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ABSTRACT

This study estimates average per acre indemnity payments for Iowa corn for traditional multiple-peril crop insurance and two new revenue insurance products, Crop Revenue Coverage and Income Protection. Yield and price difference distributions are formed and employed in 1,000 simulation runs. From these simulations, corn yields for all 99 Iowa counties and futures prices are collected. These are used to calculate per acre indemnities under the three insurance products. Income Protection has the smallest per acre indemnities across the state, followed by multiple-peril and Crop Revenue Coverage. Per acre indemnities are the lowest in northwest Iowa and highest in southeast Iowa.

COMPUTING AVERAGE PER ACRE INDEMNITY PAYMENTS FOR CORN IN IOWA

Earlier this year two new crop insurance products were introduced to the market. These packages, Crop Revenue Coverage (CRC) and Income Protection (IP), insure against losses in revenue, as opposed to the traditional multiple-peril crop insurance (MPCI), which insures against crop yield losses. The impact these products will have upon both the agricultural and insurance industries can partially be seen by examining the average indemnity (or insurance payment) for each of the insurance packages. This paper provides estimates of average per acre indemnities for CRC, IP, and MPCI at the county and state level based upon a Monte Carlo simulation from estimated yield and price distributions.

To begin such a study, estimates are needed of the relevant yield and price distributions. In order to provide adequate data with which to estimate a probability distribution, yield and price data over the period 1975 to 1995 are examined. The prices needed to examine CRC and IP are the spring and harvest prices employed to compute the revenue guarantees and actual revenue levels for the insured farms. For corn, the relevant spring price is the average daily settlement price of the harvest futures contract (December) on the Chicago Board of Trade in February. The relevant harvest price is the average daily settlement price of the harvest futures contract in the next-to-last month of trading (November). Prices are deflated by the Producer Price Index for Crude Foodstuffs and Feedstuffs and are adjusted to 1995 levels. A trend yield is established at the state level and is intercept adjusted to the county level by the difference between the 1975-95 average yields for the state and the county. The trend yields are used to calculate actual yield deviations away from trend.

A probability distribution is estimated for the price differential between the February and harvest prices. The SAS statistical package estimates the best-fitting parameter values for beta, gamma, normal, and lognormal distributions. Bounds for the beta, gamma, and lognormal distributions are set to allow the maximum historical price difference and an additional ten cent movement on both the high and low sides. The needed distribution is chosen by selecting the distribution with the highest probability of acceptance under the Chi-squared goodness-of-fit test The price differential is found to follow a beta distribution.

The state- and county-level yield deviations from trend are assumed to follow beta distributions. Data for configuring the yield distributions originates from a Federal Crop Insurance Corporation (FCIC) data set of farm-level corn yield histories. The data set contains corn yield records for more than 18,000 Iowa corn farms from 1985 to 1994. County and state averages of corn yield standard deviations and corn yield correlation among farms within a county are calculated. The county yield standard deviations are combined to form weighted (by the average 1975-95 corn acreage in the counties) crop-reporting district average yield standard deviations. Smoothed county yield standard deviations are held between two bushels above and below the district average. Allamakee County had no observations in the data set. To reach reasonable estimates for Allamakee County, farm-level figures from Clayton County (the neighboring county to the south, also along the Mississippi River) are used for Allamakee.

The yield deviation distributions are taken to have a mean of zero (implying that the mean yield is the trend yield) and a standard deviation equal to the smoothed farm-level county average Since yields are non-negative, the lower bound is set at the negative of the trend yield for all of the yield deviation distributions. The beta parameters are constrained in a given range to provide the expected shape for the yield deviation distributions. However, the parameters are allowed to vary with the county's yield mean and smoothed standard deviation as is the upper bound for the distribution Figure 1 displays the range of the yield distributions and the average county distribution.

