



## Agricultural & Applied Economics Association

---

Area-Yield Crop Insurance Reconsidered

Author(s): Mario J. Miranda

Source: *American Journal of Agricultural Economics*, Vol. 73, No. 2 (May, 1991), pp. 233-242

Published by: Blackwell Publishing on behalf of the Agricultural & Applied Economics Association

Stable URL: <http://www.jstor.org/stable/1242708>

Accessed: 15/05/2009 14:21

---

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at <http://www.jstor.org/page/info/about/policies/terms.jsp>. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at <http://www.jstor.org/action/showPublisher?publisherCode=black>.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is a not-for-profit organization founded in 1995 to build trusted digital archives for scholarship. We work with the scholarly community to preserve their work and the materials they rely upon, and to build a common research platform that promotes the discovery and use of these resources. For more information about JSTOR, please contact support@jstor.org.



Blackwell Publishing and Agricultural & Applied Economics Association are collaborating with JSTOR to digitize, preserve and extend access to *American Journal of Agricultural Economics*.

<http://www.jstor.org>

# Area-Yield Crop Insurance Reconsidered

Mario J. Miranda

One of the more promising proposals for reforming the federal crop insurance program calls for both premium rates and indemnities to be based not on the producer's individual yield but rather on the aggregate yield of a surrounding area. Area-yield crop insurance can provide more effective yield-loss coverage than individually tailored insurance, without most of the adverse selection and moral hazard problems that have historically undermined the actuarial performance of the federal crop insurance program.

*Key words:* crop insurance, optimal hedging, risk and uncertainty.

When the Federal Crop Insurance Act of 1980 was signed into law, policy makers envisioned a crop insurance program that would ultimately operate on a near actuarially sound basis with limited government financial assistance. Between 1980 and 1988, however, government outlays for the federal crop insurance program exceeded 4.2 billion dollars, accounting for over 80% of the total indemnities paid to producers. The loss ratio, indemnities paid to producers divided by premiums collected from producers, averaged 2.05, well in excess of the approximate 0.95 level generally regarded as necessary for break-even insurance operations (U.S. GAO).<sup>1</sup> The poor actuarial performance of the federal crop insurance program and its failure to attract producer participation has led to dissatisfaction with the program, including calls for the repeal of the 1980 act and elimination of federal crop insurance.<sup>2</sup>

Under the provisions of the 1980 act, crop insurance is marketed primarily through private

insurance agents and brokers. The 1980 act authorized the Federal Crop Insurance Corporation to subsidize producer premium payments and to reimburse participating private insurance companies for their administrative expenditures and part of their underwriting losses. Federal crop insurance, which is available for over fifty crops, covers all natural risks, including unavoidable losses from drought, excessive rain, and storm damage. An agricultural producer can purchase individualized coverage for either 50%, 65%, or 75% of the normal yield, and at one of three different price elections. If the producer's yield falls below the elected coverage level, he receives, per insured acre, an indemnity equal to the yield shortfall times the elected price level.

The failure of the federal crop insurance program to operate on an actuarially sound basis can be attributed to the problems inherent in trying to tailor coverage to individual yield-loss experience. The most serious of these problems, adverse selection, arises because producers are better informed about the distribution of their own yields and thus are better able to assess the actuarial fairness of their premiums than the insurer, who lacks access to reliable individual yield data and other relevant information (Skees and Reed). Producers who recognize that their expected indemnities exceed their premiums are more likely to purchase coverage than those whose premiums are actuarially high. As a result, the insurer's expected indemnity outlays exceed total premium income, and, in the long run, the insurance operation loses money. Efforts by the insurer to avoid these losses by raising premiums only result in a smaller and more adversely selected pool of participants.

Mario J. Miranda is an assistant professor in the Department of Agricultural Economics and Rural Sociology, Ohio State University.

Research was supported by U.S. Department of Agriculture Cooperative Research Agreement 58-3AEK-7-80020.

The author wishes to thank Joseph Glauber, Jerry Skees, and an anonymous reviewer for their valuable suggestions and comments and Jean Buzby for her assistance with the data.

<sup>1</sup> If government premium subsidies are included in the total premium payment, as is common practice, the loss ratio would be 1.57. Excluding the subsidies, as occurs here, provides a better measure of the current program's failure to operate on an actuarially sound basis. The 0.95 loss ratio target assumes that a loading factor of 5% is sufficient to cover administrative expenses.

<sup>2</sup> The Bush administration's 1990 farm bill proposal calls for repeal of the Federal Crop Insurance Program and replacing it with a standing disaster assistance program.

Other problems associated with individual-yield crop insurance include high administrative costs and moral hazard. Record keeping and other manpower requirements needed to verify individual production histories and to adjust individual yield-loss claims raise insurer expenditures and impose transaction costs on participating producers. Moral hazard occurs when producers, after purchasing insurance, alter their production practices in a manner that increases their chances of collecting an indemnity (Chambers, Nelson and Loehman). In order to combat moral hazard, federal crop insurance requires a deductible of at least 25% of the producer's normal yield. This provision limits the coverage provided by the insurance and reduces its value to the individual producer.

