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DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS
SYMONS HALL
UNIVERSITY OF MARYLAND
COLLEGE PARK 20742

Adverse Selection in U.S. Crop Insurance:
The Relationship of Farm Characteristics to Expected Indemnities

by

Richard E. Just
Linda Calvin

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The problems of adverse selection and moral hazard have attracted much attention in the crop insurance literature. The problem of moral hazard (in which farmers alter behavior depending on whether they are insured) can be mitigated by increased monitoring, which may be expensive, or by restructuring crop insurance contracts, e.g., as in recent area-wide experimental approaches. The problem of adverse selection (in which only farmers with more favorable expected indemnities compared to premiums participate) can be mitigated by better tailoring insurance premiums to characteristics of individual farm(er)s or by requiring participation. Federal crop insurance policy is following the latter approach of requiring participation. However, adverse selection cannot occur if parameters of insurance contracts adequately capture farm-specific yield distributions so that premiums are proportional to expected indemnities across all farmers. This paper has two purposes: (i) to investigate how well farm-specific yield distributions are captured by farm-specific FCIC insurance parameters and (ii) to investigate the potential of using readily available data on farm characteristics to better match premiums to expected indemnities. Information on acreage of the insured crop, farm size, and irrigation is readily available but not used by the FCIC to determine crop insurance premiums (irrigation is used only in some areas). Results demonstrate significant problems in FCIC parameters and show that readily available information can improve the correspondence of expected indemnities to premiums thus reducing the potential for adverse selection. However, the remaining potential for adverse selection will be substantial unless the information base is significantly expanded beyond what public information now includes.

A major component of the crop insurance literature has been devoted to showing why private markets for multiple peril crop insurance have not surfaced (e.g., Chambers; King and Oamek; Nelson and Loehman; Skees and Reed). We submit that non-viability of private farm-specific crop insurance is not clear until inexpensive means of mitigating adverse selection and moral hazard have been exhausted. Thus, studies such as presented in this paper are required before dismissing private potential. Another weakness of the literature is the fact that the critical issues of moral hazard and adverse selection are farm-specific problems whereas much of the empirical analysis has been done with aggregate or localized data. Aggregate data provides little information on market failures due to these problems and even county-level data (e.g., Gardner and Kramer; Goodwin) can reveal little if farms and farmers differ significantly within counties. Farm-level empirical analyses have been forthcoming in recent years but are either simulation analyses of few farms (e.g., King and Oamek) or econometric analyses of region-specific data that may not be representative of the national crop insurance problem. For example, Vandeveer and Loehman study corn producers in one Indiana county finding lower yields and higher variances among insurers, and Goodwin and Kastens study Kansas wheat, corn, sorghum, and soybean farmers with similar conclusions.

This paper analyzes the relationship of farm-specific information to FCIC insurance parameters using nationwide, farm-specific data. The data base was developed using the Farm Costs and Returns Survey (FCRS) sampling design. These data on farm characteristics, decisions, and performance variables were supplemented by a follow-up survey to obtain farm-specific yield distribution data. These data were further supplemented with data on insurance decisions and parameters from the Federal Crop Insurance Corporation (FCIC). This is believed to be the most extensive data base ever compiled and used to analyze federal crop insurance. With this data, we use the farm-specific yield distribution data (which is independent of the crop insurance year) to estimate expected indemnities. By comparing the relationship of these yield distributions to FCIC premiums and insurance yields between insured and non-insured groups of farmers, the results isolate specific incentives for adverse selection. Although moral hazard is also a potentially serious problem for viability of multiple peril crop insurance, moral hazard effects would presumably be reflected by further comparing the relationship of actual yields (in the specific crop insurance year) to yield distributions (independent of the crop insurance year) between insuring and non-insuring groups of farmers. This approach to separation of the adverse selection problem from the moral hazard problem assumes that farmers' responses regarding expected yields and probabilities do not reflect persistent moral-hazard-related reduction in input use that might occur year after year. This seems to be the more plausible interpretation of farmers' responses. To the extent this assumption does not hold, some of the differences attributed to adverse selection in this paper may partially reflect moral hazard.

