Journal of Agricultural and Resource Economics, 19(2): 382–395

Premium Rate Determination in the Federal Crop Insurance Program: What Do Averages Have to Say About Risk?

Barry K. Goodwin

This article reviews actuarial procedures used to calculate premium rates in the federal crop insurance program. Average yields are used as an important indicator of risk under current rating practices. The strength and validity of this relationship is examined using historical yield data drawn from a large sample of Kansas farms. The results indicate that assumed relationships between average yields and yield variation are tenuous and imply that rating procedures that rely on average yields may induce adverse selection.

Key words: actuarial practices, federal crop insurance, yield distributions.

Introduction

The U.S. federal crop insurance program plays an important role in policy efforts to provide farmers protection against catastrophic yield shortfalls. Federally regulated crop insurance programs have been in existence since the 1930s, although participation generally has been quite limited.[1] The current program has been criticized because of high costs and poor actuarial performance. Government outlays for the federal crop insurance program exceeded $9.2 billion between 1980 and 1990. Over this period, indemnity outlays totaled over $7.1 billion while premiums collected from producers were only $3.8 billion. This corresponds to net losses (excluding administrative costs) that exceed $3.3 billion and implies that, on average, farmers received $1.88 in indemnities for each $1 of premiums paid (i.e., a loss ratio of 1.88).

Many critics of the federal crop insurance program point to adverse selection and moral hazard as reasons for the poor actuarial performance of the program. Both problems are intimately related to the Federal Crop Insurance Corporation's (FCIC) actuarial determination of insurance premium rates. Adverse selection occurs if premiums do not accurately reflect an individual farmer's likelihood of loss. Because producers are better able to ascertain their likelihood of suffering losses than are insurers, adverse selection remains a serious problem affecting the actuarial soundness of the crop insurance program. Moral hazard refers to the problem that occurs if producers alter their behavior after buying insurance in order to increase their likelihood of collecting indemnities. If rates do not adjust as loss risk rises, the actuarial performance of the industry will be threatened.

In any insurance market, adverse selection problems can be traced directly to the actuarial practices that are used to calculate insurance premium rates. If individual risks cannot be identified and premiums are based upon some aggregate risk measure, then low risk producers will be overcharged for their insurance and high risk producers will be

The author is an associate professor in the Department of Agricultural and Resource Economics at North Carolina State University.

This research was supported by the Federal Crop Insurance Corporation, the North Carolina Agricultural Research Service, and the Kansas Agricultural Experiment Station.

The helpful comments of Terry Kastens, Vince Smith, Leiann Nelson, Vondie O'Conner, Jerry Skees, Myles Watts, and an anonymous reviewer are gratefully acknowledged.

undercharged. As a result, high risk producers are more likely to insure and the riskiness of the pool tends to be higher than would be the case if premiums were actuarially fair.[2]

The poor actuarial performance of the federal crop insurance program has led critics to recommend that premium rates be raised to lower losses. For example, a 1992 U.S. General Accounting Office (USGAO) report noted that ". . . our periodic financial audits . . . confirm that FCIC has not charged high enough premiums to achieve actuarial soundness" (p. 25). However, recent research (Goodwin) has demonstrated that high risk producers are less responsive to premium increases than low risk producers. In this light, efforts to lower losses through across-the-board premium rate increases may actually worsen the actuarial performance of the program as high risk producers comprise an ever-increasing proportion of a smaller insurance pool. A superior solution would require that rate-setting techniques be altered to alleviate adverse selection by charging premium rates that better reflect individual producers' risks.

This study considers the role of adverse selection in current premium-setting techniques that are used by the FCIC to rate the federal crop insurance program. The federal crop insurance program is described briefly in the following section. In the next section, a description is provided of the current actuarial practices used by the FCIC to calculate insurance premium rates. Possible shortcomings of these practices are noted. The fourth and fifth sections consider an empirical analysis of loss risks and average yields using farm-level data for a large sample of Kansas crop farms observed between 1981 and 1991. The final section contains a brief summary of the study and some concluding remarks are offered.

The Federal Crop Insurance Program

Under current federal crop insurance programs for most field crops, producers are able to select from three guaranteed yield levels (50%, 65%, or 75% of their insurable yield) and from a range of guaranteed price levels. Price election levels are determined from FCIC forecasts of expected prices. The top price election level is set at 90–100% of the expected market price. Prior to 1994, three price election levels were available for most crops. Recent program changes now allow price elections between 30–100% of the top price election level. If the producer's yield falls below the elected coverage level, the producer receives an indemnity payment equal to the product of the elected price coverage and the yield shortfall. This yield shortfall is determined by the amount that actual yields fall short of the farm's insured yield.

The per-acre premium is determined by the product of the price guarantee, the yield guarantee, the FCIC's estimate of the farm's yield, and the premium rate. Under the 1980 Act, subsidies were introduced to encourage participation in the program. There is a 30% subsidy on the 50% and 65% yield guarantees. The subsidy for the 75% yield guarantee is equal to the dollar amount of the 65% guarantee level. Federal crop insurance is currently available for about 40 different crops.