To account for the correlation between these variates when sampling from the distributions, we have employed an approach outlined by Johnson and Tenenbein (1981) Their approach uses a weighted linear combination method to construct bivariate distributions with specified marginal distributions. In this approach, independent and identically distributed (iid) random variables are combined to form random draws from the desired marginal distributions. Take, for example, the state-level yield deviation and the futures price differential. The specified marginal distributions for these variables are beta distributions and the two series have a Spearman's rank correlation coefficient (ρ_s) of −0.425 for corn in the state of Iowa. To proceed

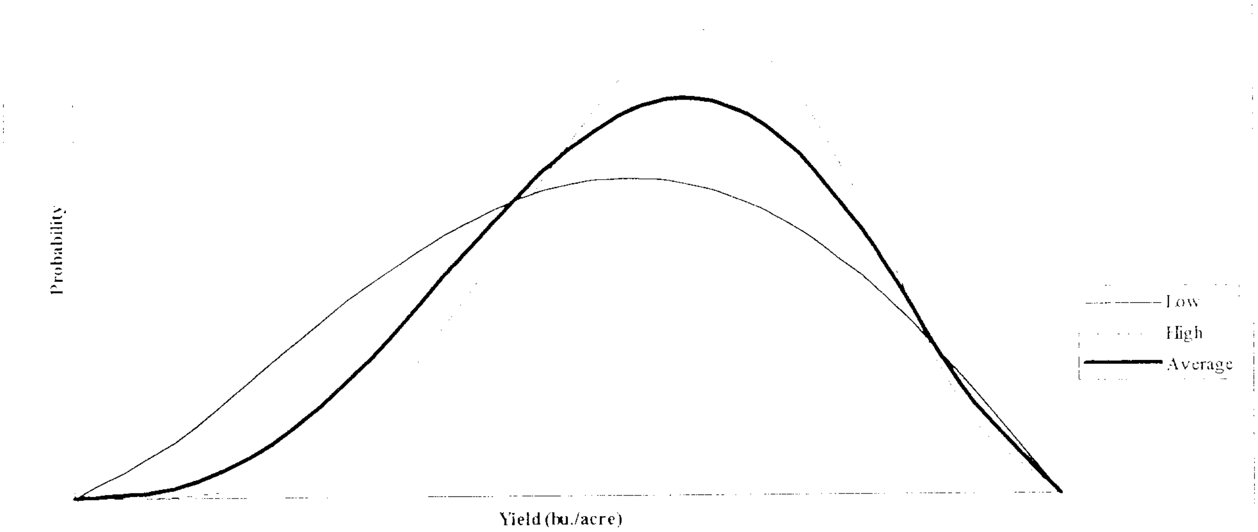

Figure 1. An Example of Possible Yield Distributions

with the weighted linear combination procedure, a probability density function must be chosen for the iid random variables. Johnson and Tenenbein provide formulas for uniform, standard normal, exponential, and double exponential distributions. We employ the standard normal distribution in the procedure to compute the required beta distributions. Once the normal distribution is chosen and a measure of dependence (such as ρ_s) for the variables is known, then these pieces of information are used to calculate a constant, c, which will be needed to weight the iid variables. For the case of standard normal and known ρ_s, c is determined by

(1) $|\rho_s| = (6/\pi)\arcsin(c/(2\sqrt{c^2 + (1-c)^2}))$.

Once c is calculated, the procedure can be used to generate the needed variables through the following formulas. Let X represent the state-level yield deviation and Y represent the February-November futures price differential. A and B are iid standard normal random variables. Let capital letters represent random variables and lower case letters represent realizations of these random variables.

(2) $A \sim N(0, 1)$ and $B \sim N(0, 1)$.

(3) $r = a$ and $s = ca + (1 - c)b$.

(4) $w = \Phi(r)$ and $z = \Phi(s / \sqrt{c^2 + (1-c)^2})$

where $\Phi(\ )$ is the cumulative density function for a standard normal variate.

(5) $x = F_X^{-1}(w)$ and $y = F_Y^{-1}(1\text{-}z)$

where $F_X(.)$ and $F_Y(.)$ are the known marginal cumulative density functions for X and Y. The known marginal distributions in this analysis are beta distributions. If, as in the cases between the state and county yield deviations, ρ_s is positive, then Equation (5) changes to

(6) $x = F_X^{-1}(w)$ and $y = F_Y^{-1}(z)$.