### **Area-Yield Crop Insurance**

The fundamental problems that accompany individual-yield crop insurance have been known since the early days of the federal crop insurance program. Halcrow, in his 1949 evaluation of the effectiveness of the federal crop insurance program's first decade of operation, concluded that individual-yield crop insurance "will work in a satisfactory manner only under a system of conditions so exacting in their specification that they will be found to a rather limited extent in American agriculture" (p. 476).

In his paper, Halcrow promoted an alternative crop insurance scheme in which both indemnities and premiums would be based not on a producer's individual yield but rather on the aggregate yield of a surrounding geographical area. Under a so-called area-yield plan, a participating producer would receive, in any given year, an indemnity equal to the difference, if positive, between the area yield and some predetermined critical yield level. Every participating producer in a given area would receive the same indemnity per insured acre, regardless of his own crop yield, and therefore would pay the same premium rate.<sup>3</sup>

Area-yield crop insurance offers numerous

advantages over individual-yield crop insurance. Because information regarding the distribution of the area yield is generally available and more reliable than information regarding the distributions of individual yields, insurers could more accurately assess the actuarial fairness of premiums under an area-yield policy, thereby significantly reducing adverse selection problems.<sup>4</sup> Moreover, because the indemnities would be based on the area yield rather than the producer's yield, a producer could not significantly increase his indemnity by unilaterally altering his production practices. Thus, under an area-yield insurance program, moral hazard essentially would be eliminated. Administrative costs would also be substantially reduced under an area-yield program because claims would not have to be adjusted individually and verification of individual production histories would no longer be required.<sup>5</sup>

In the following sections, a theoretical framework for evaluating the effectiveness and equity of area-yield crop insurance is developed and applied to western Kentucky soybean producers in an empirical illustration. Several questions are addressed: How efficiently, relative to individual-yield crop insurance, does area-yield crop insurance cover individual yield risk? How does the risk reduction effectiveness of area-yield crop insurance vary across producers? How can a producer optimize coverage under an area-yield plan? The article concludes with recommendations on how area-yield crop insurance might be implemented.

### **Theoretical Analysis**

Consider a producer  $i$  whose yield  $\bar{y}_i$  is random due to the uncertain effects of weather and other natural phenomena. Suppose the producer operates in an area where the average yield across all farms is  $\bar{y}$ . By orthogonally projecting the producer's individual yield  $\bar{y}_i$  onto the area yield  $\bar{y}$ , an identity that relates the two is obtained:

$$(1) \quad \bar{y}_i = \mu_i + \beta_i \cdot (\bar{y} - \mu) + \bar{\epsilon}_i.$$

<sup>3</sup> The program examined in this paper should not be confused with the Federal Crop Insurance Corporation's practice prior to 1981 of writing coverage provisions using area yield data while basing indemnities on individual yield experience. We adopt Halcrow's original usage of the term "area-yield" to refer to a program in which coverage, premiums, and indemnities are all based on area yield experience.

<sup>4</sup> These include intertemporal adverse selection problems, which arise under the current program when producers make participation decisions based on information that they hold privately at planting time, such as the soil moisture levels on their own land.

<sup>5</sup> In its recent study, the Commission for the Improvement of the Federal Crop Insurance Program cites many of these advantages and recommends that an area-yield crop insurance pilot program be implemented on an experimental basis in selected areas.

Here,

$$(2) \quad \beta_i = \text{Cov}(\tilde{y}_i, \tilde{y}) / \sigma_{\tilde{y}}^2$$

$$(3) \quad E\tilde{\epsilon}_i = 0 \quad \text{Var}(\tilde{\epsilon}_i) = \sigma_{\tilde{\epsilon}_i}^2 \quad \text{Cov}(\tilde{y}, \tilde{\epsilon}_i) = 0$$

$$(4) \quad E\tilde{y}_i = \mu_i \quad \text{Var}(\tilde{y}_i) = \sigma_{\tilde{y}_i}^2$$

$$(5) \quad E\tilde{y} = \mu \quad \text{Var}(\tilde{y}) = \sigma_{\tilde{y}}^2.$$

The coefficient  $\beta_i$  measures the sensitivity of the producer's individual yield to the systemic factors that affect the area yield. Equation (1) decomposes individual yield variation into a systemic component  $\beta_i \cdot (\tilde{y} - \mu)$  that is perfectly correlated with the area yield and a nonsystemic component  $\tilde{\epsilon}_i$  that is uncorrelated with the area yield.

Suppose that the producer is offered area-yield crop insurance in which the indemnity and the premium are both denominated in production units, say, bushels per acre.<sup>6</sup> The producer purchases coverage at a premium rate of  $\pi$  bushels per acre. If the area yield  $\tilde{y}$  subsequently falls below a critical yield level  $y_c$ , he receives an indemnity  $\tilde{n}$ , in bushels per insured acre, equal to the shortfall:

$$(6) \quad \tilde{n} = \max(y_c - \tilde{y}, 0).$$

Assume that the premium  $\pi$  is actuarially fair; that is, it is equal to the expected indemnity  $E\tilde{n}$ .

