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Proceedings of Regional Committee NCT-173
"Financing Agriculture and Rural America: Issues of Policy, Structure and Technical Change"
Denver, Colorado
October 6-7, 1997

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April 1998

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EVALUATING ALTERNATIVE CROP INSURANCE DESIGNS

Hong Wang[1], Steven D. Hanson, Robert J. Myers and J. Roy Black

Farmers may choose from a variety of financial instruments to manage the income risk resulting from price and yield variability. The Federal Crop Insurance Corporation (FCIC) now provides many producers with the option of purchasing crop insurance that pays indemnities based on the producer's individual yield or, alternatively, on the average yield for the county in which the producer resides.[1] The costs and benefits from using crop insurance may differ based on the design of the instrument chosen by the producer.

The objective in this paper is to investigate the relative performance of individual-yield and area-yield crop insurance programs. Performance is measured by farmer participation rates and farmer welfare in an expected utility framework. For each yield index (area versus individual) the effect of restrictions on the maximum trigger yield (the yield level which triggers insurance payouts), and on the proportion of acres insured under the program, are evaluated and compared. In addition, the impacts of alternative indemnification prices on the performance of each type of insurance program are examined. Each set of design features (yield index, trigger yield restriction, proportion of insured acres, and indemnification price) may alter the performance and implementation costs of a crop insurance program.

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The analysis is conducted in a portfolio setting where the producer may use a variety of risk management instruments including futures, options, government deficiency payments, and crop insurance.[2] Allowing for a portfolio of risk management instruments is important because the existence of other risk management instruments can influence how producers view and use crop insurance. While other instruments are allowed in the risk management portfolio, we only report participation results for crop insurance to maintain focus on the study objective. Because of the complexity of the decision problem, we use stochastic simulation and numerical optimization to investigate the risk management behavior of a representative corn farm in Iowa. Using a numerical framework allows us to specify a joint price and yield generating process that is reflective of that actually faced by corn farmers in southwest Iowa, and still solve the decision problem in an expected utility framework. The disadvantage is that the results may be sensitive to the specific assumptions used to implement the numerical model.

Background

Since 1938 the FCIC has provided some form of multiple peril crop insurance to many U.S. farmers. The Federal Crop Insurance Act of 1980 extended the scope of the program by including additional crops and counties, and by expanding the number of deductible levels. The Act also facilitated the delivery of services and retention of risk by the private sector. The FCIC retained the role of product design and rating, and also provided reinsurance to the private sector, but the private sector delivered most of the product and held some of the risk. The 1980 Act authorized subsidization of premiums in an effort to increase program participation and reduce the need for area-wide federal disaster assistance. However, high costs and low participation rates, relative to the target levels set by congress, have plagued the program in some markets.

The key component of the 1980 Act was a revised form of Multiple Peril Crop Insurance (MPCI) which protects crop farmers from all natural risks including unavoidable losses from drought and storm damage. The Crop Insurance Act of 1994 extended the range of deductibles allowing the farmer to select a coverage level between 50% and 75% of the farm's "expected" yield and then choose from a range of prices at which losses will be indemnified. The indemnity price cannot exceed the maximum level set by the FCIC, which is an estimate of what the US average price will be at harvest. If the farmer's realized yield falls below the selected coverage level, the producer receives a payment, per insured acre, equal to the yield short-fall times the elected price option. The cost of the insurance to the farmer is a function of both the coverage level and the pricing option.

The revised MPCI program has fallen short of many policy makers' expectations. The failure of the MPCI program to meet expectations in selected markets has been attributed, in part, to the use of individual farm yield in measuring yield loss. Because farmers presumably have better information about their yield probability distributions than insurers, and can influence their yield distribution after the insurance is purchased, the MPCI program has been plagued by adverse selection and moral hazard problems. Also, while each farmer's yield shortfall is used to determine the indemnity payment, the premiums charged to farmers are based on average expected indemnity payments across classified groups of farmers. In addition, the program is hindered by the high level of administrative costs necessary to implement a program which uses individual farm yields to determine indemnification levels. Thus, although premiums are subsidized, the premium offered to many farmers exceeds the actuarially fair amount.

In 1949, Halcrow proposed a crop insurance plan in which indemnification would be based on shortfalls below a reference yield for a geographic region surrounding each farm. The reference yield would be an estimate of the long-run expected average yield for the region. In 1988, Congress authorized the Commission for the Improvement of Crop Insurance which rediscovered the area-yield concept and recommended a pilot program (Baquet and Skees; Skees, Black and Barnett). In 1994 the FCIC began offering a pilot program known as the Group Risk Plan (GRP) which used county-average yields to indemnify farm losses (Baquet and Skees). The pilot program has been expanded to cover corn, sorghum, soybeans and cotton in counties that have at least 15,000 acres of the crop and 30 years of NASS yield data. Wheat and forages are also insured in a number of counties. The GRP pays an indemnity any time the average county yield falls below a selected trigger level. The trigger yield may be selected from six levels of coverage: 65%, 70%, 75%, 80%, 85%, and 90% of expected county yield (Baquet and Skees). Indemnification is determined by multiplying the percent shortfall below the trigger yield times the dollar value of protection selected.

An insurance program which uses an area-yield index to determine indemnities, such as GRP, offers a number of potential advantages over a program using an individual-yield index, such as MPCI (Miranda). Because the area-yield index is based on average yield across a geographic region, both the farmer and insurer will have roughly equal information regarding the distribution of average yields, significantly reducing the classification problems which have led to adverse selection in programs based on individual farm yield. Another advantage is that individual farmers generally have little impact on average area yield, which eliminates moral hazard. In addition, better data is typically available on the distribution of area yields than individual farm yields, which will allow insurers to more accurately determine the actuarially fair premium for the area. Finally, the costs to administer a program based on an area-yield index will be lower than for a program based on individual yields because loss adjustments for individual farms, and individual yield histories, are not needed.

A disadvantage of an area-yield index is that the indemnity payout is no longer perfectly correlated with the actual loss experienced by farmers. A farmer may experience a significant crop shortfall and receive no indemnity payment if average yields in the area remain above the selected trigger yield level. Likewise, a farmer may realize an above average yield and still receive an indemnity payment if average yields in the area fall below the selected trigger yield. The less than perfect correlation between the individual farm yield and the area-yield index is a form of "yield basis risk" and reduces the effectiveness of the insurance instrument in managing individual farm income risk. The greater the yield basis risk (the lower the correlation between farm yield and area yield) the less effective area-yield insurance will be in the management of individual farm risk.

The Model

The model contains two periods—a planting period when the level of each available risk management instrument is selected given the farmer's estimate of the conditional joint price and yield distribution; and a harvest period where prices and yields are realized and profit is determined. Let p be a random price vector consisting of cash and futures prices for corn in the harvest period, and y be a random yield vector consisting of the individual farm's corn yield and a corn yield index (which may be the individual farm's yield or some average area-yield) which is used to trigger crop insurance payouts.[3] In the planting period, the farmer chooses a portfolio of risk management instruments, x, to maximize the expected utility of per acre profits,

$$(1) \qquad \max_{x} \int_{0}^{\infty} \int_{0}^{\infty} u[\pi(p,y;\, x)]\, g(p,y|\Omega)\, dp\, dy$$

where $u(\cdot)$ is an increasing and concave von Neumann-Morgenstern utility function, $\pi(\cdot)$ is a per acre profit function, and $g(\cdot|\Omega)$ is the joint density for prices and yields conditional on Ω, a set of information available when x is chosen.[4] The utility function is assumed to have constant relative risk aversion (CRRA) $u(\pi) = (1-\theta)^{-1}\pi^{(1-\theta)}$ where the relative risk aversion parameter is set at $\theta = 2$.

