Yield and Income Risk Reduction under Alternative Crop Insurance and Disaster Assistance Designs

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This study compares the effectiveness of five crop insurance/disaster assistance plans: an individual farm-yield insurance plan similar to the current Federal Crop Insurance Corporation multiperil program, two area-yield insurance plans, a farm-yield disaster assistance plan, and an area-yield disaster assistance plan. These methods are examined for reduction in yield and gross income variability with and without participation in the government deficiency payment program using farm-level yield data from 98 dryland wheat farms and 38 dryland corn farms in Kansas. Although individual farm-yield insurance is complex, suffers from moral hazard and adverse selection problems, and is likely to be the most expensive to administer, it provides more yield and gross income risk reduction than any of the alternative insurance/ disaster assistance plans.

Key words: corn, crop disaster assistance, crop insurance, risk, wheat.

> Therefore the general conclusion in respect to the all-risk type of crop insurance is that it will work in a satisfactory manner only under a system of conditions so exacting in their specifications that they will be found to rather limited extent in American agriculture.
>
> H. G. Halcrow, p. 426

Halcrow proposes an alternative to all-risk crop insurance which is based on an expected area yield and deviations from that yield rather than the expected farm yield and deviations therefrom. In his plan, the premiums and indemnities are based on yields received in an area of uniform crop production. Indemnities are paid in bushels to any insured producer in those years in which the area average yield falls below the guaranteed area-yield level (the historical mean of the area average yield or a percentage thereof). All participating farmers receive the same per-acre indemnity and pay the same premium rate based on historical area-yield data. For example, if the historical area average yield (guaranteed area yield) for wheat is 32 bu./acre and the area average yield in the current year is 24 bu./acre, each insured producer receives an indemnity payment of eight bushels for each insured, planted acre of wheat (assuming a 0% deductible) regardless of his/ her own produced yield.

Although the use of crop insurance as a risk management tool has been widely studied,[1] little analysis has been performed to determine the effectiveness of an area-yield measurement plan. Miranda recently completed a preliminary analysis of Halcrow's alternative using farm-level data for 102 western Kentucky soybean farms. By comparing the reduction in the variance of insured and uninsured yield distributions, without crop prices or deficiency payments, he concludes that an area-yield

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[1] See Williams, Harper, and Barnaby for a review of farm-level crop insurance research.

measurement is capable of providing effective yield-loss coverage.

The objective of this study is to compare the effectiveness of the individual yield insurance plan in the current Federal Crop Insurance Corporation (FCIC) program with the area-yield methods proposed by Halcrow; by Barnaby (1989, 1990); by Barnaby and Skees; and by Miranda, as well as with two disaster assistance plans. These plans are examined for reduction in yield-equivalent and gross income variability using farm-level yield data from 98 dryland wheat farms in southcentral Kansas and 38 dryland corn farms in northeast Kansas. Yield distributions and gross income distributions, with and without government deficiency payments, are estimated for each farm.

Background and Justification

The Federal Crop Insurance Act of 1980, P.L. 96-365, expanded the availability of multiperil (all-risk) crop insurance with the goal of replacing the U.S. Department of Agriculture's (USDA) low-yield disaster assistance program. Direct payment disaster assistance programs have been criticized for their expense (averaging $436 million per year between 1974 and 1980) and for encouraging production in areas susceptible to natural disasters [General Accounting Office (GAO)]. Although the 1980 Act expanded the scope of crop insurance and made it more widely available, Congress has continued to provide disaster assistance payments to farmers with the use of emergency loans and direct payments, most recently in the drought years of 1988 and 1989. While enrollment is increasing, the amount of eligible acres enrolled in 1988 was 24.5%, well below the 50% participation goal established for the program in 1980 (GAO).

Adverse selection and moral hazard are significant problems with the current crop insurance program in addition to competition from other government programs that provide substitute income variability reduction, such as disaster assistance, Farmers Home Administration emergency loans, and the deficiency payment program. Adverse selection occurs when farmers with higher relative yield risk can buy insurance at the same cost as farmers who have lower relative yield risk when yield guarantees are based on the expected individual farm yield (Skees and Reed). If farmers recognize this, over time the insurance program will attract a larger group with relatively high yield risks, thereby causing insurance rates to increase and compounding the adverse selection problem.[2] If premiums remain constant, under the pretense of increasing participation, indemnity payments could increase relative to premiums. In fact, indemnities paid to farmers between 1980–88 exceeded the premiums collected (GAO). Moral hazard occurs when the farmer has an incentive to alter production or harvest practices to increase the chance of collecting crop insurance; conversely, "moral hazards exist . . . as long as the firm (farmer) has inadequate incentives to reduce or prevent adverse outcomes" (Robison and Barry, p. 230). This can happen when indemnity payments are based on farm-specific measured losses and the price election used to calculate the indemnity payment for yield losses is greater than the market price.

Under the area-yield or "area-hedge" approaches suggested by Halcrow; Barnaby (1989, 1990); and Barnaby and Skees, the adverse selection and moral hazard inherent in the current crop insurance program are greatly reduced.[3] In the current FCIC program, insurance premiums are based on the insured pool of farmers. The pool has tended, over time, to have more farmers who have higher yield variability and fewer farmers with lower yield variability causing insurance rates to increase, exacerbating further the adverse selection problem. By contrast, the area plan pays each producer a uniform average area-yield loss with no individual loss adjustment; the area-yield loss measurement includes both insured and uninsured farmers, thus reducing adverse selection. The probability of collecting an indemnity is the same for all insured farmers in the area, although the "effective" cost and coverage vary. Moral hazard is prevented because an individual farmer cannot influence the indemnity by altering production and/or harvest practices. In addition, accurate farm-level yield data, which historically have been difficult to

[2] Skees and Reed conclude that the current program leads to adverse selection because farmers with relatively high expected yields can expect small and infrequent indemnity payments when insurance guarantees are based on expected farm yield.

[3] The term "area-hedge" more appropriately describes this type of insurance to the industry because of its past experience with the FCIC area plan.

obtain, are not needed to actuarially determine insurance premiums.