FCIC's Actuarial Determination of Insurance Premium Rates[3]

Many believe that adverse selection is the most significant problem affecting the actuarial soundness of the federal crop insurance program (Miranda). The presence (or absence) of adverse selection is directly related to the extent to which insurance premiums accurately reflect the likelihood of losses. The FCIC adopts a number of assumptions when determining insurance premium rates that may induce adverse selection in the insurance pool. The most fundamental (though not necessarily most serious) shortcoming associated with rate-setting practices is that rates are determined for a relatively large geographic area (i.e., the county in which the farm is located). Thus, all individuals with the same average yield in a county pay an identical premium rate (dollars per hundred dollars of liability) for the same crop and practice type.

Prior to 1985, insurance levels (i.e., the liability levels calculated from insurable yields) were determined using average yields (for both insurance purchasers and nonpurchasers) in the farm's geographic area. This resulted in adverse selection since farms with loss risks above the area averages comprised an ever-increasing proportion of the insured pool. In an attempt to address the problem of adverse selection, the FCIC revised its determination of insurable yields in 1985 by instead examining the actual production history (APH) of the farm when determining insurable yield levels.

Under the APH approach, insurable yields and premium rates are calculated by examining the average yield of the farm's preceding 10 years of production data. Beginning with the 1994 crop year, producers could qualify for APH yields with only four years of production data, although up to 10 years of data are used if available. If less than four years of actual data are available, weighted Agricultural Stabilization and Conservation Service (ASCS) program yields are used in place of the missing yields. Farms purchase coverage to insure a given proportion (50%, 65%, or 75%) of their average yields. As will be developed in detail below, direct use of average yields without consideration of yield variation may poorly represent the likelihood of collecting indemnity payments.

In the actuarial determination of county-level rates, the FCIC examines a number of factors. The first step in rate determination involves an examination of the 20-year loss history of a given county. Loss cost ratios for the preceding 20 years are examined.[4] The four largest loss cost ratios are capped at the level of the fifth largest ratio. The capped data are grouped into a pool (representing a catastrophic loading factor) which later is spread over the entire state. The capped loss cost ratios plus the 16 lowest loss cost ratios are averaged to obtain a county loss cost ratio which then is used to construct an actuarially sound rate for each county. The loss cost ratios then are smoothed across county lines. This smoothing is undertaken to soften large differences in the cost of insurance for neighboring farms. The catastrophic loading factor next is spread across the entire state and rates are adjusted accordingly. The resulting rates are set for a given crop practice (e.g., irrigated versus dryland production) at the county level. The smoothing and loss-spreading practices may induce adverse selection into rates since high loss-risk counties likely will see lower rates while low loss-risk counties will see higher rates.

Next, rates are adjusted according to county average yields, as represented by yield data calculated by the National Agricultural Statistics Service (NASS).[5] Rates are adjusted inversely with county average yields. Thus, counties with high average yields realize premium rate discounts relative to counties with low average yields, regardless of actual losses or yield variation.

County rates are spread over a range of average yields using a proportional spanning procedure. Under the proportional spanning procedure, nine discrete risk categories are defined and rates in each category are inversely adjusted according to the farm's average yield. In this way, farms with higher average yields have lower premium rates. In addition, because of the proportional nature of the discounting, as average yields increase, the premium falls at an increasing rate.

A final constraint faced by the FCIC in its actuarial determination of premiums is a restriction imposed by legislation that limits the amount that a rate can increase from year to year. In most cases, premium rates may not increase by more than 20% from one year to the next. This constraint may bring about a reduction in the flexibility afforded to the FCIC for eliminating adverse selection through premium rate adjustments.

Average Yields and Yield Variation: What Do Averages Say About Risk?

An important assumption implicit in the FCIC's actuarial practices involves the assumed relationship between average yields and the likelihood of loss. Botts and Boles noted that the FCIC's use of average yields assumes a constant relationship between mean yields and the variance of yields. Specifically, they noted that the standard deviation of yields is assumed to be one-fourth of the mean of yields (i.e., that the coefficient of variation is 25%).

Skees and Reed used yield averages and standard deviations for four relatively small samples collected from corn and soybean farms in Kentucky and Illinois to evaluate the relationship between yield averages and standard deviations.[6] Their results indicated that no strong relationship existed between the mean yield and the standard deviation of yields. They also evaluated the relationship between the coefficient of variation (the ratio of the standard deviation to the average) and the mean of yields. Their results indicated that the coefficient of variation of yields tended to fall as average yields rise, giving support for rate-setting techniques that apply discounts as average yields rise.

A weakness associated with inferences drawn from such an analysis is the fact that the estimated relationship between average yields and yield variation is of an aggregate (average) nature. Although Skees and Reed do not explicitly report their regression results, the lack of a significant relationship between average yields and the standard deviation of yields suggests that considerable variation in this relationship existed across the farms in their sample. An important point to recognize is that the farms that purchase insurance are not likely to be randomly drawn from this aggregated sample. That is, finding no relationship between the mean and standard deviation of yields in an aggregate sample (or even an imperfect relationship) suggests that the potential exists for a self-selected subset of the sample to be at one extreme of this relationship. In particular, it is expected that insurance buyers will tend to have a higher yield variance relative to their mean yields than those farms that do not insure.