The Federal Crop Insurance Program

In spite of goals to make multiple peril crop insurance privately viable, federal crop insurance has been a losing proposition. The Federal Crop Insurance Act of 1980 established federal subsidies, increased coverage of crops and counties, and allowed private sector sales of federal crop insurance contracts. Resulting FCIC loss ratios (indemnities divided by premiums) averaged 2.04 from 1980 to 1988. Since 1988, participation has increased, at least in part, because crop insurance for the succeeding year was required to receive disaster assistance. Accordingly, FCIC loss ratios have declined to an average of 1.78 from 1989 to 1994. With the Federal Crop Insurance Act of 1994, participation promises to rise further because purchase of a new catastrophic insurance is required to maintain eligibility for farm program benefits for crops representing at least 10 percent of a farm's value of production. As further participation is required, the loss ratio will likely decline because potential for adverse selection is partially eliminated. Nevertheless, the loss ratio is still far above the intended level of subsidization (30 percent) as well as the level required for private viability (about .95). At the same time, by requiring more participation, federal crop insurance is moving further from representing the potential for private market viability.

A significant feature of federal crop insurance contracts to date has been that all terms were set entirely by the FCIC (except for add-on coverage). Moreover, until recently, the only farm-specific characteristic used by the FCIC to set contract terms has been average yield.[1] In other words, private vendors are not free to consider additional farm characteristics in premium determination. To induce private providers to offer crop insurance on FCIC terms, the FCIC reinsures against losses in excess of a set percentage of premiums. Reinsurance by the FCIC explains FCIC losses beyond the intended level of federal subsidization. An interesting question is whether allowing private companies to tailor premiums to readily available information on individual farm characteristics could reduce the loss ratio and facilitate private-sector provision of crop insurance with less subsidization.

Federal Crop Insurance Contracts

Farmers must decide at the outset of the planting season whether to purchase crop insurance for each crop on their farm. If insurance is purchased, then it must be purchased for all of the acreage within a county devoted to that crop by the farmer. Farmers purchasing crop insurance must choose one of several insured yield percentages (50, 65, or 75 percent of the FCIC insurance yield at the time of the survey analyzed here) and an insured price level with the insurance premium determined accordingly.[2] If a verified yield history is available, the FCIC insurance yield is the Approved Production History (APH).[3] The insured yield is the FCIC insurance yield multiplied by the insured yield percentage. The farmer receives an insurance indemnity payment if the average yield on the entire farm falls below the insured yield level (the FCIC insurance yield times the insured yield percentage). The indemnity payment is equal to the insured yield less the actual yield evaluated at the insured price.

Premium rates are set by the FCIC to reflect local (e.g., county) risk conditions but historically the only farm-specific information determining farm-specific policy parameters has been the FCIC insurance yield. At the time of data generation for this study, FCIC methods assumed constant relative risk (yield standard deviation proportional to expected yield) within rate-making areas (Driscoll).[4] Differences in relative risk among farms were taken into account only gradually and partially by setting premium rates according to loss experience at county or regional levels. Thus, differences in variability among farms were reflected only to the extent that relative variability was uniform within the counties or regions used to determine premium rates.

With little doubt, farms with higher average yields do not necessarily have proportionally higher variability even within counties. For example, Skees and Reed have argued that absolute risk is constant on the basis of a sample of Western Kentucky farmers in which they found that the standard deviation did not vary proportionally with yield and that premiums based on constant relative risk favored farmers with lower average yields.[5] In effect, assuming constant relative risk is equivalent to assuming multiplicative disturbances in production so that a per acre production relationship, $y = f(x)\varepsilon$, with random disturbance

ε, $E(\varepsilon) = \mu_\varepsilon$, $V(\varepsilon) = \sigma_\varepsilon^2$, generates expected yield, $\mu = f(x)\mu_\varepsilon$, proportional to the standard deviation of yield, $\sigma = f(x)\sigma_\varepsilon$. Similarly, however, constant absolute risk implies $y = f(x) + \varepsilon$. Such assumptions for agricultural production risk have been criticized by Just and Pope and refuted empirically by a host of studies where x represents factor inputs. For this study we let x represent other farm characteristics and demonstrate a similar conclusion.