Since we are sampling from more than two distributions, we proceed by pairing each of the county-level yield deviation and price differential distributions to the state-level yield deviation distribution. This choice is made for consistency in sampling and to link the aggregate state-level figures to the more micro-level county figures.

To account for the fact that the CRC and MPCI products allow for optional units, whereas IP is based on a basic unit (all corn acreage on the farm) approach, adjustments are made to the standard deviations of the yield deviation distributions for the CRC and MPCI analyses. Based upon the 1995 crop insurance policy and unit figures for Iowa corn, there are, on average, two units per policy. Under the assumptions of two units per farm, the units are the same size and have the same yield variability, and the correlation of yields on the units is given by ρ; then the yield deviation standard deviation for a unit is given by

(7) $StD(yd_{unit}) = [\, 2 / \sqrt{2(1+\rho)}\,] StD(yd_{farm})$

where StD(.) represents the standard deviation.

This adjustment is made on a county-by-county basis according to the correlations computed from the FCIC data set. For example, the average farm-level corn yield standard deviation for the state of Iowa is 32.95 bu./acre and the average correlation among corn yields is 0.73. Then, under the assumptions of Equation (7), the average unit-level corn yield standard deviation for the state of Iowa is given by 35.52 bu./acre.

The following analyses are based upon 1,000 random draws from the distributions described here. The February corn price is set at the 1975-95 average level of $2.64 per bushel. Once the prices and yields are drawn, per acre indemnity payments are computed for each of the insurance products. MPCI pays an indemnity when the actual yield falls below the product of the coverage level and the unit's actual production history (APH) yield. The MPCI indemnity is equal to the price election ($2.65 per bu. for 1996) times the yield shortfall. IP and CRC pay indemnities when actual revenue falls below guaranteed revenue. The indemnities are equal to the computed revenue shortfalls. For IP, guaranteed revenue is the product of the coverage level, the farm's APH yield, and the February futures price described above. Actual revenue is given by the product of the farm's actual yield and the November futures price. For CRC, guaranteed revenue is the product of the coverage level, the unit's APH yield, and 95 percent of the February futures price described above. If, however, the November futures price is greater than the February futures price, then the November price is used in the guaranteed revenue computation. There is an upward futures price movement limit of $1.50 per bushel. Thus, if the November price exceeds the February price by more than $1.50, then the February price plus $1.50 will be used in the revenue computations. Actual revenue is given by the product of the unit's actual yield and 95 percent of the November futures price.

The analyses are conducted at the county level. The county's APH yield is set at the 5-year moving average of county corn yields. The IP indemnities are computed given the farm-level yield standard deviations. The CRC and MPCI indemnities are computed from the unit-level yield standard deviations. The Spearman's rank correlation coefficient, ρ_s, between the state-level yield deviation and the futures price differential is –0.425. The rank correlations between the state- and county-level yield deviations vary from 0.697 for Muscatine County to 0.958 for Poweshiek County. Smoothed farm-level (unit-level) yield standard deviations range from 26.91 (29.28) bu./acre for Ida County to 42.62 (45.06) bu./acre for Lee County. The state average farm-level (unit-level) yield standard deviation is 32.95 (35.52) bu./acre. State and crop reporting district indemnity figures are weighted averages of the county indemnity figures. The weights are determined by the 1975-95 average corn acreage planted in the county.

Table 1. State-level Average Per Acre Indemnities

Coverage Level	CRC	IP	MPCI
(%)		($/acre)	
65	7.21	3.38	5.97
75	12.66	6.63	10.47

Table 1 presents the average indemnities under CRC, IP, and MPCI given random draws from the February price distribution. The IP package provides the smallest average per acre indemnities, followed by MPCI and CRC. If coverage shifts from 65 to 75 percent, CRC indemnities grow by $5.45 an acre or 76 percent, IP $3.25 an acre (96 percent), and MPCI $4.50 an acre (75 percent).