During discussion of the 1990 Farm Bill, several substitute/supplementary crop disaster assistance proposals were put forth. In general, they differ only in the ways in which a disaster would be defined and the disaster payments would be calculated—either at the individual farm level or the county (area) level. A farm-level disaster assistance program and an area-level disaster assistance program were proposed.[4] Both of these plans are significantly different from public policies in effect throughout the 1980s and through early 1991 because they would establish a standing crop disaster assistance program. However, these plans could suffer from high administrative costs because disaster payments are based on farm-level yields. Both proposals would suffer from adverse selection and moral hazard, though to different degrees.[5]

Analysis is needed to determine the effectiveness of area crop insurance and the disaster assistance programs as they compare to the current FCIC program. Insight can be gained into which, if any, of these alternative insurance/disaster program designs is effective by examination of their ability to reduce yield and income risks faced by farmers.

Procedures and Data

Yield-equivalent distributions and gross income distributions for five risk management programs are estimated and compared to evaluate their effectiveness in reducing risk for 98 southcentral Kansas dryland wheat farms and 38 northeast Kansas dryland corn farms. The risk management programs considered are: (*a*) individual farm-yield insurance, (*b*) area-yield insurance, (*c*) optimal-coverage area-yield insurance, (*d*) farm-yield disaster assistance, and (*e*) area-yield disaster assistance. Each of these risk management programs is first examined for relative risk reduction using per-acre yield-equivalent distributions and then examined for relative risk reduction using per-acre gross income distributions, with and without government deficiency payments. The yield-equivalent measure is equal to the actual yield plus the bushel-equivalent disaster assistance payment or insurance indemnity net of the bushel-equivalent insurance premium. The gross income measure is equal to the actual yield multiplied by the market price plus the disaster assistance payment or the insurance indemnity net of the insurance premium. Separate gross income distributions are calculated with and without government deficiency payments.

Coefficient of variation (CV) statistics for wheat and corn yield-equivalents and gross returns for each farm for each insurance/disaster assistance alternative are calculated and compared to the yield-equivalents and gross returns CVs for no insurance/disaster assistance (the baseline strategy). These comparisons are made by measuring the relative difference between the CVs for the yield-equivalents and gross incomes under the baseline strategy and the alternative strategies, thereby indicating the relative reduction in yield-equivalent and gross income variability resulting from the crop insurance or disaster assistance designs.[6]

CV statistics, rather than standard deviations, are used to measure risk reduction because the mean yield-equivalents and returns under the disaster assistance programs are different from those under the baseline strategy and the actuarially fair insurance program strategies.[7] When the means of the strategies compared are equivalent, as are the crop insurance strategies and the baseline strategy, a relative reduction in the CV indicates a lower

[4] U.S. House Representative Glenn English (Democrat, Oklahoma) proposed a farm-level disaster program with assistance payments based on a percentage of either the Agricultural Stabilization and Conservation Service program yield or the proven farm yield for program crops or the expected area yield for nonprogram crops; the FCIC program would be continued. The Bush Administration (USDA) proposed discontinuing the FCIC program and providing disaster payments to crop producers in counties where the county average yield is less than 65% of the expected county average yield based on National Agricultural Statistics Service (NASS) data. Disaster payments would be based on the difference between 60% of the expected county average yield and the actual farm yield.

[5] The English Proposal allows for proven yields; therefore, those farmers who could prove higher yields would do so, whereas those with lower yields would accept the county average yield. The Administration Proposal could encourage regional adverse selection because farmers would grow crops in marginal areas that would not be planted if the disaster program were not available. Under the English Proposal, moral hazard could arise if the price elections are above the market price and/or the growing season is poor; farmers could reduce production inputs and harvest efficiency with expectations of having a low yield and receiving a disaster payment. Under the Administration Proposal, moral hazard would occur only when it is clear that the county is going to suffer a loss and farmers do not report some of their production; reporting of "true" yields would also be difficult to enforce.

[6] Since yield-equivalents and gross incomes, rather than net incomes, are being considered, risk is defined as "the dispersion of the distribution of outcomes" rather than "the probability of outcomes below a certain level" (Fleisher, p. 62).

[7] "Actuarially fair" assumes that total premiums equal total indemnities for the actuarial period.

standard deviation; in this situation, this criterion is consistent with risk aversion. When the means of the strategies compared are not equivalent, a relative reduction in the CV is not necessarily consistent with risk aversion unless the mean for the alternative strategy is greater than (equal to) the baseline strategy and the standard deviation of the alternative is less than or equal to (less than) the baseline. In this study, the standard deviations for the strategies with higher means (disaster assistance alternatives) are never larger than the standard deviations for the baseline strategy. Therefore, in this study, comparisons of the CV statistics to measure risk are meaningful, and relative reductions in the CVs are consistent with risk-averse behavior.

Though the results of the CV comparisons provide measures of gross income variability reductions, they do suffer from the limitations of the expected value-variance criteria (Anderson, Dillon, and Hardaker). Therefore, a more direct comparison of the gross income distributions is made using second-degree stochastic dominance. Stochastic dominance relies on comparing cumulative probability distributions of possible incomes for each strategy. This is particularly useful in cases where insurance or disaster assistance alternatives are used to change the distribution of net returns. Williams, Harper, and Barnaby provide an additional review of studies examining crop insurance with alternative quantitative techniques including stochastic dominance analysis. Second-degree stochastic dominance criteria identify strategies preferred by individuals receiving greater satisfaction from increases in income at low levels of income than from increases at high levels of income. These individuals are risk averse.

Market prices for southcentral and northeastern Kansas for the period 1973 to 1987 are converted to 1988 dollars using the USDA index of prices received by farmers (Kansas State Board of Agriculture). Government deficiency payments are calculated using 1988 government program provisions. For the analysis, the mean area yields and annual deviations from the area averages are the weighted average NASS county yields from planted acres for the 15-year period. Additionally, actuarially fair premiums are used in all insurance designs.