The profit function has four components,

$$\pi(p,y;\, x) = NP + FO + CI + GP \tag{2}$$

where
$$NP = py - c;$$
$$FO = h(f_0 - f) + z[\max(0,\, s - f) - k];$$
$$CI = m\,[w\,\max(0,\, y_0 - y_i) - \lambda a(y_0,\, w)];\ \text{and}$$
$$GP = b[y_b(1 - q - r)\max(0,\, p_0 - p) - q(NP + CI)].$$

The first component, NP, is the normal profit from producing and selling corn. Thus, p is the cash price of corn at harvest, y is the individual farm yield, and c is production costs per acre.[5] The second component, FO, is net return from futures and option trading. Hence, h is the quantity of futures contracts sold (purchased if negative) per acre, f_0 is the initial futures price when h is chosen, f is the futures price at harvest, and z is the number of put options purchased (written if negative) per acre with strike price s and premium k. The third component, CI, represents net returns from crop insurance. Thus, w is the price used to value yield shortfalls in the crop insurance scheme, y_0 is the yield level which triggers crop insurance payouts (i.e. the coverage level chosen by the farmer), and $a(y_0, w)$ is the farm's actuarially fair crop insurance premium per acre which depends on y_0 and w. The constant λ inflates or deflates the actuarially fair premium to reflect transaction costs and/or difficulties in assessing the distribution of y_i.[6] Notice that the crop insurance scheme depends on realizations of a random yield index y_i which might be the individual farm yield y (as in conventional multiple peril crop insurance) but which also might be county-average yield (as in an area-yield scheme). The proportion of planted acres covered by crop insurance is given by m.

The fourth and final component of profits, GP, is net returns from participation in a government deficiency payment program. Here b is a binary variable which equals one if the farmer chooses to participate and zero if not; r is the proportion of total land which is "flexible" (not included in base acres); q is the proportion of land which must be set aside to be eligible for government payments; and p_0 is the target price. Deficiency payments are based on the difference between the target price and the market price (whenever this difference is positive) but payments are made only on the base yield for the farm, y_b. The cost to the farmer of participating in the program is the value of the set aside, which depends on realized yield not base yield.

The choice vector, $x = (h, z, y_0, m, b)$ consists of decisions about futures and options positions, the trigger yield and coverage levels for crop insurance, and whether or not to participate in government programs. It is assumed that these decisions are made simultaneously in a portfolio context taking the remaining parameters and probability distributions as given. The profit function (2) is a simplified representation of reality in a number of respects but it does incorporate a stylized version of the four main risk management instruments which are, or have recently been, available in U.S. agriculture.

Price and Yield Distributions

We calibrate a joint distribution of cash and futures prices at harvest, conditional on information available at planting, by estimating a bivariate ARCH model with a seasonal component for cash and futures prices. The data are weekly cash and futures prices for corn from the first week in May 1989 to the last week in April 1994 obtained from the Agricultural Extension Service in the Department of Economics at Iowa State University. The cash price is the average price for each Thursday in the southwestern Crop Reporting District of Iowa. Futures data are for the December contract on the Chicago Board of Trade and reflect settlement prices at the close of each Thursday.

Phillips-Perron tests suggest the presence of unit roots in the logarithm of both futures and cash price data (Phillips; and Perron). As a result, the model is estimated in first difference form.

Examination of the data suggested a cyclical pattern in the volatility of the price changes and so a seasonal component was included in the conditional variance model (Fackler). The use of sine and cosine functions are used to model seasonality because they are cyclical functions and can be combined in different frequencies to provide a flexible representation of the cycle suggested by the data (Kang and Brorsen). Lagrange multiplier tests also suggests the presence of ARCH effects which indicate stochastic, but correlated, changes in volatility are also present in the data (Green). Hence, the model contains both ARCH and seasonality components. The specification of the seasonal component and the ARCH process is determined by the data.

The bivariate cash and futures price process is modeled as:

$$(3) \qquad \Delta \ln \boldsymbol{p}_t = \boldsymbol{\mu} + \boldsymbol{\epsilon}_t, \qquad \boldsymbol{\epsilon}_t | \Omega_{t-1} \sim N(0, \boldsymbol{H}_t)$$

where $\Delta \ln \boldsymbol{p}_t = (\Delta \ln f_t,\ \Delta \ln p_t)'$ is a vector of differences in the logarithm of futures and cash prices; $\mu = (\mu_f,\ \mu_p)'$ is a vector of constants; $\epsilon_t = (v_t,\ u_t)'$ is a vector of disturbance terms; and H_t is a time-varying conditional covariance matrix given by:

$$(4) \qquad \begin{pmatrix} H_{11,t} \\ H_{21,t} \\ H_{22,t} \end{pmatrix} = \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{pmatrix} + \begin{pmatrix} \alpha_{11} & 0 & 0 \\ 0 & \alpha_{21} & 0 \\ 0 & 0 & \alpha_{31} \end{pmatrix} \begin{pmatrix} v_{t-1}^2 \\ v_{t-1}u_{t-1} \\ u_{t-1}^2 \end{pmatrix} + \begin{pmatrix} \alpha_{13} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} v_{t-3}^2 \\ v_{t-3}u_{t-3} \\ u_{t-3}^2 \end{pmatrix} + \begin{pmatrix} \alpha_{19} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} v_{t-9}^2 \\ v_{t-9}u_{t-9} \\ u_{t-9}^2 \end{pmatrix} + \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \end{pmatrix} \sin(2\pi d_t/52)$$

where d_t is an index designating the week number in the year. The model for the futures and cash price process, estimated using maximum likelihood methods, is shown in table 1 along with diagnostic tests that suggest the model does a good job of characterizing the joint price process.

The distribution of harvest prices conditional on information available at planting is the distribution of a multi-step forecast error which has no closed form in the ARCH model, even when the innovations are conditionally normal (Engle). Hence, a discrete estimate of the required joint distribution is generated through stochastic simulation (Myers and Hanson). The frequency distribution of the simulated harvest prices is then used as an estimate of the joint distribution of cash and futures prices at harvest, conditional on information available at planting.[7]

Recent work by Moss and Shonkwiler uses an inverse hyperbolic sine function to model yield distributions around a measure of central tendency. The yield process might be thought of as having stochastic shocks—which are due to factors such as weather, insects and disease—around a mean yield level which changes over time as technology improves. The residuals around the time varying mean are corrected for skewness and kurtosis by use of a transformation based on the inverse hyperbolic sine function. This model simultaneously shrinks large residuals toward zero and parameterizes the skewness and kurtosis of the distribution. Equally important, the model can characterize both trend and stationary components of yields in a way that easily accommodates the use of time series data. The model used in this study is a trend stationary variation of the model developed by Moss and Shonkwiler.

The data used to estimate the yield process are the logarithm of the average annual yield for Adair County in Iowa from 1928 to 1993. Phillips-Perron tests suggest the hypothesis of a unit root in the logarithm of yields can be rejected against the alternative of stationarity around a linear trend, so the model is estimated as:

$$
\begin{aligned}
lny_t &= a + blny_{t-1} + ct + e_t \\
e_t &= \frac{\sinh[\theta(n_t+\delta)]}{\theta} \qquad (5) \\
n_t &\sim N(0,\zeta^2)
\end{aligned}
$$

where lny_t is the logarithm of yield at time t; e_t is the non-normal disturbance; *sinh(.)* is the hyperbolic sine transformation (HST); n_t is an identically and independently distributed (i.i.d.) normal disturbance with mean zero and variance ζ^2; and δ and θ are parameters measuring skewness and kurtosis respectively. Generally, when δ is positive e_t is skewed to the right, if it is negative e_t is skewed to the left, and if it is zero e_t is symmetric. When θ is zero, e_t is as kurtotic as in the normal distribution and e_t becomes more and more kurtotic as the magnitude of θ increases either positively or negatively. The lagged term lny_{t-1} captures autocorrelation, so that e_t is i.i.d.