Table 2 presents the crop reporting district average per acre indemnities. The average per acre indemnity increases as we move from north to south and west to east. Again, IP provides the lowest indemnities, followed by MPCI and CRC. Most of the differences between districts can be explained by differences in yield standard deviations, which follow a similar trend.

Table 2. Crop Reporting District Average Per Acre Indemnities

District	Coverage Level	CRC	IP	MPCI
	(%)		($/acre)	
Northwest	65	5.19	2.08	4.24
North Central	65	5.90	2.65	4.86
Northeast	65	9.82	4.86	8.19
West Central	65	5.54	2.21	4.53
Central	65	7.15	3.33	5.90
East Central	65	8.22	3.87	6.84
Southwest	65	6.17	2.74	5.09
South Central	65	9.54	5.26	7.97
Southeast	65	10.66	5.95	8.92
Northwest	75	10.01	4.67	8.16
North Central	75	10.47	5.27	8.64
Northeast	75	16.11	8.81	13.46
West Central	75	10.73	5.06	8.74
Central	75	12.92	6.78	10.63
East Central	75	13.81	7.25	11.50
Southwest	75	11.38	5.75	9.35
South Central	75	15.38	9.18	12.88
Southeast	75	17.21	10.42	14.46

To examine the sensitivity of these results to the rank correlation between state-level yield deviation from trend and the futures price differential and to the amount of price variability, 18 separate scenarios are examined are compared to the above results. In the rank correlation scenarios, the Spearman's rank correlation coefficient is set between 0 and –0.9 at 0.1 intervals (the 1975-95 historical value is –0.425). In the price variability scenarios, both the February price and price differential distributions are adjusted to have from 0 to 2 times the price variability at 0.25 intervals.

All of the scenarios are performed at the 65 percent coverage level where the February price is set at $2.64, the 1975-95 average February corn futures price. All of the scenario results reported are at the state-level. Figure 2 displays the rank correlation scenario results. The MPCI per acre indemnities are, of course, unaffected by these changes. CRC indemnities first decrease as the rank correlation becomes more negative, then they remain constant. IP per acre indemnities decrease as the rank correlation becomes more negative. The CRC indemnities never fall below the MPCI level, but the IP indemnities fall below MPCI for rank correlations between –0.2 and –0.9. Both the IP and CRC curves show that most of the yield-price correlation effect is captured within the 0 to –0.4 range with its having the greater impact on IP indemnities. A possible explanation for this is that the yield-price correlation is the significant linkage in the indemnity determination for near-zero correlation levels, but the state-to-county yield correlations