With area-yield crop insurance, the producer's net yield equals

$$(7) \quad \tilde{y}_i^{net} = \tilde{y}_i + \tilde{n} - \pi,$$

and his yield risk, as measured by the variance of the net yield, equals

$$(8) \quad \text{Var}(\tilde{y}_i^{net}) = \sigma_{\tilde{y}_i}^2 + \sigma_{\tilde{n}}^2 + 2 \cdot \text{Cov}(\tilde{y}_i, \tilde{n}),$$

where  $\sigma_{\tilde{n}}^2 = \text{Var}(\tilde{n})$  is the variance of the indemnity. By acquiring area-yield insurance, the producer thus reduces his yield risk by an amount

$$(9) \quad \Delta_i = \text{Var}(\tilde{y}_i) - \text{Var}(\tilde{y}_i^{net}) \\ = -\sigma_{\tilde{n}}^2 - 2 \cdot \text{Cov}(\tilde{y}_i, \tilde{n}).$$

Assume now that the individual nonsystemic yield component  $\tilde{\epsilon}_i$  and the area yield  $\tilde{y}$  are conditionally independent (a mild assumption given that they are uncorrelated by definition). Then the individual nonsystemic yield component  $\tilde{\epsilon}_i$  and the indemnity  $\tilde{n}$  are uncorrelated, and it follows from (1) that

$$(10) \quad \text{Cov}(\tilde{y}_i, \tilde{n}) = \beta_i \cdot \text{Cov}(\tilde{y}, \tilde{n}).$$

Defining

$$(11) \quad \beta_c = -\frac{\sigma_{\tilde{n}}^2}{2 \cdot \text{Cov}(\tilde{y}, \tilde{n})}$$

and substituting (10) into (9), the risk reduction obtained from area-yield insurance can be re-written as follows:

$$(12) \quad \Delta_i = \sigma_{\tilde{n}}^2 \cdot \left[ \frac{\beta_i}{\beta_c} - 1 \right].$$

We refer to  $\beta_c$  as the critical beta. Because the area-yield  $\tilde{y}$  and the indemnity  $\tilde{n}$  are negatively correlated,  $\beta_c > 0$ . Moreover, because the critical beta  $\beta_c$  and the variance of the indemnity  $\sigma_{\tilde{n}}^2$  are determined by the distribution of the area yield  $\tilde{y}$  and the critical yield  $y_c$ , they are invariant among producers within a given area. It thus follows from (12):

*PROPOSITION 1.* *For a given critical yield  $y_c$ , the risk reduction obtained by producer  $i$  from area-yield insurance is completely determined by, and is positively related to, his individual beta,  $\beta_i$ .*

It also follows from (12) that:

*PROPOSITION 2.* *Area-yield insurance is risk reducing for producer  $i$  if and only if  $\beta_i > \beta_c$ , that is, if and only if his individual beta exceeds the critical beta.*

Thus, producers with high  $\beta_i$ 's can expect significant reduction in yield risk from purchasing area-yield insurance, whereas those with low  $\beta_i$ 's may actually find that area-yield insurance is risk augmenting. A characterization of  $\beta_i$  that is helpful in understanding the significance of the above results is given by

$$(13) \quad \beta_i = \rho_i \cdot \frac{\sigma_{\tilde{y}_i}}{\sigma_{\tilde{y}}},$$

where  $\rho_i$  is the coefficient of correlation between producer  $i$ 's yield  $\tilde{y}_i$  and the area yield  $\tilde{y}$ . As an

<sup>6</sup> Although straightforward, generalizing the model to account for price variation would undermine the clarity of the exposition while providing little additional insight into the structure of area-yield insurance.

<sup>7</sup> Assuming that the premium is actuarially fair allows us to evaluate the insurance coverage solely in terms of its variance reduction, provided we further assume, if only as a first-order approximation, that producers are mean-variance utility maximizers. Meyer has shown that mean-variance decision models are consistent with expected-utility maximization under much weaker behavioral restrictions than had previously been thought.

immediate consequence of proposition 1 and (13) we have:

**PROPOSITION 3.** *Ceteris paribus, the more highly correlated a producer's yield is to the area yield, the greater the risk reduction that the producer can obtain from area-yield insurance.*

**PROPOSITION 4.** *Ceteris paribus, the higher a producer's yield variance, the greater the risk reduction that the producer can obtain from area-yield insurance.*

To ascertain how the risk reduction obtained from area-yield insurance varies across producers within a given area, we must determine how the  $\beta_i$  are distributed within the area and how the critical  $\beta_c$  varies with the critical yield  $y_c$ . Although definitive answers to both of these questions can only be obtained empirically, some light can be shed from theoretical considerations.

Consider first the distribution of the  $\beta_i$ 's. If  $\omega_i$  denotes the proportion of total acreage in the area planted by producer  $i$ , then, by definition,  $\sum_i \omega_i = 1$  and  $\sum_i \omega_i \cdot \bar{y}_i = \bar{y}$ , so that

$$(14) \quad \sum_i \omega_i \cdot \text{Cov}(\bar{y}_i, \bar{y}) = \text{Cov}\left(\sum_i \omega_i \cdot \bar{y}_i, \bar{y}\right) \\ = \text{Cov}(\bar{y}, \bar{y}) = \sigma_{\bar{y}}^2.$$

Dividing both sides by  $\sigma_{\bar{y}}^2$  and using (2), it follows that

$$(15) \quad \sum_i \omega_i \cdot \beta_i = 1.$$

Thus, the acreage weighted average of the  $\beta_i$  within any area is always one. The dispersion of the  $\beta_i$  and the skewness in their distribution, on the other hand, may vary among regions and ultimately can only be determined empirically. Intuition suggests that the more homogenous are the soil and climatic conditions faced by producers in a given area, the more closely the  $\beta_i$ s will cluster around one.

