Estimating Expected Per Acre Indemnities of Yield and Revenue Insurance Products

by

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This study estimates average per acre indemnity payments for Iowa corn for traditional multiple-peril crop insurance and two 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.

Last 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 outlines an estimation method to evaluate various crop insurance products. Specifically, we provide estimates of average per acre indemnities for Iowa corn for CRC, IP, and MPCI based upon a Monte Carlo simulation from estimated yield and price distributions.

For the 1996 crop year, CRC was available for corn and soybeans in Iowa and Nebraska and for wheat in Kansas, Michigan, Nebraska, South Dakota, Texas, Washington, and selected counties in Montana. IP coverage could be obtained for corn in selected counties in Illinois, Indiana, and Iowa; for cotton in selected counties in Alabama and Georgia; and for spring wheat in selected counties in Minnesota and North Dakota. Table 1 gives a brief comparison of the three products and their 1996 sales figures for Iowa corn.

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* Chad Hart is an economics graduate student; Samarendu Mohanty is a FAPRI (Food and Agricultural Policy Research Institute) assistant scientist; and Darnell B. Smith is the managing director of FAPRI at Iowa State University, Ames IA 50011-1070.

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Table 1. Product Comparison and 1996 Iowa Corn Insurance Sales*

Feature	MPCI	CRC	IP
Unit organization	Basic and optional units	Basic and optional units	Enterprise unit
Basis for insurance guarantee	APH** yield	APH yield X the higher of the planting or harvest price	APH yield X planting price
Commodity price	Price election	95 percent of the price on the harvest futures contract	100 percent of the price on the harvest futures contract
Policies sold	68,766	32,948	28
Net insured acres	6,197,856	4,492,729	3,189
Total premiums	$46,962,919	$67,516,043	$39,695

*from FCIC, 1996 Crop Year Statistics, as of 3/24/97.
**Actual Production History

For 1997, CRC coverage has been expanded to include cotton in Arizona, Georgia, Oklahoma, and selected counties in Texas; grain sorghum in Colorado, Nebraska, Oklahoma, and selected counties in Kansas, Missouri, and South Dakota; spring wheat in Minnesota and selected counties in Montana and North Dakota; corn in Colorado, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, Ohio, Oklahoma, South Dakota, and Texas; and soybeans in Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, Ohio, Oklahoma, South Dakota, and Texas. Expansion of IP has been allowed for grain sorghum in selected counties in Texas; soybeans in selected counties in Arkansas, Illinois, Indiana, and Iowa; and winter wheat in selected counties in Kansas, Montana, and Washington. As these products expand to encompass more area and market share, the need for information on their performance increases. In this study, we attempt to provide such information on the relative indemnity structures of these products.

To begin such a study, estimates of the relevant yield and price distributions are needed. 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 planting and harvest prices employed to compute the revenue guarantees and actual revenue levels for the insured farms. For corn, the relevant planting 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 planting 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 within two bushels of 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 from trend 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 with the weighted linear combination procedure, a probability density function must be chosen for the iid random variables. Johnson and Tenenbein provide formulas for several distributions. We employ the standard normal distribution in the procedure to compute the required beta distributions. Once the 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 capital letters represent random variables and lower case letters represent realizations of these random variables. Let X represent the state-level yield deviation and Y represent the planting-harvest futures price differential. A and B are iid standard normal random variables.

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

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

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

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

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

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

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 upon 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 on the 1995 crop insurance policy and unit figures for Iowa corn, there are, on average, two units per policy. Under the assumptions of a farm has one policy with two units, the units have the same size and 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

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

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 Iowa is given by 35.52 bu./acre.

The following analyses are based upon 1,000 random draws from the distributions described here. The planting 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 planting futures price described above. Actual revenue is given by the product of the farm's actual yield and the harvest futures price. For CRC, guaranteed revenue is the product of the coverage level, the unit's APH yield, and 95 percent of the planting futures price described above. If, however, the harvest futures price is greater than the planting futures price, then the harvest price is used in the guaranteed revenue computation. There is a futures price movement limit of $1.50 per bushel. So if the harvest price exceeds the planting price by more than $1.50, the planting 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 harvest 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 given 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 2 presents the average indemnities under CRC, IP, and MPCI given random draws from the futures price differential and yield deviation distributions. 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 increase by $5.45 an acre (76 percent), IP by $3.25 an acre (96 percent), and MPCI by $4.50 an acre (75 percent).