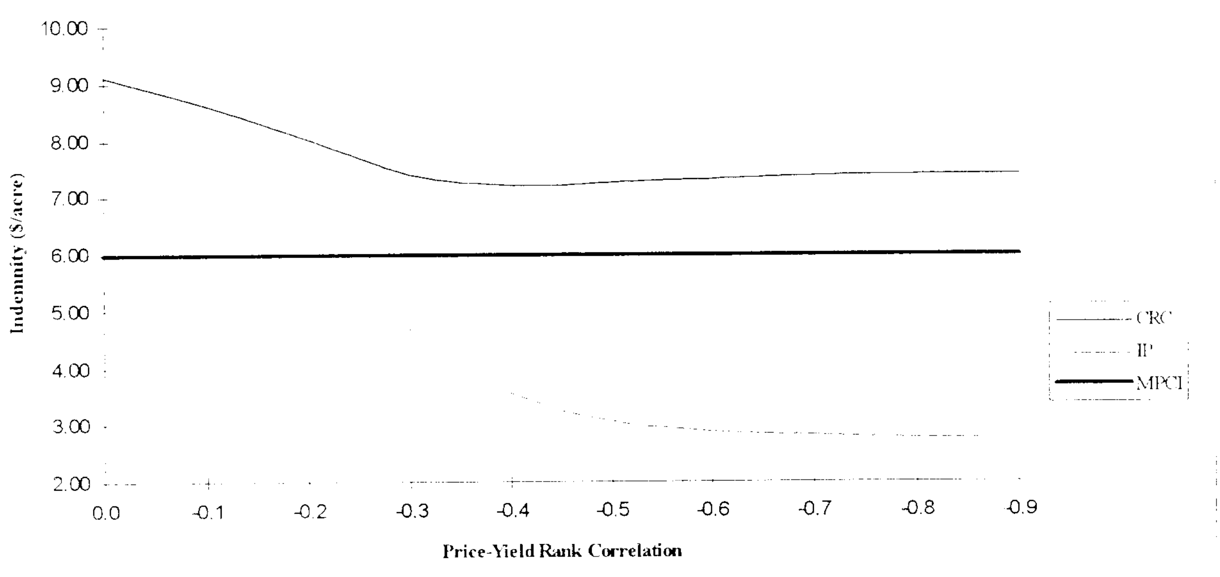

Figure 2. Per Acre Indemnity and Price-Yield Rank Correlation for Iowa Corn

are the stronger influencing factors for more negative yield-price correlations. IP indemnities vary by $5.80 per acre, while CRC indemnities change by nearly $1.90 per acre

Figure 3 shows the effects of different levels of futures price variability upon the insurance indemnities. Again, MPCI per acre indemnities are not affected by these changes. The revenue insurance products respond quite differently to changes in price variability. CRC indemnities increase with increased price variability, whereas IP indemnities decrease over the studied range. For both products, the indemnity changes are the most pronounced as price variability is shifted away from zero. The difference in how IP and CRC indemnities react to price variability arises due to CRC's adaptation of higher harvest prices into the guaranteed revenue.

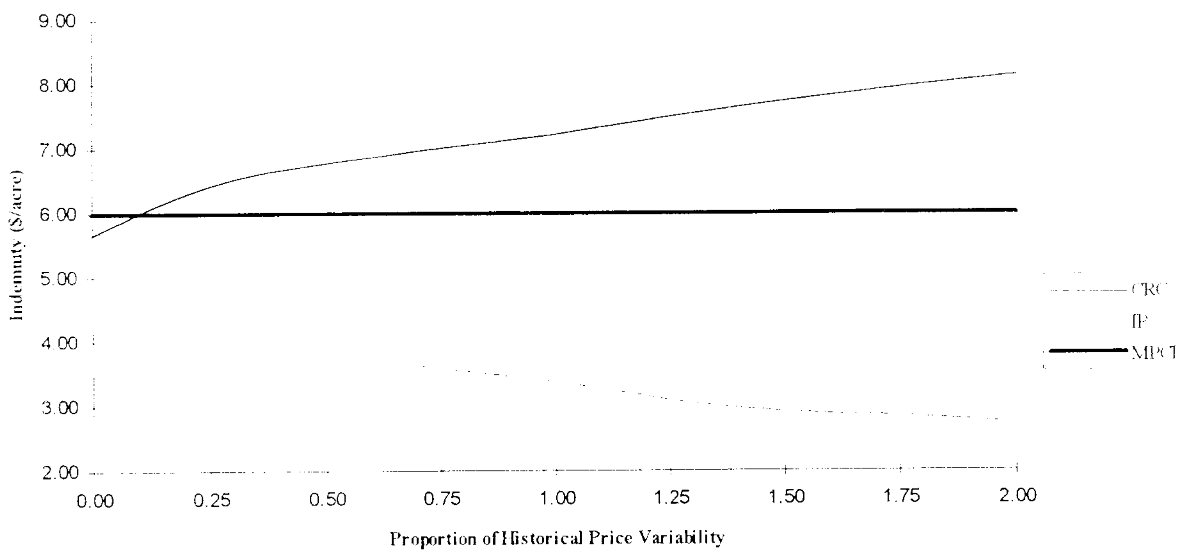

Figure 3. Per Acre Indemnity and Price Variability for Iowa Corn

As price variability declines, yield variability becomes the dominant factor in the indemnity. We would expect that the IP and CRC indemnities would approach MPCI levels in the zero price variability scenario, and they do. The only differences between the products in the zero price variability scenario are the yield standard deviations (farm vs. unit) and the price level (MPCI price election vs. the futures price). If we were to evaluate these products at the same level of insurance units (say, at the farm level) and at average historical prices with no price variability, CRC would provide the lowest indemnities followed by IP and MPCI. This occurs because the historical prices used in CRC ($2.51) and IP ($2.64) are lower than the price election of $2.65 per bu. for MPCI.