Under mild regularity conditions, the critical beta  $\beta_c$  is an increasing function of the critical yield  $y_c$ .<sup>8</sup> In general, it can be shown that<sup>9</sup>

$$(16) \quad 0 \leq \beta_c \leq 0.5, \text{ and}$$

$$(17) \quad \lim_{y_c \rightarrow 0} \beta_c = 0.0 \quad \text{and} \quad \lim_{y_c \rightarrow \infty} \beta_c = 0.5.$$

<sup>8</sup> The regularity condition holds for reasonable parameterizations of the lognormal and beta distributions often used to describe yield distributions and has been verified for the empirical distributions of 1974–86 U.S. soybean yields for all U.S. soybean-producing counties.

<sup>9</sup> Formal proofs of (16) and (17) are available from the author upon request.

It thus follows from proposition 2 that area-yield insurance will be risk reducing for any producer  $i$  from whom  $\beta_i > 0.5$ . Since the average  $\beta_i$  within an area is 1, most producers should find area-yield insurance risk reducing. Area-yield insurance is definitively risk augmenting only if  $\beta_i \leq 0$ , that is, only if a producer's yield is negatively correlated with the area yield. If  $0 < \beta_i \leq 0.5$ , area-yield insurance may or may not be risk reducing, depending on the critical yield level  $y_c$ ; the higher the critical yield  $y_c$ , the more likely that area-yield insurance will be risk reducing.

Until now, we have implicitly assumed that producers cover exactly 100% of their acreage when they purchase crop insurance. Suppose now that producer  $i$  is free to elect a coverage level  $\phi_i$  that may be more or less than 100%. At this coverage level, producer  $i$ 's net yield is

$$(18) \quad \tilde{y}_i^{\text{net}} = \bar{y}_i + \phi_i \cdot \bar{n} - \phi_i \cdot \pi$$

and the risk reduction obtained from area-yield insurance is

$$(19) \quad \Delta_i = \text{Var}(\bar{y}_i) - \text{Var}(\tilde{y}_i^{\text{net}}) \\ = -\phi_i^2 \cdot \sigma_{\bar{n}}^2 - 2 \cdot \phi_i \cdot \text{Cov}(\bar{y}_i, \bar{n}).$$

Substituting (10) into (19), the risk reduction can be rewritten more conveniently

$$(20) \quad \Delta_i = \sigma_{\bar{n}}^2 \cdot \left[ \frac{\beta_i}{\beta_c} \cdot \phi_i - \phi_i^2 \right].$$

Maximizing this expression with respect to the coverage level, it follows that:

**PROPOSITION 5.** *If the coverage level is optional under an area-yield plan, then producer  $i$  minimizes his yield risk by selecting a coverage level*

$$(21) \quad \phi_i^* = \frac{\beta_i}{2 \cdot \beta_c}.$$

Thus, if the producer is free to choose his coverage level, save that it be positive, he can reduce his yield risk using area-yield insurance if and only if his beta is positive, that is, if and only if his yield is positively correlated with the area yield. In this case, since the critical beta  $\beta_c$  rises with the critical yield  $y_c$ , the producer's optimal coverage level will fall with the critical yield. Since the critical beta  $\beta_c$  is bounded above by one-half, the producer's optimal coverage level will approach but will never drop below  $\beta_i$ . And thus, since the average  $\beta_i$  is 1, one can expect that coverage in excess of 100% will be optimal for a significant portion of, if not most, producers.

Substituting (21) into (20) and solving gives the following result:

**PROPOSITION 6.** *If the coverage level is optional, then the maximum risk reduction that producer  $i$  can obtain from area-yield insurance is*

$$(22) \quad \Delta_i^* = \rho^2 \cdot \beta_i^2 \cdot \sigma_{\bar{y}}^2,$$

where  $\rho$  is the correlation coefficient between the indemnity  $\bar{n}$  and the area yield  $\bar{y}$ .

Because the area yield  $\bar{y}$  and the individual nonsystemic yield component  $\epsilon_i$  are uncorrelated, it follows from (1) that

$$(23) \quad \sigma_{\bar{y}_i}^2 = \beta_i^2 \cdot \sigma_{\bar{y}}^2 + \sigma_{\epsilon_i}^2.$$

That is, yield risk without crop insurance can be decomposed into a systemic component  $\beta_i^2 \cdot \sigma_{\bar{y}}^2$  and a nonsystemic component  $\sigma_{\epsilon_i}^2$ . Since  $0 \leq \rho^2 \leq 1$ , proposition 6 implies that area-yield crop insurance, in effect, eliminates a portion of systemic yield risk faced by the producer but none of the nonsystemic yield risk. Since  $\rho^2$  is invariant across producers, it follows that:

**PROPOSITION 7.** *If the coverage level is optional, then the maximum risk reduction that can be obtained from area-yield insurance, as a proportion of systemic yield risk, is the same for every producer.*

## Empirical Application

We now illustrate how area-yield crop insurance might perform in practice using individual farm-level yield data for 102 western Kentucky soybean producers.<sup>10</sup> The producers are assumed to comprise the entire population of the "area" in which area-yield crop insurance is offered. All performance estimates are derived directly from the empirical yield distributions; a parametric distribution is not fitted to the data.