Continuous historical yield data for 98 southcentral Kansas dryland wheat farms and 38 northeast Kansas dryland corn farms from 1973–87 obtained from the Kansas Farm Management Data Bank are used (Langemeier). Yield statistics are reported in table 1. For the southcentral wheat farms, mean average farm yields always exceeded the average annual county yields except in McPherson County; the average CVs for farm-level yields exceeded those of the annual county yields in all counties. For the northeast corn farms, mean average farm yields exceeded the average annual county yields in all counties; the average CVs for farm-level yields were lower than those of annual county yields in seven of the 11 counties. The average farm-level yields exceeded the average county yields likely because of selection bias. The Farm Management Association farms tend to be larger and more profitable than average.

Individual Farm-Yield Insurance

Under current FCIC procedures, each farm has an insurance yield based on historical farm-level yields. The farm is reimbursed for any yield loss below the guaranteed yield (the insurance yield) less an adjustment for the deductible level selected by the producer. Under this plan, gross returns (net of the insurance premium) per planted acre are described as:

$$(1)\qquad GR_F = [\max(P, EL)\cdot Y_F] + \{[TP - \max(EP, EL)]\cdot Y_P\} - CIP + INDEM,$$

where GR_F represents gross returns to the farm enterprise (\$/acre); P is the market price (\$/bu.); EL is the effective national average loan rate (\$/bu.); Y_F is the actual farm yield produced on planted acres (bu./acre); TP is the target price (\$/bu.); EP is the expected national average price (\$/bu.); Y_P denotes the program yield based on 1980–84 farm yields (bu./acre); CIP is the actuarially fair crop insurance premium (\$/acre); $INDEM = \max\{0, IP\cdot[(HY_F\cdot LC) - Y_F]\}$, the indemnity payment (\$/acre); IP is the indemnity price election, the per-bushel price at which the yield is insured (\$/bu.); HY_F is the historical average farm yield from planted acres, the insurance yield (bu./acre); and $LC = 1 - \%$ deductible, $LC \leq 1$ (%).

Area-Yield Insurance

The indemnity calculation described in equation (2a) is based on an area-yield average and

Table 1. Summary Statistics for the Kansas Dryland Wheat and Corn Yield Data, by County, 1973-87

	National Agricultural Statistics Service Data[a]					Kansas Farm Management Association Data				
County	No. of Years	Mean[b] Yield	Minimum Yield	Maximum Yield	CV	No. of Farms	Mean[c] Avg. Yield	Mean CV	Minimum CV	Maximum CV
		(bu./acre)			(%)		(bu./acre)	(%)		
Southcentral Kansas Dryland Wheat										
Barton	15	28.51	18.63	30.06	19.66	11	36.07	20.54	14.38	24.34
Harper	15	29.06	22.94	37.52	15.66	9	36.56	20.50	16.97	26.88
Harvey	15	29.70	22.67	35.93	14.56	9	34.87	20.62	14.25	28.20
Kingman	15	29.62	23.14	36.63	13.91	2	30.01	19.27	16.88	21.66
McPherson	15	30.69	21.48	38.86	15.45	7	29.33	28.97	20.68	35.67
Pratt	15	29.34	20.16	36.85	19.19	3	32.97	19.66	15.88	22.77
Reno	15	29.01	21.35	35.46	14.14	11	35.41	19.39	11.45	34.21
Rice	15	32.97	25.76	39.67	14.06	14	35.17	22.12	15.30	31.38
Sedgwick	15	29.30	20.97	37.20	15.39	13	34.61	18.75	14.14	28.42
Stafford	15	30.82	24.36	37.03	14.53	6	32.74	23.29	16.00	32.32
Sumner	15	29.86	20.28	39.77	15.64	13	34.16	17.87	9.03	25.91
Northeast Kansas Dryland Corn										
Atchison	15	57.93	18.10	102.57	48.78	3	69.33	43.68	38.43	48.64
Brown	15	68.43	23.79	118.92	41.54	9	79.16	42.51	31.53	54.51
Doniphan	15	82.77	47.39	131.68	31.30	3	93.11	30.38	24.65	36.01
Douglas	15	60.95	12.13	120.87	47.36	3	105.48	34.68	25.04	45.13
Jackson	15	53.36	11.53	87.50	45.58	2	79.27	47.70	42.89	52.51
Jefferson	15	61.20	17.46	105.45	43.65	1	67.32	47.09	47.09	47.09
Leavenworth	15	57.32	19.28	94.32	40.87	11	82.56	42.31	31.22	58.18
Pottawatomie	15	71.17	35.75	128.72	38.60	1	88.56	34.88	34.88	34.88
Shawnee	15	81.59	19.15	134.04	37.91	3	86.61	37.67	34.61	42.48
Wabaunsee	15	48.98	5.08	84.79	44.79	1	89.23	35.14	35.14	35.14
Wyandotte	15	58.52	14.67	111.69	53.48	1	88.60	44.14	44.14	44.14

[a] Source: Kansas State Board of Agriculture.
[b] Average annual county yield from planted acres weighted by planted acres.
[c] Arithmetic mean of the average yields from planted acres for Kansas Farm Management Association member farms within the county for which continuous time-series data were available.

negative deviations (losses) from the area average and does not use or require farm-level data for calculating the indemnity payment. Equation (2a) would replace *INDEM* in equation (1); the remainder of equation (1) is unaffected:

(2a) $INDEM = \max\{0, IP\cdot[(HY_A\cdot LC) - Y_A]\}$,

where HY_A is the historical average area yield, the insurance yield (bu./acre); and Y_A is the actual area average yield produced on planted acres (bu./acre). Halcrow suggests that the indemnity be paid in bushels; therefore, when a gross income measure is not used (a strict interpretation using yield-equivalents only), *IP* is removed from the equation.

Under Barnaby's area percentage method (1990), the farmer is allowed to choose the level of dollar liability as well as the deductible level. The indemnity payment calculation for the method described by Barnaby is

(2b)
$$INDEM = \max\{0, \$LIAB\cdot[((HY_A - Y_A)/HY_A) - (1 - LC)]\},$$

where *$LIAB* is the level of liability purchased ($/acre). Equations (2a) and (2b) are identical when the liability level, denominated in bushels, is restricted to equal the historical area average yield ($\$LIAB = IP\cdot HY_A$). For simplicity, we carry this restriction throughout our analysis.