The first equation in (5) is a conditional mean equation which describes the central tendency of the current yield as being partially determined by time and last period's yield. The realized yield is a combination of the central tendency and a stochastic non-normal shock, e_t, which has a non-zero mean determined by the three parameters of the transformation. The second equation transforms the normal shocks into non-normal shocks by the modified HST (Moss and Shonkwiler). The model, estimated using maximum likelihood methods, is shown in table 2 along with some diagnostic statistics that suggest the model fits the data well.

Because the time series data on yields are annual observations, we can predict the yield process for the upcoming year by specifying the current year's yield and iterating the model forward one period. There is no closed form distribution for the prediction error for this conditional mean but it is straightforward to simulate empirically. Again, the frequency distribution of the simulated realizations is used as the estimated discrete county yield distribution.

Individual farm yield distributions were derived from the county yield distribution by making scale adjustments. Data on individual farm yields were available for each farm in the county that had purchased MPCI and had at least 10 years of yield data. The small size of the farm-level yield series leads to difficulties in identifying the higher moments of the farm-level yield generating process with an acceptable level of precision. As a result, the farm-level data was only used to provide information about the central tendency and variance of the farm-level yields. To maintain consistency, the estimated trend parameters for the county yield model (5) were imposed on the individual farm time series. The results were used to detrend the farm level yield series to determine the adjustment to the location and scale of the county yield distribution which would be representative of the individual farm yield distributions in the county. Following this procedure, the farm-level yield standard deviation was adjusted to 120% of the county yield distribution (roughly the average of the individual farm standard deviations) and the mean farm-level yield was set equal to the mean county yield.

Correlation between the simulated price and county yield distributions is imposed using the normal transformation procedure described by Taylor. Taylor's method empirically transforms the marginal distributions of any pair of general distributions to the standard normal. Bivariate standard normal random draws are then taken with the desired level of rank correlation imposed on the bivariate normal generator. The realized draws are then transformed back to the non-normal distributions using the original marginal distributions. The end result is a joint distribution with marginal distributions similar to the original independent distributions, but with a desired degree of correlation imposed. The sample correlation between yield prediction errors and April-December futures price changes from 1975 to 1995 is -0.50, which is used as the representative correlation level. Because of the importance of the price-yield correlation, and because these correlations are likely to change across regions, results are also generated for the case where zero price-yield correlation is imposed on the joint distribution, for purposes of comparison.

The correlation between county yields and individual farm yields is also important when investigating crop insurance based on area (county) yield. Hence, Taylor's method was used again to impose a representative degree of correlation between the simulated individual and county yield distributions. The sample correlation between available individual farm and county yield prediction errors in Adair county from 1983 to 1992 averaged 0.85, and so this was imposed as the correlation between the individual yield and county yield in the simulation model.[8] Table 3 shows the sample moments and correlation matrix for the simulated multivariate distribution of harvest prices, individual farm yield, and county yield, conditional on information available at planting.[9]

Other Calibrations

The remaining model parameters were selected to be representative of those faced by farmers in southwest Iowa during the 1994-95 crop year. The futures price was set at $2.56 per bushel, the Chicago Board of Trade price for the last Thursday in April 1994. The strike price for the option was set at $2.60 per bushel, the closest available strike price to the futures price, and both futures and options were restricted to be unbiased (expected gains from trading are zero). The target price was set at $2.75 per bushel, the 1994 level. There was no acreage reduction requirement in 1994. However, the normal flexible acreage requirement was set at 15% of base yield (expected yield). The insured acreage level was set initially at 100% of planted acreage as specified in the current crop insurance programs. The indemnification price was set at the expected harvest price.

The area yield crop insurance (AYCI) premium was assumed to be actuarially fair. The individual yield crop insurance (IYCI) premium level for the farm was initially set 35% above the actuarially fair level (λ=1.35), to reflect the transaction costs associated with delivering IYCI and the premium loading effect associated with adverse selection in a pool classification scheme.[10]

Results

Using the calibrations for the representative farmer, the decision problem in (1) is solved using the Optmum module in GAUSS under a variety of different scenarios. Farmer participation and welfare levels are compared for the cases where the farmer uses IYCI and AYCI. Farmer welfare is defined by a willingness-to-pay measure (WTP), calculated as the amount of sure income that must be provided to the farmer in the case where no risk management instruments are available, in order to generate the same level of expected utility achieved under optimal use of the specified risk management portfolio.[11] The impacts of trigger yield restrictions, restrictions on the amount of insured acres, alternative indemnification prices, and different premium loadings are also evaluated.

Economic Impacts of Coverage Restrictions

The current crop insurance contract designs specify the maximum trigger yield to be 75% and 90% of expected yield for IYCI and AYCI, respectively. In addition, the amount of acreage insured under each program is restricted to be 100% of the planted acreage. These restrictions may impact the effectiveness of each insurance instrument in managing risk and generating farmer welfare. We study these impacts by solving the stochastic simulation model for our representative farmer using alternative levels of trigger yield and insured acreage restrictions. The results are used to examine the impacts of coverage restrictions on the performance of IYCI and AYCI for three portfolios of risk instruments: 1) crop insurance alone; 2) crop insurance, futures, and options; and 3) crop insurance and a deficiency payment program.

Table 4 shows optimal trigger yield levels, insured acreage levels, and WTP measures for a portfolio that only uses crop insurance to manage income risk. With negative price-yield correlation (-0.50) the optimal trigger yield for IYCI is 86.8% of expected yield, which leaves the farmer's income exposed to some yield variability. This occurs because of the IYCI premium loading and the negative price-yield correlation. The premium loading lowers the expected income level of the farmer as more coverage is taken out, thus reducing the incentive to insure against yield shortfalls. The "natural hedge" provided by the negative price-yield correlation also reduces motivation to use crop insurance by reducing the impacts of yield risk on profit variability. Because the optimal trigger yield for IYCI is not much higher than the current 75% maximum, the opportunity cost to the farmer, in terms of WTP, of the current IYCI trigger yield restriction (as opposed to allowing the optimal level of 86.8%) is only $0.71 per acre.

The optimal trigger yield for AYCI is 121.6% of expected yield. This is much higher than under IYCI because the AYCI premium is actuarially fair so that the farmer can choose any coverage level without reducing expected profit. However, there is still some small residual yield risk because the natural hedge provided by the negative price-yield correlation makes it more efficient to manage income risk by keeping some yield variability. The opportunity cost to the farmer of the current 90% AYCI trigger yield restriction is $4.36 per acre. Thus, the 90% AYCI trigger yield restriction imposes a important cost on the representative farmer.