Table 1 shows how the critical beta for the 102-farm area varies with the level of the critical yield. Critical yields are expressed both in bushels per acre and as a percentage of the normal or expected area-wide yield of 30.7 bushels per acre. As seen in table 1, the critical beta rises as the critical yield is increased. For sufficiently low critical yields, the critical beta

**Table 1. Critical Beta, Per-Acre Premium, and Average Optimal Coverage Under an Area Yield Plan, Selected Critical Yields**

Percent of Normal	Critical Yield			Average Optimal Coverage (%)
	Bushels per Acre	Critical Beta	Premium (bu./acre)	
60	18.4	0.00	0.00	
65	20.0	0.04	0.06	1329
70	21.5	0.10	0.17	506
75	23.1	0.16	0.27	312
80	24.6	0.22	0.37	227
85	26.1	0.25	0.60	198
90	27.7	0.28	0.96	178
95	29.2	0.31	1.47	160
100	30.7	0.36	2.04	138
105	32.3	0.41	2.77	123
110	33.8	0.44	3.70	112
115	35.4	0.48	4.80	104
120	36.9	0.50	6.18	101
125	38.4	0.50	7.69	100

achieves its theoretical minimum of zero and, for sufficiently high critical yields, achieves its theoretical maximum of one-half.

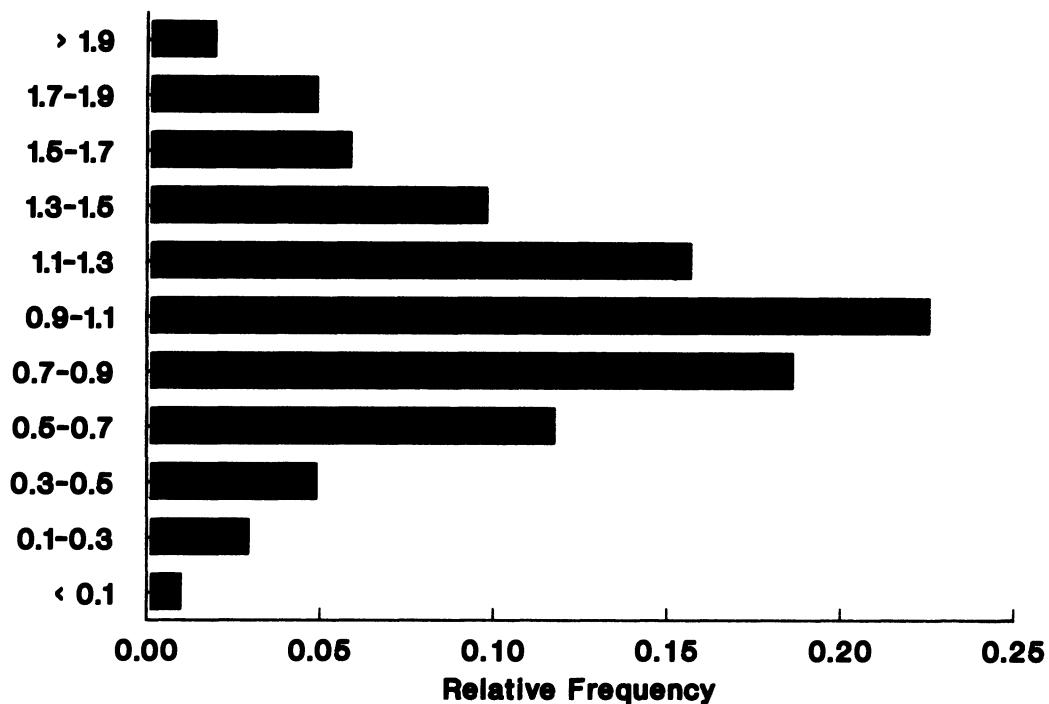
Table 1 also shows that the actuarially fair premium under a full coverage area-yield plan (or, equivalently, the expected per-acre indemnity) rises with the critical yield level. For sufficiently low critical yields, area-yield insurance is completely ineffective and the fair premium is zero; for sufficiently high critical yields, a one bushel increase in critical yield simply raises the expected indemnity, and therefore the fair premium, by the same amount.

Table 1 also shows how the optimal level of coverage under an optional area-yield plan varies with the critical yield level. Because the optimal coverage level varies among producers, only the average coverage level across producers is reported. For example, given a critical yield equal to 90% of normal, producers, on average, minimize their yield risk by purchasing coverage for 178% of their acreage. That is, on average, producers minimize their yield risk by purchasing insurance for 78% more acreage than they actually plant. If the critical yield is set too low, area-yield insurance will be ineffective and the optimal coverage level will be zero. If the critical yield is set sufficiently high, the average optimal coverage level will equal 100%. In intermediate cases, the average optimal coverage level exceeds 100% and falls as the critical yield rises.

Figure 1 shows the distribution of individual betas for the 102 producers comprising the area

<sup>10</sup> The yield data, which were provided by Jerry Skees of the University of Kentucky, cover the period 1974–88 and were adjusted for secular trends to reflect 1988 production levels.