The use of average yields as an indicator of loss risk may introduce adverse selection into the insurance pool if the relationship between average yields and relative yield variation is not strong. The important factor determining loss risk is relative yield variation (i.e., variation relative to the mean). Consider the yield distributions illustrated in figure 1.[7] The top panel of the figure illustrates the yield distribution for a farm with a high mean and a high relative variance of yields. The bottom panel illustrates a farm with a low average yield and a low relative yield variance. Assuming that both farms choose insurance coverage at the 75% yield election, indemnities are collected only when yields fall below 75% of the mean. The likelihood of suffering a collectable loss is illustrated by the shaded areas of each distribution. In this case, the farm with the higher average yield is considerably more likely to collect an indemnity payment than is the farm with the lower average yield. Further, when the farm with the higher average yield collects indemnities, the indemnity payments will be considerably higher since the indemnity is determined from a higher average yield.

In reality, considerable variation likely exists in the relationship between average yields and yield variation across different farms. That is, if one examines this relationship for a large sample of farms using regression analysis and finds a relatively low degree of explanatory power (i.e., a low R^2), it is likely that there are some farms with yield distributions similar to the one illustrated in the first panel and others with distributions like that given in the second panel. However, the important point to note is that farms of the sort illustrated in the first panel are much more likely to purchase insurance. If rates are determined using average yields, farms with high relative yield variation likely will be undercharged. Conversely, farms with relatively low relative yield variation will be overcharged for insurance and thus will be less likely to buy coverage.

An Evaluation of Yield Averages, Yield Variance, and Empirical Premium Rates

In a manner similar to that undertaken by Skees and Reed, the relationship between the mean of yields and the standard deviation of yields was evaluated using data drawn from 2,247 farms in the Kansas Farm Management Databank. Ten years of yield data (1981–90) were used to calculate yield averages and standard deviations.[8] Table 1 illustrates the

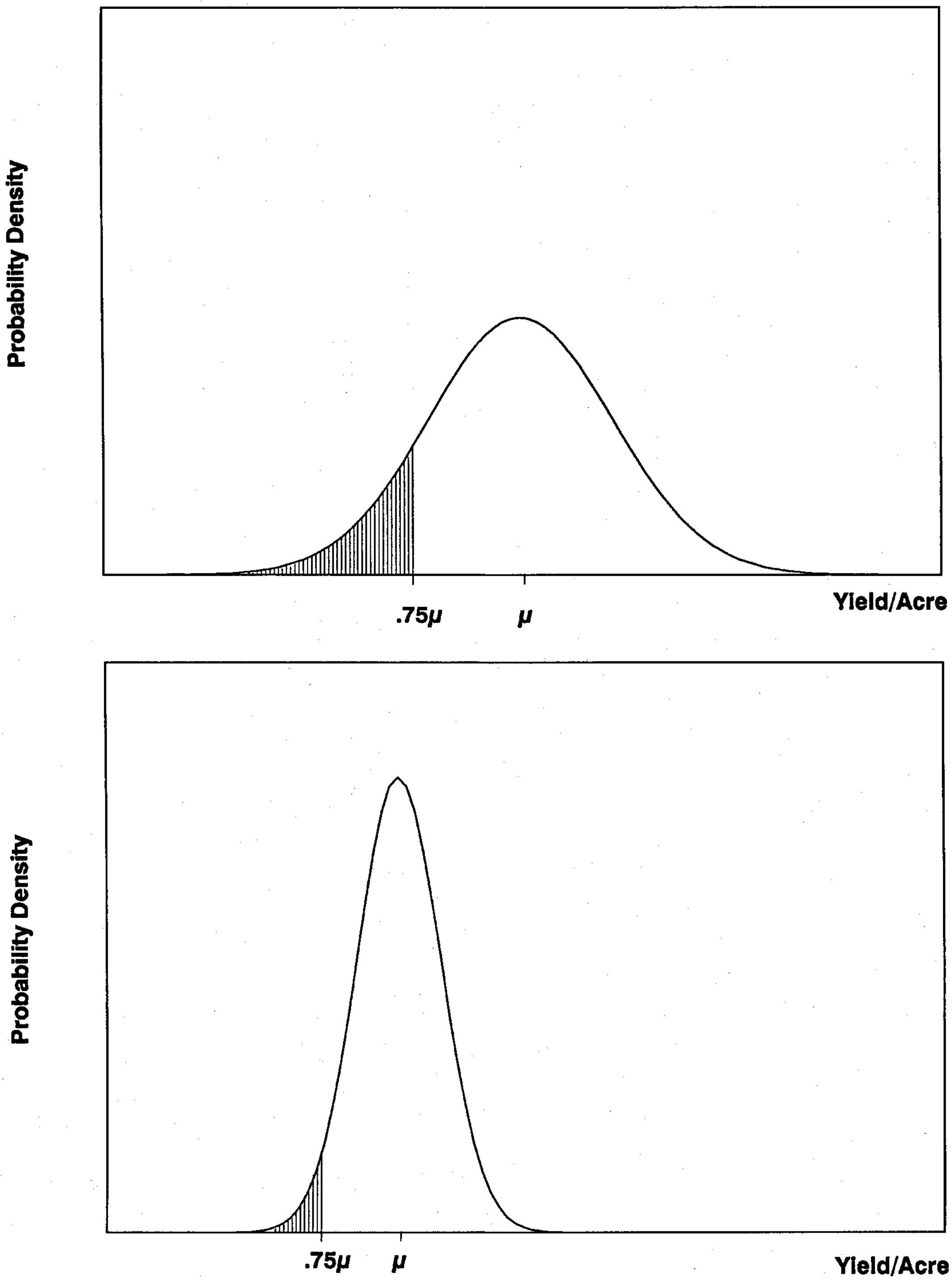

Figure 1. Effect of relative yield variability on likelihood of collecting indemnities