Table 2. State-level Average Per Acre Indemnities

Insurance Product	65% coverage level	75% coverage level
	($/acre)	
CRC	7.21	12.66
IP	3.38	6.63
MPCI	5.97	10.47

Table 3 presents the crop reporting district average per acre indemnities. Again, IP provides the lowest indemnities, followed by MPCI and CRC. The average per acre indemnity increases as we move from north to south and west to east. Most of the differences between districts can be explained by differences in yield standard deviations, which follow a similar trend.

Table 3. Crop Reporting District Average Per Acre Indemnities

District	CRC	IP	MPCI
65% coverage level		($/acre)	
Northwest	5.19	2.08	4.24
North Central	5.90	2.65	4.86
Northeast	9.82	4.86	8.19
West Central	5.54	2.21	4.53
Central	7.15	3.33	5.90
East Central	8.22	3.87	6.84
Southwest	6.17	2.74	5.09
South Central	9.54	5.26	7.97
Southeast	10.66	5.95	8.92
75% coverage level			
Northwest	10.01	4.67	8.16
North Central	10.47	5.27	8.64
Northeast	16.11	8.81	13.46
West Central	10.73	5.06	8.74
Central	12.92	6.78	10.63
East Central	13.81	7.25	11.50
Southwest	11.38	5.75	9.35
South Central	15.38	9.18	12.88
Southeast	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 compared to the results in Table 2. 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, the futures price differential distribution is adjusted to have from 0 to 2 times the historical price variability at 0.25 intervals.

All of the scenarios are performed at the 65 percent coverage level where the planting price is set at $2.64, the 1975-95 average planting 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 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 may be due to CRC's adaptation of higher harvest prices into the guaranteed revenue.

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, and CRC at the unit level with no harvest price adjustment. We refer to these various versions as CRC-1, -2, and -3. Table 4 contains the per acre indemnities for IP and CRC and variations at the 65 percent coverage level given 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 with CRC-2 (CRC-3 with CRC-1) provides the indemnity increase due to movement from farm to unit coverage; it is approximately $0.15. The effects of the higher harvest price adjustment can be seen by comparing CRC with CRC-3 (CRC-2 with 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 4. Comparison of IP, CRC, and CRC variations at the 65 percent coverage level

Insurance Product	Farm or Unit Coverage	Harvest Price Adjustment	Per Acre Indemnity
			($/acre)
IP	Farm	No	3.38
CRC	Unit	Yes	7.21
CRC-1	Farm	No	3.22
CRC-2	Farm	Yes	7.04
CRC-3	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 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, CRC and IP are provided. The presented results are dependent upon assumed distributions and distribution parameters. Historical price and yield data provided information on which the needed distributional estimates or assumptions are formed. For corn in Iowa, IP provides the smallest indemnity, followed by MPCI and CRC. Sensitivity analysis is performed with respect to the rank correlation between futures price differentials and state-level yield deviations from trend and the amount of price variability. IP and CRC 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 on the strength of the yield-price correlation and the amount of price variability. In comparing IP with CRC, the main differences in the policies are the unit 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 planting 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.