### Beta Range



**Figure 1. Frequency distribution of individual producer betas**

population. The distribution of the betas possesses a regular, bell shape which is centered on one and exhibits no discernable skewness. Of the 102 producers in the sample, 5 have betas falling below 0.28, the critical betas for a full coverage area-yield plan with a critical yield equal to 90% of normal; for those individuals, a full coverage area-yield plan would offer no protection against yield risk. Of the 5 producers, however, 4 have positive betas, indicating that they would obtain some yield risk reduction from an area-yield plan if they could select their levels of coverage optimally.<sup>11</sup>

We now turn to a comparison of specific versions of an individual-yield plan (IYP) and full coverage and optimal coverage area-yield plans (AYP). Under the IYP, each producer is assumed to choose a yield guarantee equal to 75% of his normal yield, the highest yield election

level available under the current Federal Crop Insurance Program. Under the IYP, whenever a producer's own yield falls below 75% of his normal yield, he receives an indemnity equal to the shortfall.

Under the full coverage AYP, as under the IYP, each producer purchases coverage for exactly 100% of his acreage. The critical yield under the full coverage AYP is set at 88.5% of the normal area yield, indicating that whenever the area yield falls below 88.5% of normal, each producer, regardless of his own yield, receives an indemnity equal to the shortfall in the area yield. A critical yield of 88.5% assures, though only for the present empirical application, that the fair premium paid by each producer under a full coverage AYP is equal to the average fair premium paid by producers under the 75% IYP.<sup>12</sup>

Under the optimal coverage AYP, producers choose their level of coverage and are assumed

<sup>11</sup> The 102 farms in the sample are spread over a twenty-county area. Participants in an AYP implemented on a county level would likely be more homogenous with respect to soil and climatic conditions and thus should exhibit less dispersion in their individual betas. One would therefore expect an AYP to perform better than is indicated in this empirical application.

<sup>12</sup> Since individual yields tend to be more variable than the aggregate area yield, an individual yield plan with a given yield guarantee will pay an indemnity more often and thus will require a higher premium than an area-yield plan whose critical yield is the same.

to do so in a manner that minimizes their yield risk. The critical yield under the optimal coverage AYP is assumed to equal 95% of the normal area yield, indicating that whenever the area yield falls below 95% of normal, each producer, regardless of his own yield, receives an indemnity equal to the shortfall in the area yield times his elected level of coverage.

Table 2 shows the actuarially fair premium rates per planted acre under the IYP and the two AYPs for selected producers.<sup>13</sup> Under the IYP, fair premiums are based on individual yield experience and thus vary among producers. Under a full coverage AYP, the premium is based on the area yield experience and thus is the same for all producers. Under both the IYP and full

coverage AYP, the average premium paid by producers is 0.83 bushels per planted acre, about 2.7% of the normal area yield. Under the optional coverage AYP, the optimal level of coverage per planted acre, and thus the fair premium, varies among producers. The average optimal coverage level across producers is 160%; the additional coverage raises the average premium paid by producers to 2.35 bushels per planted acre.

Table 3 gives the percentage reduction in individual yield risk for selected producers under the three alternative crop insurance plans. As seen in the table 3, risk reduction is greater, on average, under the optimal coverage AYP than under either the IYP or the full coverage AYP. Under the optimal coverage AYP, the average risk reduction is about 39.1%. In contrast, the IYP reduces risk by 30.8% on average and the full coverage AYP by 22.4%.

The relative performance of the three pro-

<sup>13</sup> Because of adverse selection and heavy government subsidization, most producers under the current crop insurance program pay premiums that are significantly less than their expected indemnity.

**Table 2. Crop Insurance Premium Under an Individual-Yield Plan, Full Coverage Area-Yield Plan, and Optimal Coverage Area-Yield Plan, Selected Producers**

Number	Beta	Normal Yield <sup>a</sup>	Premium in Bushels per Planted Acre		
			Individual Plan	Full Coverage Area Plan	Optimal Coverage Area Plan
1	2.03	22.5	2.21	0.83	4.77
5	1.84	26.5	2.49	0.83	4.33
9	1.67	29.6	1.82	0.83	3.92
13	1.51	30.1	1.53	0.83	3.55
17	1.41	25.8	1.60	0.83	3.30
21	1.32	26.2	1.55	0.83	3.11
25	1.28	32.7	0.78	0.83	2.99
29	1.23	25.9	1.34	0.83	2.88
33	1.18	27.6	1.21	0.83	2.76
37	1.15	20.9	1.27	0.83	2.69
41	1.08	27.8	0.70	0.83	2.53
45	1.06	27.3	1.52	0.83	2.48
49	1.00	32.3	1.09	0.83	2.36
53	0.98	34.8	0.96	0.83	2.30
57	0.95	27.1	0.42	0.83	2.24
61	0.91	33.0	0.33	0.83	2.13
65	0.87	28.9	0.97	0.83	2.03
69	0.85	27.2	0.51	0.83	1.99
73	0.83	28.7	0.22	0.83	1.94
77	0.79	33.2	0.39	0.83	1.86
81	0.71	23.2	0.76	0.83	1.66
85	0.64	28.3	0.43	0.83	1.50
89	0.56	35.2	0.03	0.83	1.31
93	0.53	18.7	0.98	0.83	1.25
97	0.33	40.4	1.57	0.83	0.78
101	0.27	42.5	0.80	0.83	0.63
Avg.	1.00	30.7	0.83	0.83	2.35

Note: "Selected producers" indicates every fourth producer in order of descending beta value.