Table 1. Relationship Between Means and Standard Deviations of Yields ($\sigma_i = \beta_0 + \beta_1\mu_i$) for Kansas Farms (1981-90)

Crop	β_0	β_1	n	R^2	F-Test of H$_0$: $\beta_0 = 0$, $\beta_1 = .25$	Average CV
Dryland Wheat	7.6868	.0809	864	.019	224.99*	31.5168
	(.6790)*	(.0200)*				(.3361)
Irrigated Wheat	12.6968	.0010	66	.001	10.13*	28.0701
	(3.0817)*	(.0654)				(1.2416)
Dryland Corn	20.2925	.0834	139	.035	61.02*	32.0720
	(3.3628)*	(.0377)*				(.7233)
Irrigated Corn	38.6819	−.1284	82	.066	437.67*	16.2294
	(7.4046)*	(.0538)*				(1.0472)
Dryland Sorghum	14.4434	.0866	629	.068	314.98*	33.3429
	(.8237)*	(.0129)*				(.4359)
Irrigated Sorghum	23.1458	−.0352	52	.005	12.29*	21.9779
	(6.8575)*	(.0716)				(1.5419)
Dryland Soybeans	5.9383	.1559	389	.146	521.49*	40.1726
	(.4990)*	(.0192)*				(.5329)
Irrigated Soybeans	13.7560	−.1235	39	.155	87.96*	17.5311
	(2.3109)*	(.0481)*				(1.2455)

Notes: Numbers in parentheses in β_0 and β_1 columns are standard errors, and in Average CV column are standard errors of the means. An asterisk (*) indicates statistical significance at the .05 level.

estimated relationships between the standard deviation of yields and the average yields. In contrast to the finding of Skees and Reed, in six of the eight cases, a statistically significant relationship between the average yield and the standard deviation of yields is confirmed. In three of the five significant cases, the results indicate that higher average yields correspond to higher variation in yields. An F-test of whether this relationship is of the form noted by Botts and Boles to be implicit in the FCIC's rate-making process also is presented. In every case, the restriction is strongly rejected. However, in every case, the yield coefficient is less than .25. The average coefficient of variation on yields for the different commodities varies from 17.5% for irrigated soybeans to 40% for dryland soybeans. In five of the eight cases, the average CV is greater than 25%.

The most relevant result apparent in the empirical relationship between average yields and the standard deviation of yields is revealed in the very low R^2s presented in table 1. The R^2s reflect the strength of the relationship between average yields and the standard deviation of yields in terms of the percentage of variation in the standard deviations of yields that is explained by average yields. In every case, this relationship is quite weak. In six of eight cases, the R^2 is below .07. This result implies that any assumed relationship between the average and the standard deviation of yields is precarious since considerable variation exists in the relationship between average yields and yield variation across farms.

The important implication of these results is that rate-setting practices that examine only average yields likely will introduce adverse selection into the insurance pool since average yields are an imperfect indicator of relative yield variability. A likely result is that farms having higher relative yield variation (coefficient of variation) are more likely to buy insurance and will be less responsive to rate increases. To examine this point, the coefficient of variation on yields, average yields, and the regression relationship between average yields and the standard deviation on yields was reevaluated for a subset of farms for which the insurance purchase/nonpurchase decision was known.[9]

Table 2 contains an evaluation of relative yield variation for a subsample of the data that is divided according to whether insurance was purchased for each crop. The relationship between yield averages and standard deviations appears to be somewhat stronger

Table 2. Split Sample Analysis of the Relationship Between Means and Standard Deviations of Yields ($\sigma_i = \beta_0 + \beta_1\mu_i$) for Kansas Farms (1981-90)

	Nonpurchasers				Insurance Purchasers				
Crop	CV	Mean	β_0	β_1	CV	Mean	β_0	β_1	t-Test of Equal CVs
Dryland Wheat	29.92	33.78	5.5184 (1.9671)**	.1329 (.0577)**	32.49	33.87	8.4832 (1.6575)**	.0684 (.0528)	−2.19**
Dryland Corn	27.65	86.79	21.7972 (6.6182)**	.0154 (.0748)	33.53	91.22	25.6997 (7.7968)**	.0404 (.0837)	−1.78*
Dryland Sorghum	33.78	61.04	14.4323 (2.1327)**	.0822 (.0340)**	35.16	58.66	15.1186 (2.2344)**	.0778 (.0370)**	−.73
Dryland Soybeans	39.53	27.31	7.6401 (1.5869)**	.1021 (.0567)*	41.68	24.54	8.3920 (1.5140)**	.0579 (.0598)	−.84

Notes: Numbers in parentheses are standard errors. Single and double asterisks (*) indicate statistical significance at the .10 and .05 levels, respectively.

for producers that did not purchase insurance than for those that insured. The average yield coefficient is significant in three of four cases for nonpurchasers, but only in one of four cases for insurance buyers. In every case, the coefficient of variation on yields (CV) is higher for the farms that purchased insurance than for the nonpurchasers. In several cases, the difference is substantial. On average, the mean coefficient of variation is 3% higher for farms that purchased insurance than for farms that did not purchase insurance. The statistical significance of this difference is evaluated using standard t-tests of the equality of means.[10] The difference is statistically significant for dryland wheat and corn. Average yields do not appear to differ significantly between insurance buyers and farms that did not insure.