Optimal-Coverage Area-Yield Insurance

Although area-yield insurance may offer a method for limiting adverse selection and moral hazard compared to individual farm-yield insurance, farmers whose yields (Y_F) are not highly correlated with the area yields (Y_A)

Table 2. Summary of β_F and β_c Estimates and Optimal Coverage Levels (*LC*) under an Area Insurance Plan, by County

County	No. of Farms	Frequency of β_F Estimates: ≤ 0.25	0.26 to 0.50	0.51 to 0.75	0.76 to 1.00	1.01 to 1.25	1.26 to 1.50	≥ 1.51	Min. β_F	Max. β_F	β_c	Optimal *LC* Level (%): Min.	Max.
							Southcentral Kansas Dryland Wheat						
Barton	11	·	·	2	4	4	1	·	0.602	1.279	0.341	88.3	187.5
Harper	9	·	3	1	3	1	1	·	0.299	1.290	0.260	57.5	248.1
Harvey	9	·	·	2	2	2	2	1	0.624	1.646	0.350	89.1	235.1
Kingman	2	·	1	·	·	1	·	·	0.383	1.099	0.332	57.7	165.5
McPherson	7	2	·	·	·	3	1	1	−0.027	1.642	0.333	0.0	246.5
Pratt	3	·	·	1	1	1	·	·	0.606	1.019	0.305	99.3	167.0
Reno	11	1	1	2	3	3	·	1	0.098	1.613	0.331	14.8	243.7
Rice	14	·	·	2	4	4	3	1	0.569	1.520	0.333	85.4	228.2
Sedgwick	13	2	3	·	5	2	1	·	0.230	1.303	0.347	33.1	187.8
Stafford	6	·	·	·	2	2	2	·	0.918	1.492	0.300	153.0	248.7
Sumner	13	·	1	4	5	3	·	·	0.359	1.141	0.351	51.1	162.5
Cumulative	98	5	9	14	29	26	11	4	—	—	—	—	—
							Northeast Kansas Dryland Corn						
Atchison	3	·	·	1	1	·	1	·	0.643	1.274	0.268	120.0	237.7
Brown	9	·	·	1	5	2	1	·	0.640	1.303	0.315	101.6	206.8
Doniphan	3	·	·	1	1	·	1	·	0.733	1.307	0.265	138.3	246.6
Douglas	3	·	·	1	2	·	·	·	0.708	0.978	0.319	111.0	153.3
Jackson	2	·	·	·	·	1	1	·	1.235	1.477	0.307	201.1	240.6
Jefferson	1	·	·	·	·	1	·	·	1.029	1.029	0.309	166.5	166.5
Leavenworth	11	·	·	·	2	2	6	1	0.946	1.532	0.326	145.1	235.0
Pottawatomie	1	·	·	·	1	·	·	·	0.891	0.891	0.272	163.8	163.8
Shawnee	3	·	·	·	3	·	·	·	0.933	0.997	0.341	136.8	146.2
Wabaunsee	1	·	·	·	·	1	·	·	1.206	1.206	0.305	199.7	199.7
Wyandotte	1	·	·	·	·	1	·	·	1.049	1.049	0.294	178.4	178.4
Cumulative	38	·	·	4	15	8	10	1	—	—	—	—	—

may find an area-yield plan ineffective in reducing risk. To test the relationship, Miranda suggests a simple analytical model:

$$Y_F = HY_F + \beta_F(Y_A - HY_A) + \epsilon_F, \tag{3a}$$

where $\beta_F = \rho_F \cdot [\mathrm{Var}(Y_F)/\mathrm{Var}(Y_A)]$, estimated for each farm; ρ_F is the coefficient of correlation between Y_F and Y_A; and ϵ_F is a random error term. The estimated β_Fs have a central tendency toward one and indicate whether the farm has yield deviations identical to ($\beta_F = 1$), larger than ($\beta_F > 1$), or smaller than ($\beta_F < 1$), the area-yield deviations. Generally, the higher the β_F, the greater the chance that an area-yield insurance will be risk reducing for the farm. Full-coverage [0% deductible; $LC = 1$ in equations (2a) and (2b)] area-yield insurance will be risk reducing for the farmer only if β_F is above a critical β value, β_c. Miranda presents a method for calculating β_c as:

$$\beta_c = -\frac{\mathrm{Var}(I)}{2 \cdot \mathrm{Cov}(Y_A, I)}, \tag{3b}$$

where $I = \max\{0, (HY_A - Y_A)\}$, the full-coverage area-yield plan indemnity stated in bushels. Under the area-yield insurance plan [equation (2a)], when the farmer is allowed to elect a coverage level, *LC*, in order to minimize yield risk, the calculation for the optimal *LC* is derived by Miranda as:

$$LC = \beta_F/2\beta_c. \tag{3c}$$

Under this scheme, a farmer is allowed to "overinsure" the crop if relatively higher yield variability is experienced compared to the area; conversely, a farmer with relatively lower yield variability compared to the area would seek a higher deductible (lower coverage) level. Incorporating the optimal *LC* into Barnaby's method [equation (2b)] results in a more flexible strategy, whereby the farmer could choose not only the level of coverage but also the dollar liability level. A strict interpretation of Barnaby's method limits $LC \leq 1$ and places no restrictions on *$LIAB*. It can easily be shown that electing the optimal *$LIAB* level is identical to electing the optimal *LC* level.

A summary of the β_Fs, β_cs, and optimal coverage levels is presented in table 2. Brief examination of the minimum β_Fs in relation to the β_cs indicates that we should expect a full-coverage area insurance plan to be yield-equivalent risk reducing for 89 to 93 of the southcentral farms and for all 38 of the northeast farms. The optimal coverage elections range from 0% to 248.7% for the southcentral wheat farms and from 101.6% to 246.6% for the northeast corn farms.

Farm-Yield Disaster Assistance

Farm-yield disaster assistance differs from farm-yield insurance in two significant ways: (*a*) coverage is provided only if the farm experiences a yield disaster, and (*b*) coverage is provided at no cost to the farmer. In the analysis, a farm-yield disaster is defined as a farm yield of less than 65% of the historical average farm yield on planted acres. Disaster assistance payments are calculated as the difference between 65% of the historical average farm yield and the actual farm yield. Gross returns under the farm-yield disaster program are calculated as:

$$(4)\quad GR_F = [\max(P, EL)\cdot Y_F] + \{[TP - \max(EP, EL)]\cdot Y_P\} + DAP,$$

where $DAP = \max\{0, IP\cdot[(65\%\cdot HY_F) - Y_F]\}$, the disaster payment ($/acre).