<sup>a</sup> Average detrended yield, 1974–88, bushels per acre, 1988 equivalent.

**Table 3. Yield Variance Reduction Under an Individual-Yield Plan, Full Coverage Area-Yield Plan, and Optimal Coverage Area-Yield Plan, Selected Producers**

Number	Beta	Yield Variance <sup>a</sup>	Percent Variance Reduction		
			Individual Plan	Full Coverage Area Plan	Optimal Coverage Area Plan
1	2.03	136.4	37.9	20.5	57.3
5	1.84	130.6	50.4	19.2	49.3
9	1.67	112.8	49.4	19.7	46.7
13	1.51	82.5	45.7	23.9	52.5
17	1.41	97.2	35.0	18.5	38.4
21	1.32	74.1	45.0	22.6	44.8
25	1.28	45.6	39.3	35.0	67.5
29	1.23	63.4	44.0	23.9	44.9
33	1.18	56.9	45.0	25.2	45.8
37	1.15	58.1	43.6	23.9	42.6
41	1.08	54.7	27.6	23.4	40.1
45	1.06	94.1	38.9	13.2	22.4
49	1.00	82.5	43.8	14.1	23.1
53	0.98	64.9	37.8	17.3	28.0
57	0.95	34.1	20.6	31.7	50.4
61	0.91	29.8	24.2	34.0	52.6
65	0.87	55.2	40.3	17.1	25.7
69	0.85	29.2	35.6	31.3	46.6
73	0.83	34.1	11.6	25.9	38.0
77	0.79	25.9	34.3	31.9	45.8
81	0.71	57.9	24.0	11.9	16.4
85	0.64	31.4	24.9	18.4	24.5
89	0.56	40.7	1.2	11.1	14.5
93	0.53	42.8	44.3	9.6	12.5
97	0.33	136.8	34.8	0.7	1.5
101	0.27	65.7	41.3	-0.2	2.1
Average	1.00	56.5	30.8	22.4	39.1

Note: See note, table 1.

<sup>a</sup> Variance measured in bushels per acre squared.

grams varies among producers. Table 3 confirms that producers with the highest betas tend to enjoy the greatest relative risk reduction under the optimal AYP, whereas producers with the highest yield variances tend to enjoy the greatest relative risk reduction under the IYP. The correlation coefficient between the risk reduction obtained under the IYP and that obtained under the optimal AYP is only 0.06, indicating little relation between the risk reduction benefits from one program as compared to the other. Both small and large producers will tend to prefer the optimal AYP to the IYP, but the latter appear to enjoy the greatest benefit from moving to the optimal AYP from the IYP. For the largest twenty-three producers, who account for half the acreage planted, the optimal AYP offers an average risk reduction of 40.1% and the IYP an average of 28.8%. For the smallest seventy-eight producers, the optimal AYP offers an average risk reduction of 37.3% and the IYP an average of 32.7%.

### Additional Considerations

Strictly speaking, an AYP is not a true insurance program since payments to producers are not based on their own specific yield losses. Instead, an AYP is more accurately described as a hedging instrument. Specifically, an AYP is like a put option in which the critical yield plays the role of the strike price. More precisely, because each individual's yield is a constituent of the area yield, an AYP offers a hedge against individual yield-loss in the same way that an option on a stock futures index offers a hedge against the price risk of holding one of the stocks in the index.<sup>14</sup>

While characterizing the AYP as a hedging

<sup>14</sup> With slight modification, many of the results in this paper generalize to crop insurance schemes in which indemnities are based on weather variables such as rainfall or temperature. Such schemes have been proposed in the past (Sanderson, Lee) but have failed to gain acceptance among policy makers.

instrument helps put the form and function of the AYP into perspective, it also points to some difficulties that may arise in having the program accepted by producers. Given that producers are notorious for shunning options and futures markets as means of hedging price risk, it is likely that an AYP would not automatically enjoy widespread acceptance among producers as a means of hedging yield risk. Ultimately, to achieve high rates of participation, AYPs may have to be subsidized or made a cross-compliance provision of government commodity stabilization programs.

Should producers be free to select their coverage levels under an AYP, and how high should the critical yield level be set? These two important questions regarding the implementation of an AYP are closely related. Under an IYP, a deductible, or equivalently, a yield guarantee well below the producer's normal yield, is necessary to guard against the moral hazard; for the same reason, coverage levels exceeding 100% of acreage planted cannot be permitted. Under an AYP, however, moral hazard is essentially eliminated; only through illegal and widespread collusive action by producers could the area yield be significantly reduced.<sup>15</sup> Accordingly, optional coverage levels and high critical yields are feasible under an AYP. Since, as shown above, producers can reduce yield risk by choosing coverage levels in excess of 100%, it seems sensible that coverage levels be optional under an AYP. In addition, because the risk reduction under an optimal AYP rises for all individuals as the critical yield is increased, a high critical yield level is indicated.