Implicit in any rating scheme that uses only the mean and variance to determine premium rates is the assumption that higher ordered moments of the yield distribution are irrelevant (or zero). As previously noted, recent research (Gallagher; Nelson) suggests that yield distributions may be nonnormal and exhibit significant skewness. If higher ordered moments of the distribution are relevant, the coefficient of variation for yields may not accurately reflect loss likelihoods.

An alternative evaluation of loss risk and premium rates can be obtained by considering the empirical rates implied by the yield data. As noted, an actuarially sound rate will equate premiums to expected indemnities. Thus, an empirical rate that is free of distributional assumptions can be calculated from an examination of the historical yield shortfalls.[11] An empirical rate (bushels per acre) for coverage at the $\alpha \times 100\%$ of the mean (μ) level of coverage is given by:

$$\text{(1)} \qquad \textit{Empirical Rate} = \sum_{s=t-1}^{t-10} y_s^*/N,$$

where

$$y_s^* = \begin{cases} \alpha\mu - \textit{yield}_s, & \text{if } \textit{yield}_s < \alpha\mu \\ 0 & \text{otherwise,} \end{cases}$$

and N is the number of nonmissing years of data. For comparison, the techniques of Botts and Boles, which assume a normal distribution and a coefficient of variation equal to .25 (i.e., $\sigma = .25\mu$), can be used to determine FCIC-type rates. Botts and Boles [equation (3), p. 735] show that, under these assumptions, an actuarially fair rate is given by:

$$\text{(2)} \qquad \textit{FCIC Rate} = \Phi((\alpha\mu - \mu)/.25\mu)(\alpha\mu - \mu) + \phi((\alpha\mu - \mu)/.25\mu).25\mu,$$

where $\Phi(\cdot)$ is the cumulative normal distribution function (representing the probability

Table 3. Average Empirical Premium Rates and Rates Based upon Normal Distribution with CV = 25% for .75μ Coverage Level (bu./acre): Entire Sample and Split Sample Analyses for Kansas Farms (1981–90)

Crop	Entire Sample		Nonpurchasers		Insurance Purchasers		t-Tests of Equal Rates	
	Empirical Rate	FCIC Rate[a]	Empirical Rate	FCIC Rate[a]	Empirical Rate	FCIC Rate[a]	Empirical Rate	FCIC Rate[a]
Dryland Wheat	1.4158	.6997	1.2488	.7035	1.5629	.7054	−2.61**	−.14
	(.9663)	(.1075)	(.8774)	(.0958)	(.9686)	(.1151)		
Dryland Corn	4.0887	1.8315	2.8590	1.8079	4.3478	1.9000	−2.09**	−1.52
	(2.2954)	(.3089)	(2.0034)	(.3596)	(1.9008)	(.4033)		
Dryland Sorghum	2.6314	1.3038	2.6597	1.2714	2.7628	1.2218	−.42	1.03
	(1.6708)	(.3181)	(1.6425)	(.3056)	(1.4990)	(.3027)		
Dryland Soybeans	1.6322	.5277	1.6926	.5689	1.6214	.5112	.39	1.94*
	(.7506)	(.1209)	(.8145)	(.1265)	(.7716)	(.1301)		

Notes: Entire sample refers to larger sample of 2,247 farms, while split sample analysis is conducted for 572 farms for which insurance purchase decisions are known. Numbers in parentheses are standard errors. Single and double asterisks (*) indicate statistical significance at the .10 and .05 levels, respectively.

[a] FCIC rates are calculated using the technique described by Botts and Boles, assuming normality and $\sigma = .25\mu$.

that a yield less than $\alpha\mu$ will be observed) and $\phi(\cdot)$ is the unit normal density function (representing the ordinate of the normal distribution at $\alpha\mu$).

Table 3 contains empirical rates and FCIC-type rates calculated from Botts and Boles' formulas for the 75% yield election level. Rates are presented for the entire sample of farms as well as the subsamples for which crop insurance purchases were known. For dryland wheat, corn, and sorghum, the empirical rates are significantly greater for the farms that purchased crop insurance. Confirming the results for yield CVs, the average differences are shown to be statistically significant using t-tests of the equality of means for wheat and corn. The largest difference occurs for corn, where the average empirical rate for purchasers is over 50% higher than that for nonpurchasers. The FCIC rates, based entirely upon yield averages, are very similar for buyers and nonbuyers of crop insurance. This reflects the fact that average yields are quite similar for insurance purchasers and nonpurchasers. The FCIC-based rates are significantly below the empirical rates in every case, perhaps reflecting the fact that yield CVs for these four crops are above 25%.

Because of the small number of years used to calculate the empirical rates, several farms had empirical rates of zero for the 75% yield election. Thus, some downward bias in the empirical rates might be expected and the differences between FCIC rates and the empirical rates might be even greater if more historical data were available. In all, the examination of empirical rates confirms the differences noted above for yield CVs and suggests that insurance purchasers have greater yield variation than nonpurchasers. Empirical rates also are found to be significantly above FCIC-type rates in every case.