Area-Yield Disaster Assistance

Area-yield disaster assistance differs from area-yield insurance in the same manner as farm-yield disaster assistance differs from farm-yield insurance except in the ways in which a disaster is defined and the disaster payments are calculated. In the analysis, an area-yield disaster is defined as an area yield of less than 65% of the NASS weighted historical average county yield on planted acres. Disaster assistance payments are calculated as the difference between 65% of the historical average county yield and the actual county yield. All farms within a disaster-designated area receive the same disaster assistance payment:

$$(5)\quad DAP = \max\{0, IP\cdot[(65\%\cdot HY_A) - Y_A]\}.$$

The disaster assistance payment calculation in equation (5) replaces that in equation (4); the rest of equation (4) remains unaltered. This disaster assistance plan is equivalent to the area insurance described in equation (2a) with a 35% deductible ($LC = 65\%$) and provided at no cost to the farmer ($CIP = 0$).

The initial analysis examines only the reduction in yield-equivalent variability offered by the five crop insurance/disaster assistance programs represented in equations (1)–(5), ignoring crop prices and government program deficiency payments.[8] Further analysis is presented that compares the gross income variability reduction under the crop insurance/disaster assistance programs with and without government deficiency payments. To simplify the analysis, we assume that the crop is insured using a 0% deductible plan (except for the optimal-coverage area-yield insurance) and that the premiums are actuarially fair. By using actuarially fair premiums, the means of the yield-equivalent and gross income distributions are not influenced by the insurance method. Indemnity and disaster assistance payments are based on a price election (*IP*) equivalent to the 1988 target price. Second-degree stochastic dominance analysis of the gross income distributions is also employed. Finally, consideration is given to the total indemnity and disaster assistance liabilities under the various programs that would be paid to the farms studied.

Results

The relative variability reductions in the yield-equivalent and gross income distributions under the insurance and disaster assistance programs relative to those without insurance or disaster assistance coverage, as measured by the percent reduction in the coefficients of variation, are presented in tables 3 and 4.

Yield-Equivalent Variability

The individual farm-yield insurance plan is the most effective at reducing relative yield-equivalent variability (1Y). Relative variability in yield-equivalents is reduced between 27.5% and 67.2% for all wheat farms and between 36.1% and 63.8% for all corn farms;

[8] In effect, this is equivalent to fixing the value of each bushel produced and reimbursed and charging a crop insurance premium in bushels rather than dollars.

Table 3. Frequency of Relative Reduction in Yield-Equivalent and Gross Income Variability for 98 Southcentral Kansas Farm Management Association Dryland Wheat Farms, by Crop Insurance/Disaster Assistance Plan, 1973-87

Reduction in Variability[a] (Percent)	Yield					Gross Income w/o Deficiency Payments					Gross Income w/Deficiency Payments				
	1Y[b]	2Y	3Y	4Y	5Y[c]	1GWO	2GWO	3GWO	4GWO	5GWO[c]	1GW	2GW	3GW	4GW	5GW[c]
−20 to −16	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·
−15 to −11	·	2	·	·	·	·	1	·	·	·	·	·	·	·	·
−10 to −6	·	2	·	·	·	·	1	·	·	·	·	4	·	·	·
−5 to 0	·	5	7	·	·	·	6	4	·	·	·	2	6	·	·
0 to 5	·	10	10	73	·	1	29	36	82	·	·	13	14	74	·
6 to 10	·	15	15	13	·	5	35	22	9	·	·	17	15	11	·
11 to 15	·	22	16	4	·	20	21	22	2	·	·	21	20	7	·
16 to 20	·	18	14	4	·	26	4	10	4	·	3	18	9	3	·
21 to 25	·	15	9	3	·	27	·	3	1	·	6	13	11	2	·
26 to 30	4	9	9	·	·	15	1	·	·	·	14	6	9	1	·
31 to 35	12	·	9	1	·	4	·	1	·	·	25	3	8	·	·
36 to 40	34	·	5	·	·	·	·	·	·	·	14	·	2	·	·
41 to 45	22	·	4	·	·	·	·	·	·	·	21	·	4	·	·
46 to 50	15	·	·	·	·	·	·	·	·	·	9	·	·	·	·
51 to 55	4	·	·	·	·	·	·	·	·	·	4	·	·	·	·
56 to 60	6	·	·	·	·	·	·	·	·	·	2	·	·	·	·
61 to 65	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
66 to 70	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Average (%)	41.9	13.2	17.2	3.9	—	19.8	7.3	8.6	2.8	—	36.9	13.0	16.2	3.8	—
Minimum (%)	27.5	−13.6	−3.8	0.0	—	3.4	−10.8	−5.2	0.0	—	15.5	−18.2	−3.0	0.0	—
Maximum (%)	67.2	29.0	42.5	31.5	—	32.6	28.3	31.7	22.6	—	55.7	31.6	43.8	28.5	—

[a] The reduction in relative variability is measured as the percent difference between the CV statistics for the alternative strategies and the no insurance, no disaster assistance strategy (the baseline). Under the crop insurance plans, the reduction in relative variability is also the percent difference between the standard deviations for the insurance plan strategies and the no coverage strategy because of the use of actuarially fair premiums. Standard deviations did not increase under the disaster assistance plans, therefore, a relative reduction in the CV statistic indicates a decline in the standard deviation, an increase in the expected gross income, or both.

