Staff Paper P84-23 August 1984

Staff Papers Series

ADJUSTING CROP INSURANCE PREMIUM AND PRODUCTION
GUARANTEE LEVELS TO REFLECT FARMER EXPERIENCE

by
Robert P. King
Associate Professor

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture, Forestry and Home Economics
St. Paul, Minnesota 55108

Staff Paper P84-23 August 1984

ADJUSTING CROP INSURANCE PREMIUM AND PRODUCTION GUARANTEE LEVELS TO REFLECT FARMER EXPERIENCE*

by

Robert P. King
Associate Professor

Department of Agricultural and Applied Economics
University of Minnesota

* Selected paper presented at the annual meeting of the American Agricultural Economics Association, Ithaca, New York, August 1984. This research was funded by the Minnesota Agricultural Experiment Station.

Staff Papers are published without formal review within the Department of Agricultural and Applied Economics.

The current federal all-risk crop insurance program was designed to provide effective, equitable protection for farmers against the adverse financial impacts of downside yield risk. If the program is to function as intended, however, participation must be widespread and the attractiveness of the coverage provided must be relatively uniform, both within and across locales. Given considerable differences in yield variability across farms, program inequities and adverse selection problems can be minimized if these differences are reflected in individual farm production guarantees and/or premiums.

This poses a particularly difficult problem for the Federal Crop Insurance Corporation (FCIC). Reliable farm level yield information is often not available. Furthermore, such limitations in the information base can be remedied only with the passage of time. Finally, the problem is made worse by the fact that the yield data used to set premiums and production guarantees in a given county are often based on the yield experience of a small, adversely selected group of farmers. This means premiums may be too high or yield guarantees too low to induce most producers to purchase crop insurance, but this situation cannot be corrected unless more producers participate in the program.

Recognizing this problem, the FCIC has established procedures for adjusting premiums to reflect long-term farm level experience (American Association of Crop Insurers, pp. 77-78). More recently, the Individual Yield Coverage Plan (IYCP) was instituted to allow farmers to adjust production guarantees to reflect their average historical yield over a 10-year period.

As an alternative to both of these procedures, King has proposed the target loss ratio (TLR) approach. Under this procedure, which uses the same historical data required for the IYCP, premiums or production guarantees are adjusted to levels that result in an expected loss ratio (i.e. a ratio of expected indemnities to premium) equal to a pre-specified target value.

In this paper Monte Carlo methods are used to compare the performance of these two approaches for adjusting premiums and production guarantees to reflect farm level yield experience. Speed of adjustment to an expected loss ratio of 1.0 (expected indemnities are equal to premiums paid) and the stability of the expected loss ratio around 1.0 are the performance criteria considered. After brief descriptions of the basic features of the federal crop insurance program and the two adjustment procedures, the design of the Monte Carlo experiments is outlined. The results of the experiments are then presented. Finally, issues for further study are identified and policy implications are discussed.

Basic Features of the Federal Crop Insurance Program

Federal crop insurance protects against all yield risks, including those associated with drought and disease that could not be covered by private insurers. The program offers nine basic coverage levels, which are defined by a producer's selection of a production guarantee and a price election level. The production level can be 50, 65, or 75 percent of the area average yield, and three price election levels are offered for each crop.

Crop insurance premiums are based on coverage levels--the higher the production guarantee or price election level, the higher the premium. Production guarantees and premium levels are based on actuarial data collected and analyzed by FCIC staff. All premiums are subsidized. For those who select the 50 or 65 percent production guarantee, the subsidy is 30 percent of the base premium. For those who select the 75 percent production guarantee, the subsidy is equal to the dollar value of the subsidy for the 65 percent production guarantee.

An indemnity is paid whenever the per acre yield for the entire insurance unit falls below the production guarantee selected by the farmer. The per acre indemnity is equal to the product of the yield shortfall and the price election. For example, if a wheat producer who selected a production guarantee of 20 bushels per acre and a price election of $3.50 per bushel had an actual yield of 15 bushels per acre, he would receive an indemnity of $17.50 per acre.

Premium Adjustments and the IYCP

For some time, the FCIC has used a premium adjustment scheme to lower or raise premiums in response to favorable or unfavorable crop insurance experience.[1/] A farm with a long history of federal crop insurance participation and a low historical loss ratio receives a substantial reduction in premiums. Conversely. a farm with a large number of loss years and a high loss ratio pays a considerably higher premium. This procedure helps alleviate some of the problems associated with inappropriate premiums and production guarantees, but it will not necessarily result in a stable expected loss ratio approximately equal to one. Furthermore, because the adjustment process is slow, this procedure alone may do little to attract farmers who believe existing premiums and production guarantees are not appropriate for them.