In all, the actuarial practices that are currently used to determine crop insurance premium rates may induce adverse selection by encouraging participation by higher risk farms. A key assumption that may be questionable is the sole use of average yields to determine expected loss risk and premiums for individual farms. An empirical examination of the relationship between yield variation (standard deviations) and mean yields revealed that any assumption regarding the nature of this relationship would be insupportable since there is considerable variation in the nature of this relationship from farm to farm. The insurance market is likely to be drawn from one extreme of this distribution since those individuals have a greater return to insurance under given premium schedules.

In the context of these results, it is also essential to acknowledge that the FCIC often must determine rates for individual farms with no (or very limited) knowledge of the farms' yield histories. Calculation of means and relative variation of yields to determine

Table 4. Analysis of Factors Affecting Relative Yield Variation (Yield CVs) for Kansas Farms (1981-90)

	Dryland Crops				Irrigated Crops			
Variable	Wheat	Corn	Sorghum	Soybeans	Wheat	Corn	Sorghum	Soybeans
INTERCEPT	57.4881	64.0922	57.5150	67.5894	71.4959	51.9067	45.9330	52.9282
	(2.4921)**	(4.4136)**	(2.5286)**	(3.1211)**	(11.3676)**	(9.0618)**	(12.3788)**	(11.1006)**
μ	−.7568	−.3437	−.3899	−.9083	−.6660	−.2994	−.2613	−.6855
	(.0640)**	(.0463)**	(.0290)**	(.0942)**	(.1808)**	(.0574)**	(.1077)**	(.1976)**
ACRES	−1.7598	2.1369	−2.4108	−1.6838	2.2747	1.1973	−2.6981	.9186
	(.3278)**	(1.2534)*	(.6917)**	(.6348)**	(2.3589)	(1.6563)	(3.0651)	(3.5576)
ACRES^2	.0649	.1743	.2251	.1236	−.3991	−.1109	.2174	−.4154
	(.0194)**	(.1755)	(.0850)**	(.0524)**	(.3237)	(.1844)	(.3949)	(.6023)
% RENTED	1.5137	−3.9343	−2.3181	−.9002	−7.0263	−1.2725	−4.2906	−.2280
	(1.1847)	(2.0147)*	(1.2798)*	(1.6975)	(3.7369)*	(3.4694)	(4.4327)	(4.0471)
INCOME	−.0052	−.0128	−.0074	.0041	−.0060	.0067	−.0024	.0130
	(.0063)	(.0104)	(.0067)	(.0079)	(.0244)	(.0178)	(.0360)	(.0484)
CROP ACRES	.0755	−.5388	.0559	−.0732	.2713	−.0386	.1131	.0842
	(.0622)	(.1755)**	(.0769)	(.1059)	(.1288)**	(.1895)	(.2229)	(.3106)
CHEM & FERT	−.0144	.0455	−.0307	−.0302	−.0020	−.1427	−.1009	.0998
	(.0302)	(.0594)	(.0337)	(.1059)	(.1020)	(.1046)	(.1869)	(.1397)
DIVERSIFICATION	.0174	−7.2262	1.6789	.2292	17.9368	−2.0885	−24.7194	−3.9151
	(2.0802)	(5.3843)	(2.4881)	(4.0240)	(10.9885)	(8.0697)	(11.7641)**	(13.1051)
DEBTS/ASSETS	.6640	1.3266	1.0544	−1.7130	2.0422	.1241	4.0228	−2.0331
	(.7883)	(1.8009)	(.9505)	(1.1567)	(4.0441)	(2.5129)	(3.1181)	(4.7688)
GOVT PMTS	.0243	.0002	.0127	−.0021	−.1844	−.0145	−.0550	.0039
	(.0328)	(.0749)	(.0379)	(.0564)	(.0836)	(.0981)	(.1355)	(.1355)
% CROP ACRES	.1529	1.0849	3.4435	2.3761	−12.9990	1.4068	11.6704	−9.7620
	(.2384)	(3.5200)	(1.8152)*	(2.4556)	(8.7131)	(6.7868)	(11.2490)	(13.6080)
% CROP SALES	−1.6559	−.4416	−.7413	−4.5482	−12.3720	−1.3729	8.9484	1.0353
	(1.5108)	(2.7441)	(1.7263)	(2.4495)*	(11.3321)	(6.7869)	(11.9713)	(13.1743)
CORPORATION	2.5524	1.0888	.9385	−1.0505	−1.8105	−1.3695	−2.3578	−3.9831
	(1.1900)**	(1.5760)	(1.3834)	(1.5742)	(5.0539)	(3.8329)	(6.4553)	(4.3142)
PARTNERSHIP	1.1019	−.6575	1.4554	1.5689	3.1563	1.7846	−1.5909	−1.3483
	(1.1276)	(1.7611)	(1.2086)	(1.5319)	(4.6032)	(3.8329)	(6.111)	(4.2188)
NC AREA	4.2949	6.1143	5.2540	5.7292	10.0807	2.7265	5.2766	7.9332
	(1.0246)**	(3.5918)*	(1.0843)**	(2.0510)**	(9.4842)	(7.5311)	(11.5126)	(7.6154)
SC AREA	1.0262		3.3123	3.0229		6.2813	7.3149	4.4481
	(1.0396)		(1.1799)**	(4.6368)		(5.5584)	(7.0557)	(5.0877)