Heterogeneity of Expected Indemnities

If farmers differ in characteristics that determine yield distributions and farmers know their yield distributions better than the insurer, then farmers with a higher ratio of expected indemnity to premium (farmers for whom insurance is more profitable) are more likely to participate. The more variety in characteristics and the less observable are the characteristics, the more difficult it is for the FCIC to correctly identify an individual farmer's expected indemnity and assess the appropriate premium (Halcrow). This asymmetry of information is the underlying theoretical explanation for adverse selection. When this problem occurs, the insurer must either raise premiums to reflect the higher expected indemnities associated with farmers who participate, or incur an expected loss. Even if premiums are increased, the farmers who are most profitable to the insurer are more likely to select out of the program so losses may not be eliminated. This problem has led some to propose area-yield crop insurance (e.g., Halcrow; Miranda). However, others results have called into question the ability of area-yield insurance to mitigate sufficiently farm-level risks (Williams, et al.). An alternative approach is to increase the information base upon which FCIC premiums are based.

Available information suggests that farms and farmers differ substantially in many characteristics. Land quality varies from farm to farm and farmers differ in management skills. These characteristics affect the distribution of yields. Just as different production inputs can have distinct effects on the mean and variance of production (Just and Pope), different farm characteristics can have distinct effects on each. In contrast, FCIC methods use only average yield as a proxy for both, in effect, assuming a rigid relationship between the mean and variance of yield. This paper, in effect, extends the Just-Pope concept to investigating the effects of farm characteristics on the yield distribution. For this purpose, we concentrate on the first two moments describing the yield distribution and their role in determining farm-specific likelihood and expectation of indemnities.

Adverse selection due to differences in expected yield is depicted in Figure 1. Suppose two farms have the same FCIC insurance yield $\bar{\mu}$ and yield is insured at a proportion β of that yield but that the true expected yields are μ_1 and μ_2, respectively. Then the farm with the lower expected yield will have a higher expected indemnity (represented by the probability density left of $\beta\bar{\mu}$) assuming other things are equal. The farm with the higher expected yield may even have a negligible probability of indemnity. Accordingly, the farm with the lower expected yield will be more likely to participate. Presumably because FCIC parameters are closely tied to proven farm yields where they exist, differences such as those depicted in Figure 1 should not be serious. However, some farms do not have proven histories, others have short histories that are not so heavily influenced by secular trends in yield, and others have changed technologies, e.g., adopted no-till technology.

Adverse selection due to differences in standard deviations is represented in Figure 2. Suppose two farms have the same FCIC insurance yield and true expected yield all represented by $\bar{\mu}$ but have different standard deviations of yield σ_1 and σ_2 due, say, to different land qualities or management skills. Then the farm with the higher standard deviation will have a higher expected indemnity and will be more likely to participate. Again, the farm with a low standard deviation could have a negligible probability of indemnity. This example shows that farms may differ substantially in indemnities even when the expected yield is correctly assessed by the insurer. This consideration is critical because the FCIC does not attempt to determine producer-specific yield variabilities but rather assumes a rigid relationship between the standard deviation and mean of yields.

Adverse selection, which can result from higher probabilities of indemnities and higher expected indemnities among participating farmers, is explained by a combination of phenomena represented in Figures 1 and 2.[6] Note, however, that the presence of these differences does not imply adverse selection.

For example, if the premiums charged to individual farmers fully account for these differences, then adverse selection cannot occur. Thus, a central question is how well FCIC insurance parameters capture the variation in farm-specific yield distributions.