The IYCP overcomes many of these shortcomings. Under this procedure, the farmer is allowed to base production guarantee levels on a 10-year historical average of actual yields on his farm. If this farm level average is higher than the area average yield used in the FCIC actuarial tables, the farmer realizes an immediate, favorable adjustment in the attractiveness of crop insurance coverage.

Together, these two procedures allow for both immediate and longer term adjustments in premiums and production guarantees. Though they do not ensure that the long-term expected loss ratio will be in the neighorhood of 1.0 for each farm, they represent an important step toward individualizing rate and average levels.

The Target Loss Ratio Approach

The TLR approach is based on the fact that the expected loss ratio, ELR, is defined by the expression:

$$(1) \quad ELR = (PE/PR)\int_0^{PG} F(y)dy,$$

where PE is the price election per unit of production, PR is the premium per acre, PG is the production guarantee, and F(y) is the cumulative distribution function of crop yield per acre.[2/] If PE and F(y) are known, the problem of setting PR and PG at levels that will equate ELR to some target value is easily solved. Of course, the true F(y) cannot be known for any given farm. A sample cumulative distribution function can, however, be constructed from historical data using non-parametric procedures described in Mood, Graybill, and Boes (p. 512).[3/] Once a sample cumulative has been constructed, simple numerical integration procedures described in King can be used to determine levels of PR and PG that result in an ELR equal to the target level. In effect, if the target loss ratio is 1.0 and the premium is considered fixed, these procedures solve for a production guarantee that would have equated indemnities to premiums over the sample period.

On average, this procedure should ensure an expected loss ratio equal to the target level and it should result in rapid convergence of the expected loss ratio to the neighborhood of the target. The difficulty with this approach is that 10 years of yield data may not be sufficient to construct an accurate sample cumulative distribution function. Therefore, the true (and unknowable) ELR associated with the premium and production guarantee derived in this way may be quite different from the target level.

Monte Carlo Experiment Design

Under either adjustment procedure, the problem facing the FCIC is to set production guarantee and premium levels without knowing the true underlying yield distribution. In effect, both procedures can be viewed as means for estimating the proper production guarantees and/or premium levels using only a small sample of historical yields. Clearly such estimates are, themselves, random variables, since they depend on the particular sample observations that are available. Ideally, the true expected loss ratios associated with these estimates should have distributions tightly clustered around the target loss ratio.

Monte Carlo methods (see Judge, et. al., pp. 387-88) can be used to investigate the sampling properties of the expected loss ratios associated with alternative schemes for premium production guarantee and ajustment. In a Monte Carlo experiment, a large number of samples is drawn at random from a known underlying distribution. Each sample is then used to estimate some parameter related to the underlying distribution. The resulting estimates, one for each sample, are then compared to the true value of the parameter, which is derived analytically from the underlying distribution. In this way the distribution of the estimate around the true value can be studied.

In this analysis, underlying yield distributions were assumed to be from the triangular family. The cumulative distribution function, F(y), for a triangular distribution is given by the following expression (Law and Kelton, p. 167):

$$(2) \qquad F(y) = \begin{cases} 0 & \text{if } y < a \\ \dfrac{(y-a)^2}{(b-a)(c-a)} & \text{if } a \leq y \leq c \\ 1 - \dfrac{(b-y)^2}{(b-a)(b-c)} & \text{if } c < y \leq b \\ 1 & \text{if } b < y, \end{cases}$$

where a is the minimum possible value of y, b is the maximum possible value of y, and c is the modal (most likely) value of y. The triangular distribution was used in this study because of its flexibility and analytical convenience. It may not be the best distribution for representing crop yields, however, and in future analyses other distributions may be used.

In this experiment, 50 samples of 20 years of yield data were drawn from each underlying yield distribution. Each sample was then used to simulate adjustments in production guarantees and premium levels over a 10-year period. The first 10 yield levels in a sample were treated as a 10-year yield history. The second 10 yield levels represented actual yields over a subsequent 10-year period of participation in the federal crop insurance program. As the simulation progressed within a sample, both the current FCIC and the TLR adjustment procedure were used to set premium levels and production guarantees at values based on available yield data. These production guarantees and premium levels were then used to calculate the true expected loss ratios using the pre-specified parameters of the underlying triangular distribution.