Table 4. Continued

Variable	Dryland Crops				Irrigated Crops			
	Wheat	Corn	Sorghum	Soybeans	Wheat	Corn	Sorghum	Soybeans
SW AREA	5.9664		−1.9578		−1.6587	12.9571	6.9363	5.7862
	(1.2768)**		(1.8372)		(3.0889)	(5.8262)**	(6.7971)	(5.6683)
NE AREA	.9682	3.4005	−.0749	2.2877		8.2749		
	(.9945)	(1.4275)**	(.9808)	(1.1148)**		(5.5869)		
NW AREA	8.4684		−1.3584			9.2788		
	(1.4519)**		(2.2047)			(6.0235)		
n	857	139	626	386	65	82	52	38
R^2	.2452	.4876	.4439	.3365	.4550	.4724	.4581	.6282
F-Statistic	14.308**	7.257**	25.455**	10.978**	2.505**	2.922**	1.691*	1.988*

Notes: Numbers in parentheses are standard errors. Single and double asterisks (*) indicate statistical significance at the α = .10 and .05 levels, respectively.

expected loss risk is difficult or even impossible in this case. Farms that often collect indemnities may even drop in and out of the program to prevent developing a yield history that would result in their paying high rates.[12] In the case of farms with insufficient yield histories upon which to base an estimate of relative yield variation, a high expected risk level should be assigned. To some extent, the FCIC does apply such a penalty by using transition yields (t-yields) which determine rates and insurable yields by using a proportion of ASCS program yield data.

Prediction of Relative Yield Variation

Given the tenuous nature of the relationship between yield averages and standard deviations, a relevant question is whether observable farm characteristics could be used to improve measurement of yield risk in rating insurance. Private insurance contractors (e.g., property, life, and health insurance providers) typically use observable factors which are correlated with risk to assign premium rates. A number of observable farm operation characteristics were collected from the Kansas data and used in conjunction with the yield histories to evaluate factors that might be useful in improving estimates of the likelihood of yield shortfalls. In addition to average yields (μ), these factors include the size of the enterprise (*ACRES*), size squared ($ACRES^2$), the percent of the operation that is rented (*% RENTED*), net farm income (*INCOME*), total crop acres (*CROP ACRES*), fertilizer and chemical expenditures per crop acre (*CHEM & FERT*), a Herfindahl index of diversification calculated from sales shares (*DIVERSIFICATION*), leverage (*DEBTS/ASSETS*), government payment receipts per crop acre (*GOVT PMTS*), the percent of total farm acres engaged in crop production (*% CROP ACRES*), the percent of total sales represented by crops (*% CROP SALES*), dummy variables representing corporate enterprises (*CORPORATION*) and partnerships (*PARTNERSHIP*), and a series of regional dummy variables that distinguish six different geographic regions of Kansas. Coefficients of variation for each of the eight different crop enterprises were regressed against these variables. Average values of the observable farm characteristics over the 1981 through 1990 period are used in the regressions. The results are presented in table 4.

Average yields are inversely correlated with relative yield variation in every case. This relationship is highly significant for every crop. Significant size effects are also revealed for the dryland enterprises. For wheat, grain sorghum, and soybeans, relative yield variation falls at a decreasing rate as enterprise size increases. Conversely, a significant positive relationship between size and relative yield variability is revealed for dryland corn. The implied size effects for dryland commodities are illustrated in figure 2. It is relevant to note that the statistical significance of the corn effect is lower than that found for other commodities. No significant relationship between size and yield variability is revealed for the irrigated crops.

The proportion of the enterprise that is produced on rented land is negatively correlated with yield variability in every case, though this effect is statistically significant only for dryland corn and soybeans and irrigated wheat. Total crop farm size, as measured by total crop acres, is negatively related to yield variation for dryland corn and positively related to yield variation for irrigated wheat. This effect is not statistically significant for the remaining enterprises.

Income, chemical and fertilizer expenditures, leverage, and government payment receipts are not significantly related to relative yield variation. Diversification is negatively correlated with yield variability for irrigated grain sorghum, but is not significant for the remaining commodities. The proportion of total acres engaged in crop production was included to represent overall land quality. Farms with lower land quality are likely to have more waste and set-aside. This variable is significant only in the dryland sorghum equation, where, counter to expectations, it is positively correlated with relative yield variation. The proportion of total sales that comes from crops is significantly related to yield variability for dryland soybeans, but is not significant in any other equation. Cor-