Under the current trigger yield restrictions of 75% for IYCI and 90% for AYCI, and assuming a 35% premium loading for IYCI and 0.85 correlation between area and individual farm yield, then IYCI is the preferred instrument, providing an additional $3.28 per acre compared to AYCI. Notice, however, that relaxation of the 90% trigger yield restriction under AYCI generates an additional $4.36 per acre in WTP, making it the preferred instrument (by $1.08 per acre). There are sound economic reasons why coverage restrictions should be placed on an IYCI program because such restrictions can partially counteract moral hazard and adverse selection problems. In the case of AYCI, however, there is no compelling economic justification for coverage restrictions. Moral hazard and adverse selection should be virtually non-existent under AYCI, so there are no economic costs associated with letting farmers choose whatever coverage level they want. Once the coverage restrictions on AYCI are removed, the negative effects of yield basis risk are dominated by the positive effects from elimination of the premium loading, and AYCI becomes the preferred instrument.[12]

With no price-yield correlation, the optimal trigger yields increase to 92% of expected yield for IYCI and to the maximum yield under AYCI. This increase in the optimal trigger yields occurs because, in the absence of the natural hedge which resulted from the negative price-yield correlation, the farmer uses crop insurance solely to manage yield risk. It is still not optimal for the farmer to completely eliminate yield risk when IYCI is being used because the premium loading still reduces expected income as the coverage level is increased. However, there is no premium loading under AYCI and full insurance is taken out in this case.

Under no price-yield correlation and the current trigger yield restrictions, IYCI is again the preferred instrument, with a WTP measure which is $4.82 above that provided by AYCI. However, as in the case of negative price-yield correlation, if the coverage restriction for AYCI is removed, AYCI becomes the preferred instrument with a WTP that is $4.53 above the level provided by IYCI.

The bottom half of table 4 shows the participation levels and welfare measures when the farmer is allowed to choose both the coverage level and the amount of insured acres. With negative price-yield correlation and no coverage restrictions the optimal trigger yield for IYCI is 87.9% of expected yield and the optimal amount of insured acreage is 95.1% of planted acreage. For AYCI, the optimal trigger yield is 132.4% of expected yield and the optimal insured acreage is 85.3% of planted acreage. The amount of insured acreage increases when trigger yield restrictions are imposed, suggesting that increasing the level of insured acreage can act as a partial substitute for maximum restrictions on coverage levels. At the current levels of trigger yield restrictions, the optimal level of insured acreage is above 100% of planted acreage for both IYCI and AYCI.

Restricting the level of insured acreage to 100% of planted acreage when there is negative price-yield correlation imposes only a small opportunity cost on the farmer when there are no trigger yield restrictions, decreasing WTP only $0.02 per acre for IYCI and $0.30 per acre for AYCI. Under current trigger yield restrictions, the decrease in WTP is $0.22 per acre for IYCI and $0.16 per acre for AYCI. With no price-yield correlation, the level of insured acreage tends to increase relative to the case of negative price-yield correlation. Once again, however, the opportunity cost to the farmer of restricting the level of insured acreage to planted acreage is relatively small ranging from zero to $0.64 per acre.

Table 5 shows participation levels and farmer welfare measures for alternative trigger yield and insured acreage restrictions when the representative farmer can include crop insurance, futures, and options in the portfolio. Adding instruments into the portfolio which are designed specifically to manage price risk may change the performance of the crop insurance instruments because crop insurance no longer needs to be used to cross hedge price risk.

With futures and options in the portfolio, the optimal trigger yield levels increase slightly with negative price-yield correlation and, as expected, remain essentially the same with no price-yield correlation. In the case of negative price-yield correlation, futures and options are used to decrease the level of price risk, allowing crop insurance to be used specifically to manage yield risk. With zero price-yield correlation, crop insurance could not be used cross hedge price risk anyway, and so the addition of futures and options has little impact on the optimal trigger yield.

The marginal value of the opportunity to trade futures and options is relatively small compared to the WTP for the opportunity to take out crop insurance alone. The addition of futures and options to the portfolio increases the WTP in the range of $0.15 to $2.15 per acre with negative price-yield correlation and $2.81 to $5.86 per acre with zero price-yield correlation, depending on coverage restrictions. Futures and options are more valuable in the case of no price-yield correlation because crop insurance cannot be used to cross hedge price risk, and so the availability of an instrument aimed specifically at managing price risk is more valuable. By comparison, the WTP for adding crop insurance only to the portfolio ranged from $18.32 to $33.49 per acre for the representative farmer. Note, however, that the marginal value of futures and options may be much higher if crop insurance is excluded from the portfolio.

IYCI continues to perform better than AYCI under the current trigger yield restrictions when futures and options are added to the portfolio. However, when the AYCI trigger yield restriction is removed, AYCI is preferred to IYCI at the current 75% restriction. Once more, this suggests that removing the AYCI trigger yield restrictions will improve its relative performance to the point where it is preferred to IYCI.

The bottom half of table 5 shows the participation and welfare levels when both the trigger yield and insured acreage level are selected by the representative farmer using crop insurance, futures and options. With negative price-yield correlation, the optimal insured acreage levels increase slightly when futures and options are added to the portfolio, allowing more efficient management of both price and yield risk. When there is no price-yield correlation, adding futures and options to the portfolio causes little change in the level of insured acreage. The opportunity cost of restricting insured acreage to 100% of planted acreage is again relatively small, ranging from $0.00 to $1.38 per acre. Once again, IYCI is the preferred instrument at the current levels of trigger-yield restriction, while AYCI is the preferred instrument when the AYCI trigger-yield restriction is removed.

Table 6 shows participation levels and welfare measures when crop insurance and a government deficiency payment program are included in the portfolio. The deficiency payment program provides a mechanism which may help manage price risk, as well as provide an implicit subsidy to program participants. The current farm bill has recently eliminated the deficiency payment program for the foreseeable future. However, it is still informative to analyze the role of crop insurance in the presence of the deficiency payment program. Contrasting these results with the earlier analysis, which did not include a deficiency payment program, will provide insights into potential changes in the role of crop insurance as a result of eliminating the program.

With deficiency payments included in the portfolio and negative price-yield correlation the optimal trigger yield is slightly higher than in alternative portfolios under IYCI, and goes to the maximum yield under AYCI. WTP for relaxing the trigger yield under AYCI remains substantial. Indeed, the current 90% coverage restriction under AYCI has a $7.66 per acre opportunity cost (compared to $4.36 under crop insurance only and $6.37 under crop insurance, futures, and options). The WTP measures increase significantly when the deficiency payment program is included in the portfolio, mostly as a result of the $33 per acre expected subsidy implicit in the program.

When both trigger yield and insured acreage are allowed to be selected, the participation levels are similar to the portfolio containing futures and options. Once again, the opportunity costs of the current restrictions on insured acreage are relatively small, ranging from $0.00 to $1.59 per acre.

As in the other portfolios, IYCI is the preferred insurance instrument at the current levels of trigger yield restriction but AYCI is preferred when the AYCI trigger-yield restriction is removed. Elimination of the deficiency payment program does not have strong impacts on the role of crop insurance or relative performance of IYCI and AYCI for the representative farm studied here, although it does reduce farmer welfare considerably (given exogenous prices).

Each portfolio was also examined using three alternative choices for crop insurance indemnification price—expected futures price, realized futures price, and realized cash price. The preferred pricing mechanism varied depending on the portfolio and the degree of price-yield correlation for both IYCI and AYCI. However the difference in WTP was generally less than $1 per acre across the different pricing alternatives, much below the potential gains from eliminating the AYCI trigger yield restrictions.

Impacts of Yield Basis Risk

Because of the moral hazard and adverse selection problems associated with IYCI, a number of restrictions have been built into the contract design. In addition, the IYCI premium is typically set at a level which is above the actuarially fair amount for many farmers in a given risk pool. One result is lower program participation by farmers than would occur in a more complete insurance market with instruments that are priced near actuarially fair levels to each potential participant.