The experiment was replicated for three case farms selected from the group of Colorado dryland wheat farmers who participated in the study by King and Oamek. Information on the assumed underlying yield distributions, which are based on historical yields, is given in table 2. In each instance the minimum yield level, a, was set at zero, and the maximum yield level, b, was set at a subjective level supplied by the case farmer. The following expression was used to set the value of c:

$$(3) \quad c = 3d - a - b,$$

where d is a 10-year historical average yield.[4/] The yield distribution for case farm 1 is skewed to the left, that for case farm 2 is approximately symmetrical, and that for case farm 3 is skewed to the right, since the value of c for these three distributions are, respectively, above, near, and below the midpoint of the range between a and b.

Table 2. Information on Underlying Yield Distribution for the Three Case Farms

	Case Farm		
	1	2	3
Distribution Parameters			
a	0.0	0.0	0.0
c	28.0	24.7	3.8
b	40.0	50.0	40.0
mean	22.7	24.9	14.6
standard deviation	8.4	10.2	9.0
Base Program Parameters*			
production guarantee (bu./ac.)	12.5	13.0	7.5
premium ($/ac.)	6.00	5.00	6.00
expected loss ratio	.34	.42	.47

* This assumes the 65 percent production guarantee and the $3.50 per bushel price election.

In each replication of the experiment, the producer was assumed to select the 65 percent production guarantee and the $3.50 price election. Production guarantee and premium levels for the county and area in which each case farm was located were used to establish the base program parameters presented in table 2. The expected loss ratio for each case farm is well below the target level of 1.0. This was by design, since the premium adjustment procedures are intended to make federal crop insurance more attractive to these producers.

Results

Summary information on the expected loss ratio distribution associated with the two adjustment schemes is presented in table 3. For each case farm, descriptive statistics are given for the expected loss ratio in years 1, 5, and 10 of a 10-year participation period. Perhaps the most noteworthy feature of these results is the poor performance of both procedures. Even with 20 years of yield data--the information base after 10 years of participation--neither approach consistently yields a true expected loss ratio close to 1.0. Clearly the TLR procedure performs better in this regard, but it succeeds in placing the true expected loss ratio between 0.81 and 1.09 only about one-third of the time in year 10. This points to the difficulty of the information-related problem facing the FCIC.

Looking at the mean expected loss ratio levels, both procedures consistently yield expected loss ratios that average less than 1.0. This is not surprising for the current FCIC procedures, since their design does not ensure "unbiased" estimates of appropriate premium and production guarantee levels. Under the TLR approach, this downward bias seems to occur because the procedure for constructing the sample cumulative distribution function over-states the area under a convex cumulative. As

TABLE 2. SUMMARY INFORMATION ON EXPECTED LOSS RATIO DISTRIBUTIONS ASSOCIATED WITH THE TWO ADJUSTMENT PROCEDURES

	EXPECTED LOSS RATIOS UNDER THE FCIC ADJUSTMENT PROCEDURE									EXPECTED LOSS RATIOS UNDER THE TLR ADJUSTMENT PROCEDURE								
CASE FARM	1			2			3			1			2			3		
YEAR	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10
MINIMUM	0.27	0.25	0.19	0.37	0.36	0.23	0.25	0.33	0.17	0.29	0.25	0.36	0.24	0.24	0.34	0.38	0.42	0.39
PERCENT BETWEEN 0.0 AND 0.20	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.21 AND 0.40	28.0	24.0	10.0	4.0	2.0	4.0	20.0	12.0	8.0	16.0	10.0	6.0	26.0	14.0	8.0	2.0	0.0	2.0
0.41 AND 0.60	40.0	36.0	40.0	34.0	30.0	16.0	18.0	20.0	18.0	32.0	22.0	10.0	22.0	16.0	12.0	18.0	12.0	10.0
0.61 AND 0.80	18.0	32.0	36.0	20.0	18.0	24.0	14.0	18.0	24.0	8.0	18.0	30.0	8.0	26.0	28.0	28.0	34.0	22.0
0.81 AND 1.09	14.0	8.0	10.0	18.0	38.0	38.0	20.0	32.0	30.0	28.0	26.0	30.0	28.0	22.0	30.0	30.0	26.0	38.0
1.10 AND 1.19	0.0	0.0	2.0	8.0	2.0	8.0	4.0	6.0	6.0	4.0	4.0	2.0	4.0	2.0	0.0	6.0	6.0	12.0
1.20 AND 1.39	0.0	0.0	0.0	16.0	8.0	4.0	14.0	4.0	4.0	0.0	8.0	10.0	0.0	6.0	10.0	4.0	8.0	4.0
1.40 AND 1.69	0.0	0.0	0.0	0.0	2.0	6.0	10.0	8.0	4.0	0.0	4.0	6.0	0.0	6.0	6.0	0.0	10.0	8.0
1.70 AND GREATER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	12.0	8.0	6.0	12.0	8.0	6.0	12.0	4.0	4.0
MAXIMUM	0.94	1.01	1.12	1.39	1.53	1.52	1.64	1.67	2.32	2.17	2.62	2.58	2.39	2.78	2.92	2.10	2.53	2.20
MEAN	0.55	0.56	0.60	0.79	0.80	0.83	0.81	0.82	0.84	0.82	0.89	0.92	0.81	0.88	0.91	0.92	0.96	0.96
STANDARD	0.19	0.17	0.19	0.30	0.28	0.29	0.38	0.35	0.39	0.50	0.48	0.41	0.56	0.52	0.45	0.42	0.40	0.34
PROBABILITY THAT FCIC ELR LESS THAN TLR ELR	0.80	0.82	0.92	0.50	0.60	0.56	0.68	0.76	0.74									