[b] Comparisons: 1Y = Individual Farm-Yield Insurance versus No Coverage (Yield); 2Y = Area-Yield Insurance versus No Coverage (Yield); 3Y = Optimal-Coverage Area-Yield Insurance versus No Coverage (Yield); 4Y = Farm-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage (Yield); 5Y = Area-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage (Yield); 1GWO = Individual Farm-Yield Insurance versus No Coverage, No Deficiency Payments (Gross Income); 2GWO = Area-Yield Insurance versus No Coverage, No Deficiency Payments (Gross Income); 3GWO = Optimal-Coverage Area-Yield Insurance versus No Coverage, No Deficiency Payments (Gross Income); 4GWO = Farm-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, No Deficiency Payments (Gross Income); 5GWO = Area-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, No Deficiency Payments (Gross Income); 1GW = Individual Farm-Yield Insurance versus No Coverage, With Deficiency Payments (Gross Income); 2GW = Area-Yield Insurance versus No Coverage, With Deficiency Payments (Gross Income); 3GW = Optimal-Coverage Area-Yield Insurance versus No Coverage, With Deficiency Payments (Gross Income); 4GW = Farm-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, With Deficiency Payments (Gross Income); 5GW = Area-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, With Deficiency Payments (Gross Income).

[c] During the 15-year period, none of the counties experienced a disaster. A disaster is defined here as the annual county yield dropping below 65% of the historical weighted county average yield.

Table 4. Frequency of Relative Reduction in Yield-Equivalent and Gross Income Variability for 38 Northeast Kansas Farm Management Association Dryland Corn Farms, by Crop Insurance/Disaster Assistance Plan, 1973-87

Reduction in Variability[a] (Percent)	Yield					Gross Income w/o Deficiency Payments					Gross Income w/Deficiency Payments				
	1Y[b]	2Y	3Y	4Y	5Y	1GWO	2GWO	3GWO	4GWO	5GWO	1GW	2GW	3GW	4GW	5GW
−20 to −16	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
−15 to −11	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·
−10 to −6	·	·	·	·	·	·	1	3	·	·	·	·	·	·	·
−5 to 0	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·
0 to 5	·	·	·	1	4	·	1	3	·	6	·	·	·	·	3
6 to 10	·	·	·	3	3	·	3	1	3	4	·	·	·	1	4
11 to 15	·	·	·	4	12	·	4	4	4	6	·	·	3	6	9
16 to 20	·	1	·	8	13	·	5	6	4	13	·	3	1	3	12
21 to 25	·	7	1	8	5	1	3	5	5	6	·	5	4	6	9
26 to 30	·	10	7	7	1	·	6	1	4	3	·	7	4	10	1
31 to 35	·	8	3	6	·	2	9	3	11	·	·	9	4	4	·
36 to 40	4	7	4	1	·	8	6	8	4	·	1	8	3	6	·
41 to 45	10	5	6	·	·	4	·	1	3	·	3	5	5	2	·
46 to 50	8	·	5	·	·	6	·	1	·	·	7	1	5	·	·
51 to 55	11	·	8	·	·	12	·	·	·	·	6	·	5	·	·
56 to 60	2	·	3	·	·	3	·	·	·	·	15	·	3	·	·
61 to 65	3	·	1	·	·	2	·	·	·	·	4	·	·	·	·
66 to 70	·	·	·	·	·	·	·	·	·	·	2	·	1	·	·
Average (%)	48.7	32.0	43.0	22.3	14.8	47.1	24.4	20.5	26.9	15.2	54.9	32.4	38.9	24.4	16.0
Minimum (%)	36.1	18.5	22.1	4.8	3.3	24.8	−6.1	−10.9	7.2	2.5	40.4	15.9	13.2	5.6	3.8
Maximum (%)	63.8	45.2	64.9	38.3	26.0	60.9	40.2	48.8	43.2	26.5	69.4	47.4	66.0	37.4	26.8

[a] The reduction in relative variability is measured as the percent difference between the CV statistics for the alternative strategies and the no insurance, no disaster assistance strategy (the baseline). Under the crop insurance plans, the reduction in relative variability is also the percent difference between the standard deviations for the insurance plan strategies and the no coverage strategy because of the use of actuarially fair premiums. Standard deviations did not increase under the disaster assistance plans, therefore, a relative reduction in the CV statistic indicates a decline in the standard deviation, an increase in the expected gross income, or both.

[b] Comparisons: 1Y = Individual Farm-Yield Insurance versus No Coverage (Yield); 2Y = Area-Yield Insurance versus No Coverage (Yield); 3Y = Optimal-Coverage Area-Yield Insurance versus No Coverage (Yield); 4Y = Farm-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage (Yield); 5Y = Area-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage (Yield); 1GWO = Individual Farm-Yield Insurance versus No Coverage, No Deficiency Payments (Gross Income); 2GWO = Area-Yield Insurance versus No Coverage, No Deficiency Payments (Gross Income); 3GWO = Optimal-Coverage Area-Yield Insurance versus No Coverage, No Deficiency Payments (Gross Income); 4GWO = Farm-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, No Deficiency Payments (Gross Income); 5GWO = Area-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, No Deficiency Payments (Gross Income); 1GW = Individual Farm-Yield Insurance versus No Coverage, With Deficiency Payments (Gross Income); 2GW = Area-Yield Insurance versus No Coverage, With Deficiency Payments (Gross Income); 3GW = Optimal-Coverage Area-Yield Insurance versus No Coverage, With Deficiency Payments (Gross Income); 4GW = Farm-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, With Deficiency Payments (Gross Income); 5GW = Area-Yield Disaster Assistance (35% Loss Trigger) versus No Coverage, With Deficiency Payments (Gross Income).

average reductions are 41.9% and 48.7%, respectively. The second most effective plan at reducing yield-equivalent variability is the optimal-coverage area-yield insurance plan (3Y). As anticipated, the full-coverage area-yield insurance plan (2Y) reduces relative yield-equivalent variability for 89 of the southcentral wheat farms and all of the northeast corn farms; however, it is the least effective of the three insurance plans. Of the two disaster assistance plans, the farm-yield disaster assistance plan (4Y) is most effective. However, neither of the disaster assistance plans is as effective at reducing relative yield-equivalent variability as the three insurance plans. During the 15-year period, the NASS county yield estimates for the southcentral wheat farm counties never fell below 65% of the expected county yields; therefore, no area-yield disaster occurs for these counties under an area-yield disaster assistance plan (5Y). For the northeast corn counties, there are eight years in which none of the counties experienced area-yield disasters (as defined previously). All of the insurance and disaster assistance programs provide a greater reduction in yield-equivalent variability, on average, for the corn farms than for the wheat farms; this result is likely due to the fact that the relative yield variability for corn is greater than for wheat (table 1).