Reference

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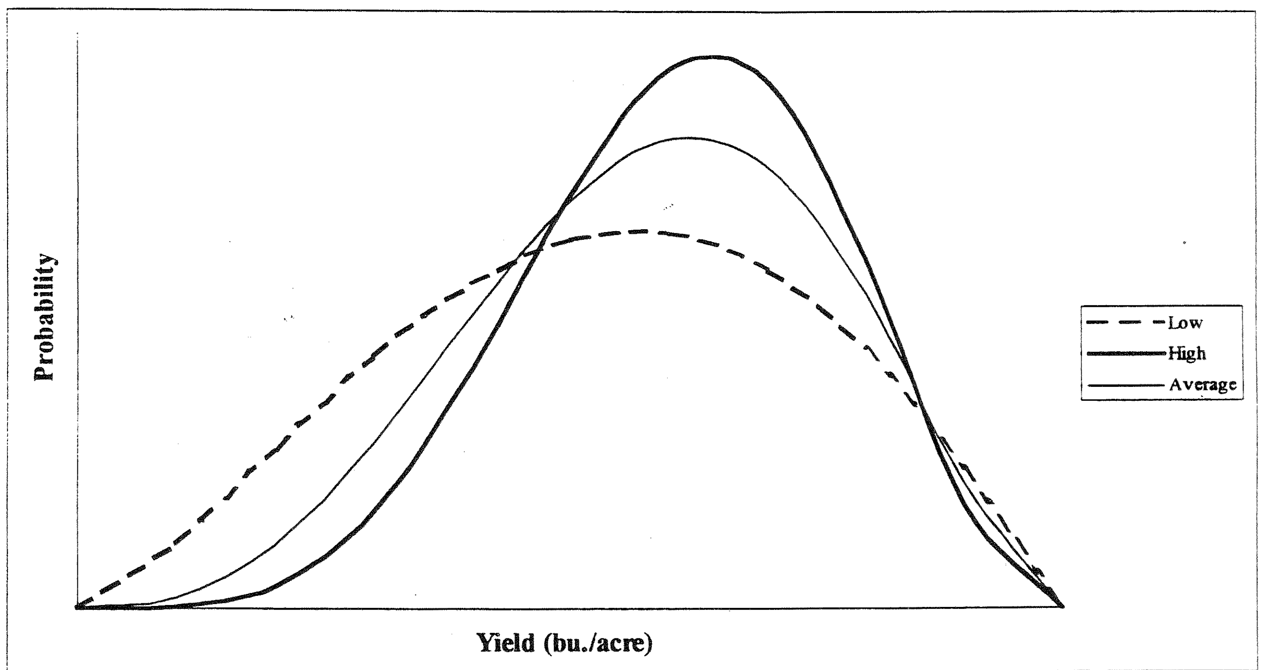