The empirical work in this paper is developed in two stages. First, we consider whether the variation in yield distributions among farmers is captured by parameters of the FCIC insurance contract. Specifically, yield distributions are regressed on FCIC insurance parameters to determine the extent to which APH and premium captures the variation in expected yield and yield standard deviation across farmers. After determining that they are not well captured, we consider whether additional characteristics for which data are readily available can improve explanation.

Additional Observable Characteristics Explaining Expected Indemnities

In this section, we discuss several additional characteristics that can be expected to affect expected indemnities. The set of characteristics is not intended to be exhaustive but rather represents a set of characteristics for which information is readily available and thus could be added to the list of proxy variables considered by the FCIC in setting premiums with negligible cost.

Farms vary widely in overall size as well as by the amount of acreage devoted to a particular crop. Farms with more acreage of the subject crop (holding farm size fixed) may have smaller expected yields because opportunities for rotation are reduced, because given capacities of machinery result in poorer timing of production practices, because the management capacity for a given crop must be spread over a larger acreage, and because a manager's attention is more likely to focus on enterprises that account for more of the farm's production activity.

Farms of larger size (holding the subject crop acreage fixed) may tend to have higher expected yields because of better crop rotation practices or because greater diversification allows better timing of production practices. Larger farms also tend to have acreage spread across more tracts and a wider geographic area. Thus, risk is more effectively pooled across varying pest and weather conditions as hail damage, pest infestations, and rain sometimes occur in narrow strips. Also, if a large farm has a variety of land qualities, the impact of certain climatic conditions may vary since poor land responds differently than good land. According to FCIC practices, the payment of an indemnity depends on the average yield across the entire farm unit. A total loss on one tract may not result in an indemnity if other tracts are less affected. Thus, smaller or more localized farms have higher expected indemnities per acre.

Irrigation also differs widely among farms. Some yield differences that occur with irrigation may be captured by historical loss rates which depend on county-level irrigation intensity or by yield histories on individual farms. However, farms with inadequate production history may not have FCIC insurance yields differentiated by irrigation because ASCS yields in some states are not differentiated by irrigation. Thus, some irrigating farmers may have little or no insurance possibilities because their FCIC insurance yield is unrealistically low while non-irrigating farmers insure yields much higher than 75 percent of their expected non-irrigated yields (Cawley). Even when appropriate APH's are available, irrigation may have a different impact on yield risk than embodied in FCIC assumptions. Irrigation is often regarded as a risk reducing input whereas the FCIC assumes increasing absolute risk in its premium structure.

Data reflecting these characteristics have not been used or have been used only indirectly by the FCIC in setting premiums and farm-specific insurance terms. The purpose of this paper is to determine the potential of such characteristics in explaining adverse selection in U.S. crop insurance. To the extent these characteristics explain adverse selection, insurance terms could be modified to reflect them and FCIC losses due to adverse selection can be reduced accordingly.

Data Requirements

The analysis of adverse selection requires several types of data. First, subjective yield distributions of individual farmers are needed to assess differences in yield distributions among farms. Because many farmers do not keep yield histories and no suitable farm-level panel data are available, subjective distributions of farmers must be solicited by direct interviews of farmers. Assessing the probabilities of obtaining less than 50, 65, and 75 percent of the FCIC insurance yield (the only three yield levels available at the time of this survey) is a critical part of the data collection. Second, data on farm size, irrigation, and acreage of the insurable crop are needed. Perhaps the best nationwide data reflecting this information is provided by the Farm Costs and Returns Survey (FCRS) administered annually by the National Agricultural Statistical Service (NASS) on behalf of the Economic Research Service (ERS). Third, data on crop- and farm-specific premiums and insurance choices are needed. Of course, the best nationwide data reflecting this information comes from the records of the FCIC.