Gross Income Variability

Comparisons indicate that the relative reductions in gross income variabilities are, in most cases, less than the relative reductions in their yield-equivalent counterparts; this is explained by the additional risk associated with price variations. Examination of the gross income without government deficiency payments results indicates that the individual farm-yield insurance plan (1GWO) provides the highest average relative reduction in gross income variability (19.8% and 47.1% reductions for the wheat and corn farms, respectively) in comparison to the alternative plans. The area-yield insurance plan (2GWO) reduces relative gross income variability on 90 (92%) of the wheat and 37 (97%) of the corn farms; relative gross income variability is reduced by an average of 7.3% and 24.4% per farm for the wheat and the corn farms, respectively. The optimal-coverage area-yield insurance plan (3GWO) is only slightly more effective at reducing gross income variability for the wheat farms than the full-coverage area-yield insurance plan. For the corn farms, it is less effective at reducing gross income variability than the full-coverage area-yield insurance (2GWO); this is because the optimal level of coverage is based on the relationship between farm-specific yields and area yields and does not take the additional risk of variable prices into account. The farm-yield disaster assistance plan (4GWO) is the second most effective at reducing relative variability in gross income for the corn farms (26.9%) but is only marginally effective for the wheat farms (2.8%). The area-yield disaster assistance plan (5GWO) is the least effective at reducing gross income variability for corn.

Participation in the government deficiency payment program reduces the variability of gross income on planted acres for most of the farms, as indicated by comparing the average, minimum, and maximum reduction statistics for the corresponding strategies with and without government payments. The fact that the relative variability of gross income with government payments is, in some cases, higher than without government payments indicates that participation may introduce additional, but beneficial, upward income risk. Under all the insurance/disaster assistance alternatives, except the farm-yield disaster assistance plan (4GW) for the northeast corn farms, the reductions in gross income variability with deficiency payments included are larger, on average, than the variability reductions in gross incomes without deficiency payments. The rankings of the insurance/disaster assistance plans, based on the average percent reduction in relative variability, for wheat do not change when government payments are included. However, for corn farms the farm-yield disaster assistance plan (4GW) is relatively less effective than the optimal-coverage area-yield insurance (3GW) and area-yield insurance (2GW) when deficiency payments are accounted for.

Stochastic Dominance Analysis

Analysis of the gross income distributions, both with and without deficiency payments included, supports the previous CV results. When deficiency payments are not included in the gross income distributions, second-degree stochastic dominance analysis (table 5) indicates that risk-averse wheat producers would prefer

Table 5. Second-Degree Stochastic Dominance Results

Deficiency Payments	Strategy[a] Wheat (98 Farms) NC	FI	AI	OAI	FDA	ADA	Corn (38 Farms) NC	FI	AI	OAI	FDA	ADA
	Number of Times Dominated by Alternative Strategies											
Without	70	0	33	23	24	70	38	4	33	32	2	30
With	72	0	49	31	26	72	38	0	24	13	2	30

[a] NC = No Insurance/Disaster Assistance Coverage; FI = Individual Farm-Yield Insurance; AI = Area-Yield Insurance; OAI = Optimal-Coverage Area-Yield Insurance; FDA = Farm-Yield Disaster Assistance (35% Loss Trigger); ADA = Area-Yield Disaster Assistance (35% Loss Trigger).

the individual farm-yield insurance plan (FI). However, the individual farm-yield insurance (FI) and farm-yield disaster assistance (FDA) plans are approximately equally preferred by corn producers. The strategy most often dominated by any of the other strategies for corn is the baseline strategy of no crop insurance or disaster assistance coverage (NC). For wheat, the no coverage (NC) and the area-yield disaster assistance (ADA) strategies are equally dominated.

The analysis of the strategies that include government deficiency payments indicates that risk-averse wheat producers as well as corn producers would prefer the individual farm-yield insurance plan (FI) because it is never dominated by any of the alternative strategies on any of the 98 wheat farms and 38 corn farms. The second least dominated strategy for wheat and corn (dominated by alternative strategies on 26 wheat farms and two corn farms) is the farm-yield disaster assistance plan (FDA). For corn, the strategy most frequently dominated by any of the other strategies is the baseline strategy (NC). The NC and ADA strategies are equally dominated for wheat.

Program Outlays

The total insurance indemnity/disaster assistance liability outlays, calculated as the sum of all indemnities/assistance payments to all farms not allowing for administrative costs, occurring under the alternative plans are presented in table 6. As anticipated, the alternative that would result in the smallest outlay per acre, for both farming regions, is the area-yield disaster assistance plan (ADA); the farm-yield disaster assistance plan (FDA) is slightly more expensive. If the level of insurance coverage is restricted to 100% of the expected farm or area yield, the largest liability occurs under the individual farm-yield insurance plan (FI). If farmers are allowed to "overinsure," the optimal-coverage area-yield plan (OAI) results in the largest outlay for corn enterprises, but the individual farm-yield plan (FI) is still the most expensive for wheat enterprises. This result is likely due to higher variability in yields experienced on the corn farms.

Conclusions and Implementation Considerations

Although an individual farm-yield insurance plan is complex, it provides more reduction in farm-level yield-equivalent and gross income variability than any of the alternative crop insurance or disaster assistance plans as measured by the difference between the coefficient of variation statistics between the baseline strategy of no insurance or disaster assistance coverage and the alternative strategies.