The relatively low level of transaction costs, moral hazard, and adverse selection associated with AYCI allow more flexibility in contract design, and premiums that may be close to actuarially fair for all participants. However, these advantages may be offset by the existence of yield basis risk which reduces the ability of AYCI to manage individual farm yield risk. The tradeoff between the combined impact of transaction costs, moral hazard, and adverse selection associated with IYCI, and the reduced ability of AYCI to manage individual farm risk as yield basis risk increases, is evaluated in this section.

For each level of yield basis risk in AYCI, there exists an IYCI premium loading which makes the representative farmer equally well off using either IYCI or the actuarially fair AYCI. This premium loading is the amount the IYCI "indifference premium" exceeds the actuarially fair IYCI premium, and can be thought of as a measure of the importance of yield basis risk. If the premium loading is zero then farmers are not willing to pay more than the actuarially fair premium in order to eliminate yield basis risk, and so yield basis risk has negligible effects. But as the premium loading gets larger then farmers are willing to pay much higher than the actuarially fair premium in order to move to an IYCI program which eliminates yield basis risk. Thus, higher levels of premium loading are expected to be associated with higher levels of yield basis risk (lower levels of area-individual farm yield correlation).

Figure 1 shows the size of the premium loading as a function of the level of yield basis risk for the three portfolios of risk instruments: a) crop insurance only; b) futures, options, and crop insurance; and c) deficiency payment program and crop insurance. The premium loading is defined as the ratio of the “indifference premium” (the IYCI premium that causes indifference between the IYCI instrument and an actuarially fair AYCI instrument with the degree of yield basis risk indicated) to the actuarially fair IYCI premium. For each portfolio, the premium loading is shown for four cases: 1) negative price-yield correlation and current trigger yield restrictions; 2) zero price-yield correlation and current trigger yield restrictions; 3) negative price-yield correlation and no trigger yield restriction; and 4) zero price-yield correlation and no trigger yield restriction.

As expected, when yield basis risk decreases (farm-county yield correlation increases) the premium loading decreases, approaching the actuarially fair premium as farm-county yield correlation goes to one. At high levels of farm-county yield correlation, AYCI is better able to manage yield risk and so the premium loading is relatively small. The premium loading begins increasing significantly as the yield correlation drops below 0.90 and the rate of increase becomes relatively steep as the correlation falls below 0.75. The availability of pricing instruments in the portfolio reduces the size of the premium loading at low levels of farm-county yield correlation.

With no trigger yield restrictions, the premium loading is 1.33 (33 percent higher than the actuarially fair premium) at the average level of farm-county yield correlation (0.83) when the farmer uses only crop insurance. In this case, the farmer would prefer AYCI when the IYCI premium loading is at the 35% benchmark. Indeed, for any farm-county yield correlation level above the average of 0.83, the farmer prefers AYCI in all portfolios with one exception, the portfolio with negative price-yield correlation and the government program.

Under current trigger-yield restrictions, the premium loading tends to be higher than in the absence of trigger-yield restrictions. This is because trigger yield restrictions reduce the value of AYCI much more than they reduce the value of IYCI. While AYCI is still preferred at high levels of farm-county yield correlation, IYCI is the preferred instrument at the average level of yield basis risk when the IYCI premium loading is 35%.

For each portfolio, restricting the trigger yield causes an unambiguous increase in the premium loading which is larger in magnitude than the change that results from altering the level of price-yield correlation. This suggests trigger yield restrictions are more important than price-yield correlation in determining the cost of yield basis risk and the relative performance of the two insurance instruments. As expected, the performance of the AYCI instrument is sensitive to the level of yield basis risk. A geographically local area-yield index which enhances farm-area yield correlation can improve the relative performance of AYCI, but the trade off is that as the geographic region included in the index is concentrated then the level of transaction costs, as well as potential moral hazard and adverse selection problems, increase.

Impacts of IYCI Premium Loading

Figure 1 highlights the tradeoff between the IYCI premium loading and the level of basis risk associated with AYCI. Farmers who participate in IYCI are placed in a risk classification pool. All farmers in a pool face the same premium. The transaction costs related to moral hazard, adverse selection, and other administrative and implementation fees typically result in premium loadings for each risk pool. In the base model, the farmer faced a premium loading equivalent to 35% of the actuarially fair premium. However, the actual premium loading faced by a farmer will vary depending upon the characteristics of the farmer's yield distribution. In a given risk pool, farmers with higher indemnification risk (due to potential yield losses) will face lower effective premium loadings than farmer's with lower indemnification risk. The result is that, while all farmers in a pool pay the same premium, some farmers may have a premium loading below 35% of their actuarially fair premium while others may be paying a premium loading above 35% of their actuarially fair premium. As suggested in the previous section, the size of the premium loading faced by a farmer can have significant impacts on crop insurance participation and farmer welfare as well as the relative performance of IYCI and AYCI.

Table 7 shows the participation and willingness-to-pay levels for IYCI in the base model under alternative premium loadings between 0% and 50%.[13] When the maximum IYCI trigger yield is restricted to 75% of expected yield the farmer never chooses a trigger yield that is less than the maximum, irrespective of the premium loading. Furthermore, the reduction in WTP from increasing the premium loading from 0% to 50% ranges from $5 to $7 per acre under the 75% trigger yield restriction on IYCI. Comparing the WTP results from the top half of table 7 with those in tables 4-6 indicates that, even with no IYCI premium loading, AYCI (with no trigger yield restriction) is almost as valuable as IYCI (with the 75% trigger yield restriction) in all portfolios, and actually more valuable in many of them. This highlights the fact that the yield basis risk disadvantage of AYCI can be largely overcome by relaxation of the maximum trigger yield restriction, even when IYCI is actuarially fair. With a 20% premium loading on IYCI (and the 75% trigger yield restriction) AYCI (with no trigger yield restriction) is the preferred design in all cases, except when only crop insurance is available and there is a negative price-yield correlation.

Turning to the results in the bottom half of table 7, when there is no IYCI trigger yield restriction the optimal trigger yield is above the current 75% trigger yield restriction, even at a 50% premium loading. As the IYCI premium loading decreases the optimal trigger yield increases. When the premium is actuarially fair the optimal trigger yield is close to, or at, the maximum possible yield (i.e. complete insurance is selected). The reduction in WTP from increasing the IYCI premium loading from 0% to 50% of the actuarially fair premium ranges from around $10 to $16 per acre and, as expected, is higher than when the 75% trigger yield restriction was imposed. Comparing the WTP results in the bottom half of table 7 with those in tables 4-6, then without trigger yield restrictions AYCI is preferred in all portfolios when the IYCI premium loading is above 40% of the actuarially fair premium. When the IYCI premium loading is 20% IYCI is preferred in the crop insurance only and futures, options, and crop insurance portfolios. And, as expected, with no premium loading or trigger yield restriction, IYCI is preferred to AYCI in all portfolios. In general, as the premium loading decreases, the performance of IYCI improves relative to AYCI because the farmer is able to capture the benefits of yield insurance at a lower cost without incurring the yield basis risk inherent in AYCI. However, this benefit can be largely offset by imposing the current 75% trigger yield restriction on IYCI and leaving trigger yield unrestricted under AYCI.

Summary and Conclusions

In this paper we examine the relative performance of individual yield and area yield crop insurance programs for a representative Iowa corn farm. Numerical optimization and simulation techniques are used to evaluate the behavior of a representative farmer who uses various combinations of crop insurance, futures, options, and a deficiency payment program.

Time series methods are used with historical data to calibrate a joint distribution of harvest cash price, futures price, individual farm yield, and county yield, conditional on information available at planting. The joint distribution has no closed form, so stochastic simulation is used to generate a discrete estimate of the distribution. The model is then solved for parameters reflective of those faced by a representative farmer in southwest Iowa during the 1994-95 crop year.