Figure 1. An Example of Possible Yield Distributions

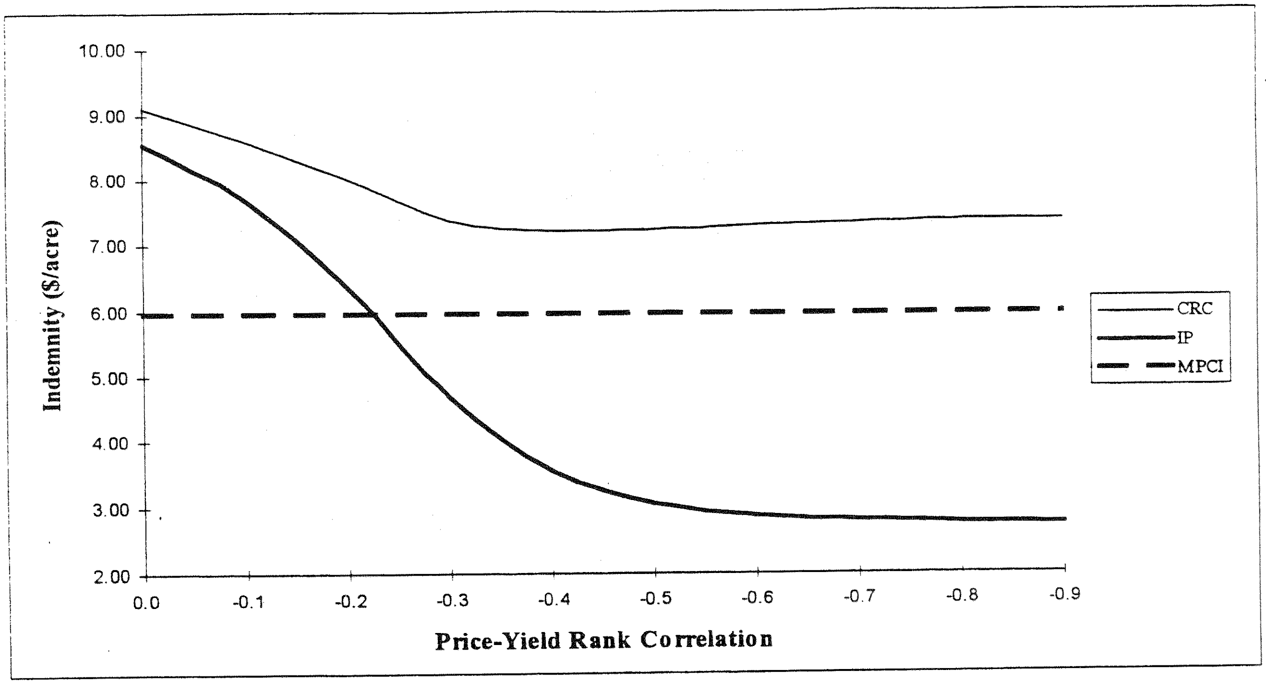

Figure 2. Per Acre Indemnity and Price-Yield Rank Correlation for Iowa Corn

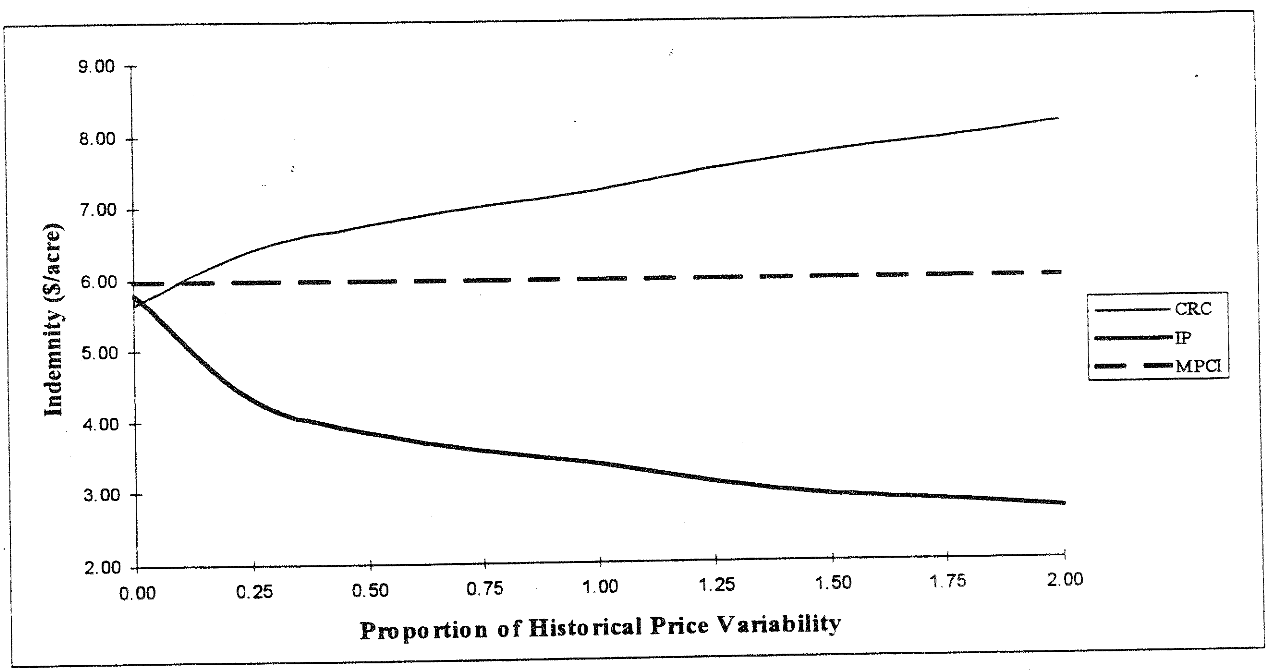

Figure 3. Per Acre Indemnity and Price Variability for Iowa Corn