Such a data set was developed at the national level by first compiling all of the observations from the 1988 FCRS for farmers growing corn, sorghum, soybeans, and wheat (see U.S. Department of Agriculture for a complete description). These data were then supplemented by a NASS-administered telephone survey of the same farmers and further data from FCIC insurance records on a farm-by-farm basis. The telephone survey contained questions to characterize farm-specific means and standard deviations of annual average yield and the probability of an insurance indemnity under each type of insurance contract for each crop for both irrigated and non-irrigated cases. Two types of data were obtained for estimation of farm-specific standard deviations of yield: (i) farmers' estimates of the worst annual average yield in a given period of years, and (ii) farmer's assessment of the probability of yields below 50, 65, and 75 percent of the FCIC insurance yield.[7] The two types of data produced similar results so only the results of with the latter are reported here.[8]

Estimation of Standard Deviations

To estimate standard deviations of yields for individual farmers, the farmer's estimates of probabilities of achieving 50, 65, and 75 percent of the FCIC insurance yield were used in a three point probit-type regression assuming normality of yields. Suppose y is yield, μ is actual expected yield, $\bar{\mu}$ is the FCIC insurance yield, and ψ^β represents the farmer's probability of achieving a yield less than $\beta\bar{\mu}$ where $\beta = .5, .65, .75$ and σ is the standard deviation of yield. Then $(\beta\bar{\mu} - \mu)/\sigma = \Phi^{-1}(\psi^\beta)$ where Φ is the cumulative distribution function of the standard normal distribution. This implies that σ can be estimated by a farmer-specific regression using the equation $\beta\bar{\mu} = \mu + \sigma\Phi^{-1}(\psi^\beta)$. For this purpose, the farmer's estimate of mean average yield was used as the estimate of μ.

While some empirical results refute normality of yields, it provides a reasonable approximation here. The applicability of eleven alternative distributions was considered for each crop: the normal, Weibull, gamma, lognormal, exponential, inverse Gaussian, Pearson types 5 and 6, and extreme value distributions of types A and B. The Kolmogorov-Smirnov test did not reject normality for corn and sorghum. Normality was rejected at the 5 percent level for soybeans, but no other distribution fit the data better. Normality was rejected for wheat, but only the logistic distribution fit the data better and only marginally so. In every case, skewness was close to zero and kurtosis was close to 3 suggesting normality.

Some Hypotheses About FCIC Insurance Parameters

Consider how well the variation in yield distributions among farmers is captured by the variation in FCIC insurance contract parameters among farmers. First, consider how well FCIC insurance yields reflect farmers' expected yields, H_1: $\mu = \bar{\mu}$. Failure of $_1$H implies inequalities in the potential for indemnities as depicted in Figure 1, other things equal. Second, consider whether the relationship of FCIC insurance yield to expected yield differs between insurers and non-insurers, H_2: $\mu = f(\bar{\mu},\delta)$, $f_\delta = 0$, where δ is zero if uninsured and 1 if insured and $f_\delta \equiv f(\cdot,1) - f(\cdot,0)$. If $f_\delta = 0$, then the relationship of FCIC insurance yield to expected yield does not differ between the insured and uninsured cases. However, if $f_\delta < 0$, then farmers with higher FCIC insurance yields relative to expected yields are participating, i.e., not only does Figure 1 apply but the left distribution represents insured farmers and the right distribution represents uninsured farmers. To consider whether an outcome with $f_\delta < 0$ is due to adverse selection requires considering a third hypotheses investigating whether the differences in FCIC insurance yields relative to expected yields is captured by variation in premiums, H_3: $\mu = f(\bar{\mu},\delta,\rho)$, $f_\delta = 0$, where ρ is the insurance premium (the actual premium paid by the farmer rather than the premium plus government subsidy received by the FCIC). If variation of insurance premiums among farmers does not compensate for differences in the relationship of FCIC insurance yield to expected yield, then $f_\delta = 0$ will be rejected. (Note, however, that non-rejection of $f_\delta = 0$ does not necessarily imply that the variation of permiums among farmers is adequate to avoid adverse selection; the implication is one-way).