The government deficiency payment program alone provides some degree of relief from gross income variability; for some of the sampled farms, it augments upward gross income variability which is beneficial. Additional gross income variability may be introduced by changes in government programs; however, such changes cannot be modeled a priori. When a crop insurance or disaster assistance plan is combined with the government deficiency payment program, relative gross income variability is reduced more than by any of the programs alone for nearly all of the sampled farms. Second-degree stochastic dominance analysis of gross returns including government deficiency payments net of any insurance premiums indicates that risk-averse wheat and corn producers would prefer an individual farm-

Table 6. Total Insurance Indemnity/Disaster Assistance Liabilities under Five Crop Insurance/Disaster Assistance Plans, Southcentral Kansas Dryland Wheat Farms and Northeast Kansas Dryland Corn Farms, by Year and County, 1973-87

	Planted	Southcentral Kansas Wheat Farms						Planted	Northeast Kansas Corn Farms				
	Acres	FI[a]	AI	OAI	FDA	ADA		Acres	FI[a]	AI	OAI	FDA	ADA
	(1,000)	(1,000 1988 dollars)						(1,000)	(1,000 1988 dollars)				
By Year													
1973	43.7	84.5	0.0	0.0	13.1	0.0		8.7	24.1	21.1	31.0	0.0	0.0
1974	49.8	1,242.3	900.7	1,329.1	52.0	0.0		10.1	876.9	858.2	1,512.8	171.1	220.6
1975	53.7	769.2	527.0	739.8	6.8	0.0		8.6	384.3	602.4	1,078.8	27.8	76.1
1976	54.5	892.5	840.8	1,108.7	56.2	0.0		9.0	683.8	435.0	780.8	74.9	47.9
1977	55.2	1,191.9	797.7	1,187.4	75.2	0.0		6.5	234.8	219.4	390.6	11.8	5.0
1978	48.1	643.8	468.0	714.0	57.9	0.0		6.9	52.2	0.3	0.4	0.0	0.0
1979	49.9	95.9	0.0	0.0	0.0	0.0		8.8	2.1	0.0	0.0	0.0	0.0
1980	54.8	890.8	469.5	685.5	81.9	0.0		9.0	1,645.2	1,056.7	1,778.9	888.2	485.2
1981	59.9	999.9	915.8	1,330.4	54.2	0.0		7.3	4.0	0.0	0.0	0.0	0.0
1982	58.3	191.1	0.0	0.0	8.9	0.0		7.4	0.0	0.0	0.0	0.0	0.0
1983	46.2	93.8	282.4	383.9	0.0	0.0		6.4	854.4	665.2	1,136.5	325.5	261.1
1984	48.4	195.8	1.5	2.3	0.2	0.0		7.5	276.8	112.1	202.6	47.7	18.2
1985	48.2	410.0	265.8	349.7	0.0	0.0		8.3	0.0	0.0	0.0	0.0	0.0
1986	46.5	341.0	172.2	231.9	0.0	0.0		8.9	0.0	0.0	0.0	0.0	0.0
1987	47.8	653.5	195.9	259.7	11.7	0.0		8.2	11.4	0.0	0.0	0.0	0.0
By County													
Barton	77.8	919.5	760.8	1,014.9	31.2	0.0	Atchison	9.5	426.7	362.9	720.7	117.0	106.7
Harper	85.4	1,052.0	614.7	920.9	26.5	0.0	Brown	35.1	1,408.2	1,106.7	1,740.2	506.8	338.4
Harvey	46.3	503.6	313.3	459.5	19.5	0.0	Doniphan	9.2	352.3	307.0	633.5	31.8	13.5
Kingman	6.2	61.0	43.3	50.1	0.0	0.0	Douglas	10.7	430.6	303.9	418.6	133.5	115.9
McPherson	29.9	413.7	271.2	385.7	79.2	0.0	Jackson	3.2	123.8	84.0	181.1	34.3	25.3
Pratt	26.3	279.9	267.0	360.8	9.3	0.0	Jefferson	2.2	86.8	72.8	121.3	32.0	22.2
Reno	92.3	988.5	636.2	820.1	33.4	0.0	Leavenworth	24.2	1,055.9	758.7	1,463.8	304.5	207.3
Rice	101.6	1,282.8	818.3	1,345.4	96.0	0.0	Pottawatomie	2.2	85.1	69.9	114.5	23.3	5.4
Sedgwick	85.4	958.9	609.2	790.9	31.9	0.0	Shawnee	9.0	325.5	353.8	498.0	100.8	84.5
Stafford	54.8	699.3	431.4	852.8	60.3	0.0	Wabaunsee	7.4	277.0	191.7	379.5	68.3	53.8
Sumner	158.8	1,536.9	1,072.1	1,321.3	30.9	0.0	Wyandotte	8.8	478.0	359.1	641.3	194.6	141.0
Total	765.0	8,696.0	5,837.4	8,322.4	418.1	0.0		121.6	5,050.0	3,970.4	6,912.5	1,547.0	1,114.0
Avg. Liability ($/Planted Acre)		11.37	7.63	10.88	0.55	0.00			41.54	32.66	56.86	12.73	9.16

[a] Strategies: FI = Individual Farm-Yield Insurance; AI = Area-Yield Insurance; OAI = Optimal-Coverage Area-Yield Insurance; FDA = Farm-Yield Disaster Assistance (35% Loss Trigger); ADA = Area-Yield Disaster Assistance (35% Loss Trigger).

yield insurance design similar to that described in our study. In the presence of tightening federal budgetary constraints, this poses two policy considerations: (*a*) an adjustment in the deficiency payment program may be as effective in reducing gross income variability as any crop insurance or disaster assistance program, and (*b*) implementation of a crop insurance or disaster assistance program may be more effective in reducing gross income variability for some crops than the existing deficiency payment program.

Implementation of these crop insurance and disaster assistance plans requires further research consideration. The area "yield hedge" insurance plans could be based on percentage measures and dollars of liability, as Barnaby proposes, rather than bushels of liability as originally proposed by Halcrow. This would eliminate the need for price forecasting to determine premiums, an issue that the FCIC presently faces, and would allow for implementation procedures similar to those for private hail insurance with which the insurance industry is already acquainted. Each farmer would have to determine the optimal amount of liability and the deductible level to purchase, thereby eliminating the need for the insurer to maintain farm-level records.

In light of the late-1990 discussion on Capitol Hill of continuation or elimination of the crop insurance provisions in the Farm Bill, additional analysis should consider these insurance and disaster assistance methods using a broader scope. Important issues to consider in future analyses include the ease of implementation for farmers as well as for the FCIC or other insurance institutions, the administrative costs of the alternatives, and the cost effectiveness of insurance plans in comparison to direct disaster assistance programs.

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