.750	–	0.250
	Majority corn	0.875	–	0.125
	Majority wheat	0.562	–	0.438
Mississippi	Half-and-half	0.647	0.353	–
	Majority corn	0.810	0.190	–
	Majority soybeans	0.440	0.560	–
North Dakota	Half-and-half	0.655	–	0.345
	Majority corn	0.816	–	0.184
	Majority wheat	0.448	–	0.552

Table 3. Optimal Coverage Level and Optimal Scale by Representative Farm and Crop Mix [a, b].

State	Acreage share	Optimal Scale	Optimal Coverage Level
Kansas	Corn only	2.74	1.35
	Wheat only	1.63	1.40
	Half-and-half	2.02	1.25
	Majority corn	2.28	1.35
	Majority wheat	1.87	1.35
North Dakota	Corn	2.59	1.30
	Wheat	1.79	1.35
	Half-and-half	1.98	1.35
	Majority corn	2.21	1.45
	Majority wheat	1.81	1.30
Illinois	Corn	1.45	1.30
	Soybean	1.46	1.40
	Half-and-half	1.29	1.20
	Majority corn	1.32	1.30
	Majority wheat	1.41	1.20
Mississippi	Corn	2.01	1.25
	Soybean	2.32	1.50
	Half-and-half	2.40	1.20
	Majority corn	2.12	1.25
	Majority wheat	2.85	1.20

[a]All optimal scale coefficients are significant at the 1% level.
[b]By assumption, major crop occupies 70% of planted acres.

Table 4. Optimal CAWFI versus Restricted CAWFI by State and Crop Mix [a, b].

State	Crop	Optimal Scale for Optimal CAWFI	Optimal Coverage Level for Optimal CAWFI	Maximum GRP Scale for Restricted CAWFI	Maximum GRP Coverage Level for Restricted CAWFI	Percent CE Reduction in Optimal CAWFI (%)
Kansas	Corn only	2.74	1.35	1.50	0.90	-12.98
	Wheat only	1.63	1.40	1.50	0.90	-10.77
	Half-and-half	2.02	1.25	1.50	0.90	-9.15
	Majority corn	2.28	1.35	1.50	0.90	-10.36
	Majority wheat	1.87	1.35	1.50	0.90	-8.49
North Dakota	Corn only	2.59	1.30	1.50	0.90	-13.57
	Wheat only	1.79	1.35	1.50	0.90	-5.44
	Half-and-half	1.98	1.35	1.50	0.90	-6.28
	Majority corn	2.21	1.45	1.50	0.90	-8.38
	Majority wheat	1.81	1.30	1.50	0.90	-4.48
Illinois	Corn only	1.45	1.30	1.45	0.90	-4.78
	Soybeans only	1.46	1.40	1.46	0.90	-3.12
	Half-and-half	1.29	1.20	1.29	0.90	-3.64
	Majority corn	1.32	1.30	1.32	0.90	-3.92
	Majority soybeans	1.41	1.20	1.41	0.90	-3.56
Mississippi	Corn only	2.01	1.25	1.50	0.90	-9.61
	Soybeans only	2.32	1.50	1.50	0.90	-11.94
	Half-and-half	2.40	1.20	1.50	0.90	-11.27
	Majority corn	2.12	1.25	1.50	0.90	-9.95
	Majority soybeans	2.85	1.20	1.50	0.90	-13.85

[a]All optimal scale coefficients are significant at the 1% level.
[b]By assumption, major crop occupies 70% of planted acres.

Table 5 Optimal CAWFI versus No-Insurance and 90% FWFI by State and Crop Mix [a].

State	Crop	Ratio of CE in 90% FWFI to No Program	Ratio of CE in Optimal CAWFI to No program	Ratio of CE in Restricted CAWFI to No Program	Ratio of Expected Indemnity in Optimal CAWFI to 90% FWFI	Ratio of Expected Indemnity in Restricted CAWFI to 90% FWFI
Kansas	Corn only	1.23	1.23	1.08	3.84	0.28
	Wheat only	1.31	1.32	1.18	2.36	0.75
	Half-and-half	1.15	1.17	1.07	3.41	0.39
	Majority corn	1.18	1.19	1.08	4.09	0.34
	Majority wheat	1.15	1.17	1.08	4.41	0.44
North Dakota	Corn only	1.28	1.27	1.12	2.86	0.35
	Wheat only	1.11	1.12	1.06	3.76	0.57
	Half-and-half	1.10	1.11	1.05	4.40	0.45
	Majority corn	1.15	1.16	1.07	4.43	0.40
	Majority wheat	1.07	1.09	1.04	4.66	0.48
Illinois	Corn only	1.10	1.10	1.04	4.94	0.63
	Soybean only	1.03	1.05	1.02	7.49	0.56
	Half-and-half	1.03	1.06	1.02	5.67	0.52
	Majority corn	1.04	1.07	1.03	6.48	0.59
	Majority soybeans	1.01	1.04	1.01	7.07	0.44
Mississippi	Corn	1.10	1.13	1.03	4.14	0.16
	Soybeans	1.81	1.70	1.55	3.36	0.32
	Half-and-half	1.09	1.15	1.03	4.20	0.14
	Majority corn	1.09	1.13	1.03	4.76	0.15
	Majority soybeans	1.11	1.18	1.04	4.06	0.13

[a] Scale and coverage levels for Optimal and Restricted CAWFI included in Table 4.