Next consider whether variation in standard deviations of yield among farmers is captured by the variation in parameters of FCIC insurance contracts among farmers. A methodology parallel to the investigation of expected yield hypotheses suggests H_4: $\sigma = g(\bar{\sigma},\delta)$, $g_\delta = 0$ and H_5: $\sigma = g(\bar{\sigma},\delta,\rho)$, $g_\delta = 0$ where g_δ is defined similar to f_δ . However, the FCIC does not produce explicit estimates of yield variability by farm. Rather, a relationship of the form $\bar{\sigma} = h(\bar{\mu})$ is used. That is, the FCIC insurance yield is used as a proxy for the standard deviation of yield. Rates are then adjusted by loss experience over time to compensate for imperfections in the relationship. Substituting into H_4 and H_5 obtains hypotheses H_4^*: $\sigma = g^*(\bar{\mu},\delta)$, $g_\delta^* = 0$ and H_5^*: $\sigma = g^*(\bar{\mu},\delta,\rho)$, $g_\delta^* = 0$. Thus, failure of H_4^* with $g_\delta^* > 0$ implies that farmers with relatively higher yield variability are participating, i.e., Figure 2 applies with the wider distribution representing insured farmers and the narrower distribution representing uninsured farmers. Finally, to consider the specific assumptions employed at the time of data generation for this study, we consider H_6: $\sigma = \alpha\bar{\mu}$ for some constant α. If relative risk is constant ($\sigma = \alpha\mu$) and this the FCIC assessment of mean yields is correct ($\mu = \bar{\mu}$), then H_6 should hold.

After determining that these hypotheses fail, we consider whether additional characteristics for which data are readily available can improve representation of yield expectations and standard deviations (which would suggest opportunity to improve premium determination). Specifically, the regression relationships

(1) $\mu = f(\bar{\mu},\delta,\rho,F,A,I)$

(2) $\sigma = g^*(\bar{\mu},\delta,\rho,F,A,I)$

are thus used to determine how much of the variation in means and standard deviations among farms can be captured with readily available information where F is farm size in acres, A is acreage of the subject crop, and I is the proportion of the subject crop acreage irrigated. For the purpose of these regressions, farm-specific yield expectations and standard deviations are used as the dependent variables. The objective is not to explain farmer insurance choices, but rather to determine the extent to which yield distributions can be predicted by information available to the FCIC. In this respect, the regression analysis should be regarded as a correlation analysis rather than a causal model.

Accuracy of FCIC Insurance Parameters

These regression results and hypothesis tests are reported in Tables 1-4. In each case, the equations are estimated in log-linear form except for the participation and irrigation variables which are not logged for obvious reasons (disturbances are assumed spherical). The regressions are based on 502 observations for corn, 386 observations for soybeans, 91 observations for sorghum, and 359 observations for wheat. Tables 1 and 2 consider how well FCIC assumptions fit the data by means of baseline regressions that do not consider additional characteristics. The regressions in Table 1 examine how well FCIC insurance yields reflect expected yields on individual farms and the extent to which adverse selection occurs because FCIC insurance yields do not reflect expected yields.

The first regression for each crop in Table 1 investigates H_1 and H_2. If the FCIC insurance yield is accurate then the constant term should be zero and the coefficient of the logarithm of FCIC insurance yield should be 1 ($\mu = \bar{\mu}$). If participating farmers do not have relatively lower yields, then the coefficient of the insurance decision should be zero whereas a negative coefficient implies that farmers with relatively lower yields insure. In every case, the constant term is significantly greater than zero and the coefficient of the FCIC yield is significantly less than one.[9] Thus, H_1 is rejected. These results imply that variation in FCIC yields among farmers overestimates the variation in expected yields among farmers. In other words, either farmers with lower FCIC yields tend to have better expected yields or farmers with higher FCIC yields tend to have worse expected yields than reflected by their FCIC insurance yield or both.