An individual farm yield index for crop insurance payouts allows more efficient management of farm yield risk than an area yield index which is subject to yield basis risk. However, the transaction costs, moral hazard, and adverse selection problems which accompany use of an individual farm yield index have led to a premium loading for many farmers in a given risk pool. On the other hand, an area yield index has relatively low levels of transaction cost, moral hazard incentives, and adverse selection problems, leading to a premium that should be close to actuarially fair for all farmers. As a result of these differences, an insurance contract based on an area yield index is less expensive to implement, and may have more attractive premiums than a contract based on an individual farm yield index. The optimal index from the representative farmer's perspective is found to be particularly sensitive to restrictions on trigger yields, the size of premium loadings, and the level of yield basis risk.

When an individual farm yield index requires a 35% premium loading, and trigger-yield restrictions are set at their current levels, individual yield crop insurance (IYCI) is preferred to area yield crop insurance (AYCI). However, redesigning the area yield contract by eliminating the AYCI trigger yield restrictions makes AYCI preferable to IYCI, even with farm-area yield correlations as low as 0.8. This is an interesting result because the low moral hazard and adverse selection incentives associated with an area yield index provide little economic justification for the current restrictions on AYCI trigger yield. Altering the amount of planted acres allowed to be insured by the farmer was also examined and found to be a partial substitute for relaxing restrictions on the trigger yield level. However, economic gains from relaxing the current 100% of planted acreage restrictions are small.

The level of yield basis risk also has significant implications for the relative performance of IYCI and AYCI. At high levels of yield basis risk, an area yield index does not allow a farmer to manage yield risk efficiently and an individual farm yield index is a preferred design, even with a significant premium loading. This raises the issue of the appropriate level of geographic aggregation to use in area yield index. Area yield indices defined over a small geographically local region will reduce the yield basis risk faced by farmers and increase the ability to manage yield risk. However, as the geographic region over which the area yield index is defined becomes more concentrated, transaction costs will tend to increase, as well as potential problems associated with moral hazard and adverse selection. We provide some evidence on the trade-off between these effects. Furthermore, we show that eliminating the trigger yield restriction on AYCI, for which there is little economic justification, can more than compensate for the negative effects of yield basis risk at reasonable levels of farm-area yield correlation.

The premium level for each type of crop insurance may differ and can also impact the relative performance of IYCI and AYCI. All farmers in a particular region face the same crop insurance premium. Because of the transaction costs associated with moral hazard, adverse selection, and program administration, a premium loading (or subsidy) will occur for most farmers in an individual-yield based crop insurance program. The size of the premium loading will vary for each farmer depending on the farmer's indemnification risks. As the size of the IYCI premium loading decreases, the performance of IYCI improves relative to AYCI (with no premium loading). If the IYCI premium is actuarially fair and there is no trigger yield restriction, then IYCI is preferred to an actuarially fair AYCI instrument because the farmer can obtain the same amount of "fairly" priced coverage without the basis risk associated with AYCI. However, when both instruments are priced actuarially fair but the 75% trigger yield restriction is imposed on the IYCI instrument (to reduce moral hazard and adverse selection problems) the two instruments perform about the same in terms of the WTP measure with preference being conditional on the portfolio of risk instruments available. However, when the IYCI premium loading faced by the farmer reaches 35% of the actuarially fair premium, AYCI is preferred to IYCI in all portfolios even if no trigger yield restrictions are imposed on IYCI.

It is important to recognize that these results are based on the behavior of a representative farmer facing a specific risk structure. Future research might focus on extending the results to farmers producing multiple crops and/or a dynamic analysis. Additional attention should also be given to the impacts of different geographic aggregation levels for area yield schemes..

Table 1. The Bivariate Cash and Futures Price Process

Coefficient	Estimate	t-Value	p-Value
μ_f	0.0586	0.526	0.300
μ_p	0.1949	1.583	0.057
ω_1	4.7732	8.639	0.000
ω_2	4.2835	8.727	0.000
ω_3	5.1533	9.208	0.000
α_{11}	0.0499	1.114	0.133
α_{21}	0.0538	1.424	0.078
α_{31}	0.0697	1.412	0.080
α_{13}	0.0179	0.867	0.193
α_{19}	0.0252	1.249	0.106
ψ_1	3.7641	6.481	0.000
ψ_2	3.3444	6.172	0.000
ψ_3	3.4265	5.353	0.000

Futures Residual Statistics	Cash Residual Statistics	Cross Product Residual Statistics
$M_3 = 0.178$	$M_3 = -0.266$	na
$M_4 = 2.934$	$M_4 = 5.626$	na
$Q(1) = 0.056$	$Q(1) = 0.368$	na
$Q(5) = 5.348$	$Q(5) = 5.824$	na
$Q(10) = 12.68$	$Q(10) = 11.28$	na
$Q(15) = 15.29$	$Q(15) = 14.44$	na
$Q(20) = 18.55$	$Q(20) = 15.92$	na
$Q^2(1) = 0.808$	$Q^2(1) = 0.808$	$Q^3(1) = 0.068$
$Q^2(5) = 8.388$	$Q^2(5) = 8.388$	$Q^3(5) = 5.071$
$Q^2(10) = 16.68$	$Q^2(10) = 16.68$	$Q^3(10) = 9.879$
$Q^2(15) = 17.50$	$Q^2(15) = 17.50$	$Q^3(15) = 11.66$
$Q^2(20) = 24.84$	$Q^2(20) = 24.84$	$Q^3(20) = 14.55$

Note: M_3 is sample skewness; M_4 is sample kurtosis; $Q(df)$ is a Q statistic for df degree autocorrelation in the residuals; $Q^2(df)$ is a Q statistic for df degree autocorrelation in the squared standardized residuals; $Q^3(df)$ is a Q statistic for the standardized cross product of the residuals from the futures price and cash price equations; and na indicates not applicable.

Table 2. County Yield Model Estimates

Coefficient	Estimates	t-Value
a	360.5	918.5
b	0.052	9.8
ν	1.86	35.0
ζ	0.0032	3.5
θ	-16.21	-41.3
δ	-0.41	-31.4
M_2	1987.47	
M_3	-4.3532	
M_4	26.9436	
Q(1)	0.388	
Q(5)	4.483	
Q(10)	5.384	

Note: M_2 is sample variance; M_3 is sample skewness; M_4 is sample kurtosis and Q(*df*) is a Q statistic for *df* degree autocorrelation in the residuals.

Table 3. Sample Moments and Correlation Matrix for the Base Model

Variable	Sample Moments				Sample Correlation			
	Mean	Standard Deviation	Skewness	Kurtosis	Futures Price	Cash Price	County Yield	Farm Yield
Futures Price	$2.56	$0.39	0.41	3.57	1.00	0.84	-0.37	-0.31
Cash Price	$2.48	$0.38	0.43	3.55		1.00	-0.46	-0.38
County Yield	117.51/bu	30.40/bu	-1.20	4.07			1.00	0.83
Farm Yield	117.51/bu	36.48 bu	-0.97	3.28				1.00
Revenue	$286.43	$89.20	-0.62	3.32				

Note: Revenue is defined by the product of cash price and farm-level yield with no risk instruments included in the portfolio.