The higher premiums that producers would pay under an AYP for increased coverage and a higher critical yield need not be a major concern to producers: if the premium is actuarially fair, then producers can expect to recover the higher premium through higher indemnities while enjoying the benefits of reduced yield risk. There are, however, some potential problems that the government may face if critical yield levels are high and optional coverage is permitted under an AYP. First, coverage levels in excess of 100% and critical yields in excess of the normal yield would be difficult to rationalize politically, particularly if the AYP is promoted as an insurance program. Second, higher critical yields and cov-

erage levels would raise the level and variability of total indemnity outlays. Thus, whether the government acts as a direct insurer or reinsurer, substantial yield risk could ultimately be transferred to the government, raising the variability of federal budgetary outlays.

Risk reduction under an optimal AYP varies among producers, raising questions about the equity of such a program. Recall, however, that an optimal coverage AYP would reduce systemic yield risk in the same proportion for all producers. If areas are defined so as to be homogenous with regard to soil and climatic conditions, then nonsystemic yield risk would be attributable almost exclusively to producer-specific factors such as choice of production practice. It is arguable, therefore, that the proper goal for a government crop insurance program should be the reduction of systemic risk, not total risk; otherwise, the program would promote a misallocation of societal resources by encouraging risky production. Thus, if areas are properly defined, an optimal coverage AYP will be equitable in a socially meaningful way.

Because of the abundance of reliable historical yield data and the pre-existence of administrative structures, the most practical definition of area under an AYP will likely be the county. If the AYP is administered on a county basis, the maximum efficacy and equity of the AYP will be achieved in counties that are homogeneous with regard to soil and climate. In some regions, however, area boundaries that cut across established county lines may be needed for the AYP to function well. Regardless of how areas are determined, however, it is conceivable that some producers will find the yield of an adjacent area more representative of their own individual yields. In such cases, the producers would improve their coverage by participating in the AYP of the adjacent area and thus should not be discouraged from doing so.

### Concluding Comments

An individual producer's total yield risk can be decomposed into a systemic component that is explained by factors affecting all producers in his area and a nonsystemic residual component. Individual-yield crop insurance, such as the one currently underwritten by the federal government, covers total individual yield risk but is limited in its effectiveness by the large deductibles that must be imposed in order to combat moral hazard. Area-yield crop insurance would

<sup>15</sup> A collusive arrangement would be difficult to sustain since a noncolluding producer could maximize his individual yield and still obtain the benefits of the higher indemnity brought about by the actions of the colluding producers.

cover only systemic individual yield risk but would also be free of moral hazard and thus would not require large deductibles or limits on coverage levels. For most producers, the improved coverage of systemic yield risk obtained through lower deductibles and higher coverage under an area-yield plan would outweigh the nonsystemic yield risk protection provided by an individual-yield plan. That is, for most producers, area-yield insurance would provide better overall yield risk protection than individual-yield insurance.

Because information pertaining to the distribution of an area yield is not privately held and is generally available, the asymmetric information problems that have given rise to adverse selection under the current federal crop insurance program would be significantly reduced under an area-yield program. The reduction of adverse selection and the virtual elimination of moral hazard would significantly improve the actuarial performance of the federal crop insurance program. Moreover, because verification of individual production histories and adjustment of individual yield-loss claims would not be necessary under an area-yield program, an area-yield crop insurance program would be less expensive to administer.

The evidence presented in this paper suggests that area-yield crop insurance should receive serious consideration as an alternative to the current crop insurance program. At the very least, area-yield crop insurance should be examined on an experimental basis with long-term pilot programs established for regions where tradi-

tional crop insurance has historically performed poorly.

[Received February 1990; final revision received June 1990.]

## References

- Chambers, Robert G. "Insurability and Moral Hazard in Agricultural Insurance Markets." *Amer. J. Agr. Econ.* 71(1989):604-16.
- Commission for the Improvement of the Federal Crop Insurance Program. *Recommendations and Findings to Improve the Federal Crop Insurance Program*. Washington DC, July 1989.
- Halcrow, Harold G. "Actuarial Structures for Crop Insurance." *J. Farm Econ.* 21(1949):418-43.
- Lee, Ivan M. "Temperature Insurance—An Alternative to Frost Insurance in Citrus." *J. Farm Econ.* 35(1953):15-28.
- Meyer, Jack. "Two-Moment Decision Models and Expected Utility Maximization." *Amer. Econ. Rev.* 77(1987):421-30.
- Nelson, Carl H., and Edna T. Loehman. "Further Toward a Theory of Agricultural Insurance." *Amer. J. Agr. Econ.* 69(1987):523-31.
- Sanderson, Fred H. "A Specific-Risk Scheme for Wheat Crop Insurance." *J. Farm Econ.* 25(1943):759-76.
- Skees, Jerry R., and Michael R. Reed. "Rate-Making and Farm-Level Crop Insurance: Implications for Adverse Selection." *Amer. J. Agr. Econ.* 68(1986):653-59.
- U.S. Department of Agriculture, Office of Publishing and Visual Communication. *1990 Farm Bill: Proposal of the Administration*. Washington DC, Feb. 1990.
- U.S. General Accounting Office. "Disaster Assistance: Crop Insurance Can Provide Assistance More Effectively Than Other Programs." Report to the Chairman, Committee on Agriculture, U.S. House of Representatives, Washington DC GAO/RCED-89-211, Sep 1989.