To further examine the different aspects of CRC due to the unit coverage and the higher harvest futures price adjustment, we have included three more scenarios: CRC at the farm level with no harvest price adjustment (the only difference between this package and IP is the proportion of futures price), CRC at the farm level with the harvest price adjustment in place, and CRC at the unit level with no harvest price adjustment. We refer to these various versions as CRC-1, 2, and 3. Table 3 contains the per acre indemnities for IP, CRC, and these variations at the 65 percent coverage level at historical price variability. The comparison between IP and CRC-1 shows the indemnity value of the futures price proportion difference (1 vs. 0.95) to be $0.16 per acre. Comparing CRC and CRC-2 or CRC-3 and CRC-1 provides a measure of the indemnity increase due to movement from farm to unit coverage. This shift in coverage raises per acre indemnities approximately $0.15. To see the effects of the higher harvest price adjustment, we can compare CRC and CRC-3 or CRC-2 and CRC-1. The price adjustment adds roughly $3.85 per acre to the indemnity. Thus, the higher harvest price adjustment represents the largest difference between IP and CRC.

Table 3. Comparison of IP, CRC, and CRC variations

Insurance Product	Coverage Level	Farm or Unit Coverage	Harvest Price Adjustment	Per Acre Indemnity
	(%)			($/acre)
IP	65	Farm	No	3.38
CRC	65	Unit	Yes	7.21
CRC-1	65	Farm	No	3.22
CRC-2	65	Farm	Yes	7.04
CRC-3	65	Unit	No	3.34

To conclude, this paper presents an estimation method for internally consistent evaluation of traditional yield and revenue insurance products. Preliminary estimates are provided of average per acre indemnities at the state and crop reporting district levels for multiple-peril crop insurance and the two new revenue insurance packages, Crop Revenue Coverage and Income Protection. The presented results are dependent upon assumed distributions and distribution parameters. Historical price and yield data provided information upon which the needed distributional estimations or assumptions are formed. For corn in Iowa, Income Protection provides the smallest indemnity, followed by multiple-peril and Crop Revenue Coverage. Sensitivity analysis is performed with respect to the rank correlation between futures price differentials and yield deviations and the amount of price variability. Income Protection and Crop Revenue Coverage respond to changes in these variables differently.

Viewing MPCI as standard yield insurance and IP as standard revenue insurance, then revenue insurance may or may not pay more in indemnities than yield insurance. The differences in expected indemnities will depend upon the strength of the yield-price correlation and the amount of price variability. In comparing IP and CRC, the main differences in the policies are the level of coverage (farm vs. unit), the proportion of the futures price (1 vs. 0.95), and the higher harvest price adjustment. In this analysis, CRC's unit coverage and higher harvest price adjustment will, all other things equal, cause its indemnities to be higher than IP's. If the February price is employed in computing revenues, IP's higher proportion of the futures price will, all other things equal, cause its indemnities to be higher than CRC's. The results here show that the higher harvest price adjustment is the dominant factor in the differences between IP and CRC and thus, CRC is found to have consistently higher per acre indemnities than IP.

Errata

Corrections of typographical errors in the working paper:

p. 6, para 1: In the statement "Table 1 presents..." "February price" should be replaced by "futures price differential."

9. 7, line 2: The statement "In the price variability scenarios,..." should read as "In the price variability scenarios, the futures price differential distribution is adjusted to have from 0 to 2 times the price variability at 0.25 intervals."

REFERENCE

Johnson, Mark E. and Aaron Tenenbein. "A Bivariate Distribution Family with Specified Marginals." *Journal of the American Statistical Association* 76(March 1981):198-201.