Table 4. **Participation Levels and Willingness-to-pay for Crop Insurance Under Alternative Coverage Restrictions**

Maximum Trigger Yield Restriction	IYCI			AYCI		
	Trigger Yield	Insured Acreage	WTP	Trigger Yield	Insured Acreage	WTP
Restricted Insured Acreage						
		Negative Price-Yield Correlation				
None	0.868	1.000	$26.37	1.216	1.000	$26.74
1.20	0.868	1.000	26.37	1.200	1.000	26.72
1.00	0.868	1.000	26.37	1.000	1.000	24.92
0.90	0.868	1.000	26.37	0.900	1.000	22.38
0.75	0.750	1.000	25.66	0.750	1.000	18.32
		Zero Price-Yield Correlation				
None	0.918	1.000	$30.47	Max.	1.000	$33.49
1.20	0.918	1.000	30.47	1.200	1.000	32.79
1.00	0.918	1.000	30.47	1.000	1.000	28.12
0.90	0.900	1.000	30.45	0.900	1.000	24.14
0.75	0.750	1.000	28.96	0.750	1.000	19.75
Unrestricted Insured Acreage						
		Negative Price-Yield Correlation				
None	0.879	0.951	$26.39	1.324	0.853	$27.04
1.20	0.879	0.951	26.39	1.200	0.890	26.90
1.00	0.879	0.951	26.39	1.000	1.090	24.98
0.90	0.879	0.951	26.39	0.900	1.157	22.54
0.75	0.750	1.184	25.88	0.750	1.489	19.08
		Zero-Price-Yield Correlation				
None	0.933	0.965	$30.48	Max.	1.040	$33.49
1.20	0.933	0.965	30.48	1.200	1.065	32.85
1.00	0.933	0.965	30.48	1.000	1.156	28.34
0.90	0.900	1.016	30.45	0.900	1.316	24.28
0.75	0.750	1.298	28.96	0.750	1.398	20.39

Note: All parameters are set at the values used in the base model. Trigger yield levels are expressed as a percent of expected yield and insured acreage is expressed as a percent of base acreage. WTP is the willingness-to-pay measure.

Table 5. Participation Levels and Willingness-to-pay for Crop Insurance, Futures and Options

Maximum Trigger Yield Restriction	IYCI			AYCI		
	Trigger Yield	Insured Acreage	WTP	Trigger Yield	Insured Acreage	WTP
Restricted Insured Acreage						
			Negative Price-Yield Correlation			
None	0.895	1.000	$27.47	Max.	1.000	$28.89
1.20	0.895	1.000	27.47	1.200	1.000	28.55
1.00	0.895	1.000	27.47	1.000	1.000	25.43
0.90	0.895	1.000	27.47	0.900	1.000	22.52
0.75	0.750	1.000	26.38	0.750	1.000	18.74
			Zero Price-Yield Correlation			
None	0.929	1.000	$33.41	Max.	1.000	$37.49
1.20	0.929	1.000	33.41	1.200	1.000	36.80
1.00	0.929	1.000	33.41	1.000	1.000	33.15
0.90	0.900	1.000	33.37	0.900	1.000	30.00
0.75	0.750	1.000	31.77	0.750	1.000	24.90
Unrestricted Insured Acreage						
			Negative Price-Yield Correlation			
None	0.880	1.058	$27.49	Max.	1.006	$28.89
1.20	0.880	1.058	27.49	1.200	1.034	28.56
1.00	0.880	1.058	24.49	1.000	1.161	25.63
0.90	0.880	1.058	27.49	0.900	1.181	22.72
0.75	0.750	1.318	26.93	0.750	1.506	19.21
			Zero-Price-Yield Correlation			
None	0.939	0.968	$33.41	Max.	1.045	$37.52
1.20	0.939	0.968	33.41	1.200	1.067	36.92
1.00	0.939	0.968	33.41	1.000	1.248	33.66
0.90	0.900	1.028	33.37	0.900	1.355	30.75
0.75	0.750	1.316	32.36	0.750	1.676	26.28

Note: All parameters are set at the values used in the base model. Trigger yield levels are expressed as a percent of expected yield and insured acreage is expressed as a percent of base acreage. WTP is the willingness-to-pay measure.

Table 6. **Participation Levels and Willingness-to-pay for Crop Insurance and a Government Deficiency Payment Program**

Maximum Trigger Yield Restriction	IYCI			AYCI		
	Trigger Yield	Insured Acreage	WTP	Trigger Yield	Insured Acreage	WTP
Restricted Insured Acreage						
			Negative Price-Yield Correlation			
None	0.906	1.000	$52.89	Max.	1.000	$56.89
1.20	0.906	1.000	52.89	1.200	1.000	56.46
1.00	0.906	1.000	52.89	1.000	1.000	52.67
0.90	0.900	1.000	52.89	0.900	1.000	49.23
0.75	0.750	1.000	51.45	0.750	1.000	44.58
			Zero Price-Yield Correlation			
None	0.905	1.000	$58.85	Max.	1.000	$64.33
1.20	0.905	1.000	58.85	1.200	1.000	63.75
1.00	0.905	1.000	58.85	1.000	1.000	60.09
0.90	0.900	1.000	58.85	0.900	1.000	57.11
0.95	0.750	1.000	57.58	0.750	1.000	52.66
Unrestricted Insured Acreage						
			Negative Price-Yield Correlation			
None	0.887	1.064	$52.92	Max.	1.046	$56.92
1.20	0.887	1.064	52.92	1.200	1.084	56.56
1.00	0.887	1.064	52.92	1.000	1.282	53.34
0.90	0.887	1.064	52.92	0.900	1.354	50.04
0.75	0.750	1.349	52.25	0.750	1.661	46.17
			Zero-Price-Yield Correlation			
None	0.910	0.982	$58.85	Max.	1.054	$64.37
1.20	0.910	0.982	58.85	1.200	1.082	63.83
1.00	0.910	0.982	58.85	1.000	1.269	60.66
0.90	0.900	1.998	58.85	0.900	1.373	57.91
0.75	0.750	1.286	58.08	0.750	1.705	54.17

Note: All parameters are set at the values used in the base model. Trigger yield levels are expressed as a percent of expected yield and insured acreage is expressed as a percent of base acreage. WTP is the willingness-to-pay measure.

Table 7. Participation Levels and Willingness-To-Pay for Alternative IYCI Premium Loadings

Premium Loading	Trigger Yield: IYCI	Trigger Yield: Govt. Prog. and IYCI	Trigger Yield: Futures, Options and IYCI	Willingness-To-Pay: IYCI	Willingness-To-Pay: Govt. Prog. and IYCI	Willingness-To-Pay: Futures Options and IYCI
Restricted Trigger Yield (maximum 0.75)						
			Negative Price-Yield Correlation			
1.0	0.75	0.75	0.75	$29.51	$55.90	$30.23
1.2	0.75	0.75	0.75	27.29	53.35	28.01
1.35	0.75	0.75	0.75	25.66	51.45	26.38
1.4	0.75	0.75	0.75	25.13	50.82	25.84
1.5	0.75	0.75	0.75	24.06	49.57	24.77
			Zero Price-Yield Correlation			
1.0	0.75	0.75	0.75	$33.58	$57.78	$36.63
1.2	0.75	0.75	0.75	31.59	55.24	34.34
1.35	0.75	0.75	0.75	29.93	53.36	32.66
1.4	0.75	0.75	0.75	29.38	52.73	32.10
1.5	0.75	0.75	0.75	28.29	51.48	31.00
Unrestricted Trigger Yield						
			Negative Price-Yield Correlation			
1.0	Max.	1.333	1.320	$34.78	$65.61	$38.46
1.2	0.954	1.005	0.999	29.24	56.77	30.73
1.35	0.868	0.906	0.895	26.37	52.89	27.47
1.4	0.846	0.879	0.870	25.58	51.85	26.60
1.5	0.798	0.823	0.827	24.18	50.00	25.07
			Zero Price-Yield Correlations			
1.0	1.418	1.368	1.363	$43.62	$68.29	$46.97
1.2	1.016	1.020	1.032	35.13	58.75	38.12
1.35	0.920	0.909	0.929	31.51	54.75	34.36
1.4	0.897	0.882	0.901	30.54	53.70	33.36
1.5	0.848	0.830	0.852	28.85	51.85	31.61

Note: All parameters are set at the values in the base model. Trigger yield levels are expressed as a percent of expected yield.