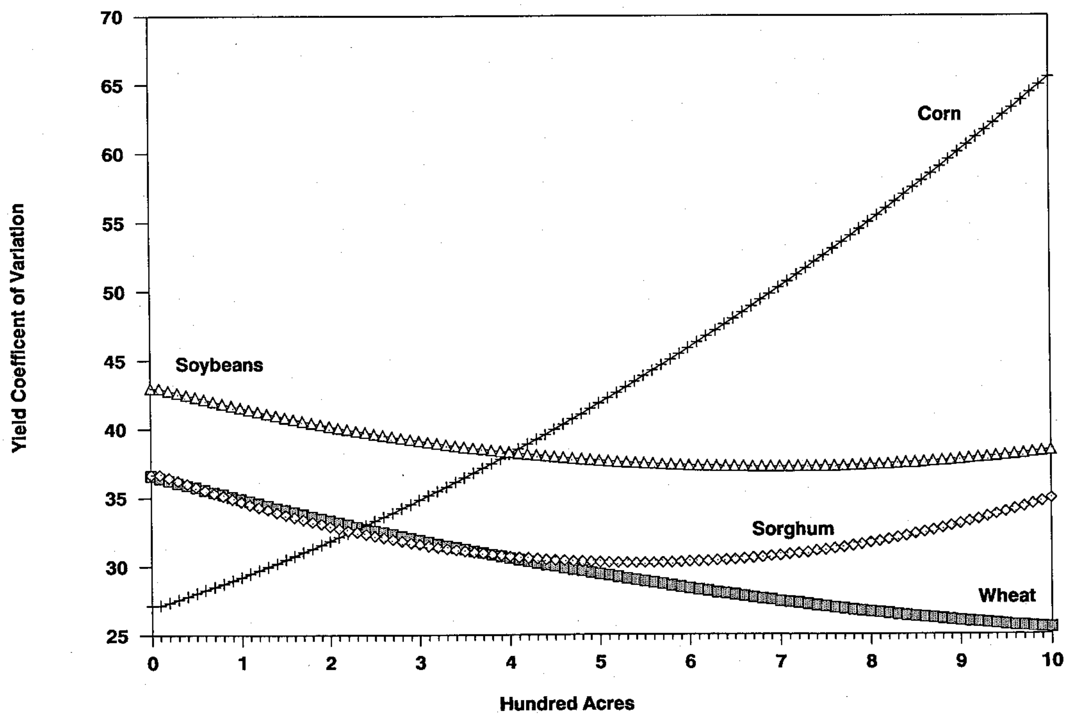

Figure 2. Relative yield variation and size

porate dryland wheat farms have significantly more yield variation than do sole-proprietor enterprises. However, no significant difference in yield variability among different farm enterprise organizations is detected for the other commodities. Finally, a series of regional dummy variables confirm that significant regional differences exist in relative yield variation. This provides support for the FCIC's practice of determining rates for individual counties.

The R^2s of the equations are considerably larger than those revealed in preceding analyses, indicating that information other than average yields could be used to improve predictions of yield variability. The important implication is that these factors may provide useful insights into expected losses in situations where yield histories are unavailable. However, the basic point remains that the relationship between yield variation and average yields and other observable factors is quite limited and thus yield histories should be used directly when available to calculate measures of variation that directly measure risk.

In all, these results provide a degree of support for current FCIC practices that apply discounts for farms with higher average yields. However, even in the best of cases, this relationship is imperfect, and thus basing risk measures solely on averages may induce adverse selection. Actuarial practices would likely benefit from directly measuring yield variability to assign expected risk.

Summary and Concluding Remarks

This study reviews the actuarial practices currently used by the Federal Crop Insurance Corporation to determine premium rates for multiple peril crop insurance. The role of adverse selection, which occurs when rates do not accurately represent the true likelihood of losses, is discussed. The FCIC's emphasis on average yields as an indicator of yield variability is evaluated using data drawn from 2,247 Kansas crop farms.

The results indicate that averages are indeed inversely correlated with relative yield variation. However, the results also indicate that this relationship is tenuous, and that rates that depend heavily on average yields may imperfectly represent loss probabilities and thus cause adverse selection. A superior solution would be to directly use yield histories to measure variation rather than just expected yields. Relative yield variability, represented by the coefficient of variation of yields, offers a suitable metric for measuring expected loss risk.

The FCIC often is constrained to working with a small number of previous yield observations (perhaps even zero) when attempting to assign individual producers rates. In such cases, an examination of alternative observable farm factors, including size variables, tenure, and diversification may be useful. Significant scale effects are revealed for dryland crops.

[*Received November 1993; final revision received May 1994.*]

Notes

[1] Between 1980 and 1990, the average participation rate in the federal crop insurance program was about 17% of eligible acres (U.S. General Accounting Office 1992).

[2] An actuarially fair premium is one which equates premiums to expected indemnities. With actuarially fair premiums, expected loss ratios (the ratio of indemnities paid out to premiums collected) are one.

[3] Material in this section is based upon personal communications with the Federal Crop Insurance Corporation.

[4] The loss cost ratio is given by the ratio of indemnity outlays to total liability.

[5] The NASS dataset used to determine rates is updated rather infrequently. In some cases, a lag of five years may occur before yields are updated.

[6] Skees and Reed examined yield histories drawn from four samples of 54, 54, 48, and 65 farms in Illinois and Kentucky.

[7] For convenience, a normal yield distribution is illustrated. However, considerable evidence (Gallagher; Nelson) suggests that significant skewness may exist in yield distributions. Allowing skewness may exaggerate the effects described here. This point also is made in other research, including Just and Calvin and U.S. General Accounting Office (1993).

[8] Farms missing more than a single year of data were excluded from the analysis.

[9] Of the 2,247 farms in the sample, information regarding insurance purchases was known for 572 farms. Irrigated crops were excluded from this portion of the analysis because of very small samples.

[10] The t-tests allow for differences in standard deviations in constructing the t-statistics.

[11] A limitation of using empirical rates to examine loss risk is that relatively large samples may be needed to accurately measure risk. For example, with only 10 years of data, one may not observe yields below the proportion of the mean of interest (e.g., 65%), implying an empirical premium rate of zero. However, the probability of loss is likely to be greater than zero for any realistic yield election.

[12] Farms can "lose" their yield history by dropping coverage for a year, after which they assume ASCS transition yields. In addition, farms also have been able to lose their yield histories by changing insurance companies or transferring insurance among operators, although improved record keeping is eliminating such practices.

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