the number of years experience increases, this problem is alleviated. It should be noted, however, that mean expected loss ratios are always closer to 1.0 under the TLR approach and that, on average, both procedures make federal crop insurance considerably more attractive than it is with unadjusted premiums and production guarantees. Standard deviations of expected loss ratio distributions associated with the FCIC procedures tend to be smaller than those associated with the TLR approach. Given the biases in both procedures, however, these standard deviations must be interpreted with caution, since they do not reflect deviations from the target level.

Finally, the figures at the bottom of table 2 indicate that the true ELR associated with the TLR procedure has a high probability of being greater than that based on FCIC procedures. This suggests, once again, that adjustment procedures based on the TLR approach should result in a program that is more attractive to farmers. At the same time, adoption of the TLR approach should not put the FCIC at undue risk, since the overall FCIC expected loss ratio should still be approximately 1.0 if participation is high and widely dispersed geographically.

Concluding Remarks

The results of this study demonstrate the difficulty of individualizing premiums and production guarantee levels in a federal crop insurance program. They suggest that the TLR adjustment procedures are more effective than those currently being used, but the difference in performance may not be sufficient to warrant a costly change in procedures. Further research is needed to identify other adjustment schemes and to explore the possibility of using composite adjustment procedures that base premiums and production guarantees on a weighted average of results from these two methods.

FOOTNORES

1/ See American Association of Crop Insurers, pp. 77-78 or Lemieux, Richardson and Nixon, p. 145 for a detailed description of this procedure.

2/ Let I be the crop insurance indemnity per acre for a particular price election and production guarantee. Given the design of the federal crop insurance program,

$$I = \begin{cases} PE\ (PG - y) & \text{if } 0 \leq y < PG \\ 0 & \text{if } y \geq PG \end{cases}$$

I is a random variable because it is a function of crop yield, y, which is a random variable. Let the density function of y be f(y). The expected indemnity, EI, is defined by the expression:

$$EI = \int_0^\infty If(y)dy$$

$$= \int_0^{PG} PE(PG-y)f(y)dy + 0.$$

Integrating by parts,

$$EI = PE \int_0^{PG} F(y)dy.$$

It follows that:

$$ELR = EI/PR = (PE/PR) \int_0^{PG} F(y)dy.$$

3/ These procedures require no assumptions about the form of the true yield distribution.

4/ It should be noted that this procedure defines underlying yield distributions that could occur, even though they are not necessarily perfect representations of the true yield distributions for these case farms.

REFERENCES

American Association of Crop Insurers. 1984 MPCI Reference Manual. Washington, D.C., 1984.

Judge, G.C., R.C. Hill, W.E. Griffiths, H. Lütkepuhl, and T.C. Lee. Introduction to the Theory and Practice of Econometrics. New York: John Wiley and Sons, 1982.

King, R.P. Response of Dryland Wheat Farmers to Changes in the Federal All-Risk Crop Insurance Program, unpublished report to the Federal Crop Insurance Corporation, September 1982.

_____ and G.E. Oamek. "Risk Management by Colorado Dryland Wheat Farmers and the Elimination of the Disaster Assistance Program." American Journal of Agricultural Economics. 65(1983): 247-255.

Law, A.M. and W.D. Kelton. Simulation Modeling and Analysis. New York: McGraw-Hill Book Company, 1982.

Lemieux, C.M., J.W. Richardson, and C.J. Nixon. "Federal Crop Insurance vs. ASCS Disaster Assistance for Texas High Plains Producers: An Application of Whole-Farm Simulation." Western Journal of Agricultural Economics. 7(1982): 141-53.

Mood, A.M., F.A. Graybill, and D.C. Boes. Introduction to the Theory of Statistics, Third Edition. New York: McGraw-Hill Book Company, 1974.