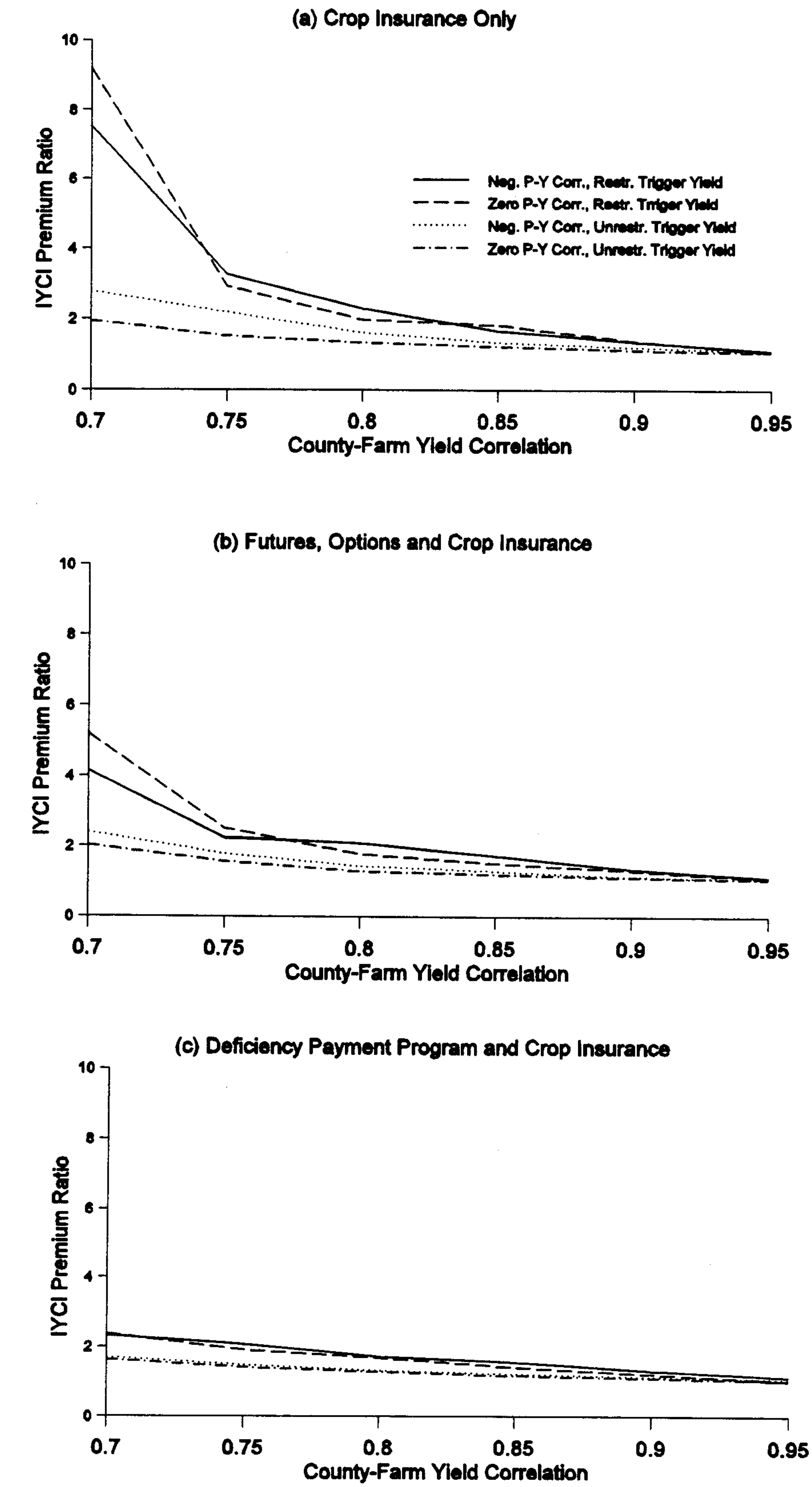

Figure 1. Welfare-equivalent Tradeoff Between IYCI Premium Loading and AYCI Basis Risk

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Endnotes

1. The Federal Crop Insurance Corporation was reorganized in 1996 and renamed the Risk Management Agency.

2. The 1996 Federal Agricultural Improvement Act (FAIR) has replaced the deficiency payment program with a series of lump sum payments which will be phased out over time. We examine the performance of the alternative crop insurance instruments for cases with and without a deficiency payment program. This allows us to evaluate the impacts of eliminating the deficiency payment program on the role of crop insurance.

3. The first term in the yield vector designates the farmer' own yield which is used to determine the net profit from directly producing and selling the commodity. The second yield term denotes the index that is used to determine the net profit from using crop insurance. If the index is specified to be the farmer's own yield then the farmer's yield determines both the direct profit from production and sale as well as the profit from using crop insurance. In this case, the model could have been specified in terms of a single yield variable (the farmer's yield). However, we wish to allow the yield index which triggers insurance payouts to be different from the farmer's individual yield.

4. Profit is defined on a per acre basis to simplify the model. The results of the analysis can be extended to any farm size by multiplying by the number of acres. However, adding an additional wealth term to profits will impact both the per acre and whole farm results.

5. Note that farm yield is treated as exogenous, in the sense that the decision problem is assumed to take place after the yield distribution at harvest has been determined. This assumes the risk management decision is made after the farmer has made production decisions, or that the farmer follows a set production practice regardless of the income distribution faced at harvest.

6. In this paper, the term "actuarially fair" means that the premium faced by the farmer is equal to the expected indemnity payment to the farmer.

7. The mean of the futures price distribution is set equal to the futures price at planting which contains all market information available about the futures price at harvest. The forward cash price, at planting, is used as the mean of the estimated cash price distribution at harvest. Thus both the futures price and cash price distributions at harvest take into account the information available when the farmer makes the risk management decisions at planting.

8. Imposing correlation between cash price and county yield and then separately imposing correlation between county yield and individual yield implies that cash price and individual yield are also correlated.

9. The sample correlations from the simulated data are not exactly equal to the theoretical correlations imposed a priori because of simulation error.

10. Crop insurance participants in each state are placed in one of three risk classification pools. The FCIC subsidy to private insurance providers to cover delivery costs have historically been set somewhere around 30% of the "actuarially fair" pool premium for MPCI in the past. In addition, the FCIC provides rating and other services which cost an estimated 5% or more of the actuarially fair premium.

11. Throughout this paper "performance" of crop insurance instruments is evaluated in terms of the WTP measure. For example, if IYCI produces a higher WTP measure than AYCI in a particular case, then we say that IYCI outperforms AYCI in that case.

12. Note that AYCI is also preferred to IYCI when the trigger yield restrictions are removed for both instruments. This is a result of the small opportunity cost of the 75% coverage restriction under IYCI.

13. Note that the definition of an actuarially fair premium used in this paper excludes the transaction costs associated with administrating and implementing the insurance program. Therefore a 0% premium loading is associated with substantial losses to insurance providers once these costs are taken into account.