The coefficients of insurance participation are insignificant for corn, sorghum, and wheat (Corn 1, Sorghum 1, Wheat 1) suggesting little adverse selection with respect to mean yields (i.e., Figure 1 does not apply). In the case of soybeans (Soybeans 1), however, the coefficient of participation is negative and highly significant suggesting that insuring farmers have relatively lower expected yields. Thus, H_2 is rejected only for soybeans. After correcting for differences in FCIC yields, insuring soybean farmers have expected yields that are 10.4 percent lower than non-insuring farmers (using the coefficient of insurance participation, $e^{-.11} = .896$ implies insured yields are 89.6 percent of non-insured yields). Note also that FCIC yields reflect farmers' expected yields less well for soybeans than the other crops (the coefficient of FCIC yield is less and the constant term is greater). This problem may be due to the fact that ASCS yields are not kept for soybeans. Corn ASCS yields are multiplied by an adjustment factor to calculate soybean APH yields for farmers without adequate production histories.

The second regression for each crop in Table 1 investigates H_3. Again, the hypothesis that participation makes no difference is rejected only for soybeans. However, the estimated coefficients on the insurance premium variable are interesting. For sorghum (Sorghum 2), these results imply that the premium does not compensate for errors in FCIC insurance yields because higher premiums are associated with higher relative yield expectations. For each of the other crops (Corn 2, Soybeans 2, Wheat 2), premiums compensate for errors in FCIC insurance yields significantly (with the right sign so that a lower relative yield is associated with a higher premium). However, premiums do no not capture much of the errors in FCIC insurance yields. The estimated coefficients of both the constant term and the FCIC yield are almost identical to results where the premium is not included and the R^2 statistics for the second regression are almost the same as the first regression, respectively.

The third regression for each crop in Table 1 gives another perspective on H_1. By eliminating the constant term, this regression investigates whether FCIC insurance yields tend to be high or low on average. The estimates for insurance participation and premium are similar to the unconstrained case but, as expected, the estimated coefficient of FCIC yield is near 1. However, for corn, soybeans, and wheat (Corn 3, Soybeans 3, Wheat 3), the coefficient is significantly greater than 1 again implying rejection of H_1. This difference can be explained by the fact that FCIC yields tend to lag behind actual yields. That is, yields tend to increase over time due to technological advances but APH yields used by the FCIC are generally 10-year moving averages of past yields (except when histories are inadequate in which case as few as 4 past years may be averaged). Again, the insurance participation variable is significant only for soybeans. The interesting result in these regressions is that lower relative expected yields are not associated with higher insurance premiums for corn, soybeans, and sorghum (Corn 3, Soybeans 3, Sorghum 3). This effect is significant for soybeans and necessarily implies an adverse selection problem because lower expected yields tend to be associated with both participation and lower premiums.

The results in Table 2 investigate hypotheses H_4^*, H_5^*, and H_6. If constant relative risk holds under H_6, then the regressions in Table 2 should have a non-zero constant term, the coefficient of the logarithm of FCIC insurance yield should be 1, and other coefficients would be zero ($\ln \sigma = \ln \alpha + \ln \bar{\mu}$). Alternatively, if the assumption of constant absolute risk holds, the coefficient on FCIC insurance yield should be zero. The results of the first regression for each crop in Table 2 show that farmers' standard deviations increase significantly with FCIC yields but significantly less that proportionally. If FCIC premiums account for differences in relative risk among regions, then the premium in the second regression for each crop in Table 2 would also have a non-zero coefficient but the coefficient of the logarithm of FCIC insurance yield should still be 1. Obviously, this is also not the case so H_6 is rejected.

Turning to the hypothesis H_4^*, the estimated participation coefficients in the first regression for each crop in Table 2 show that farmers with higher yield standard deviations are participating in crop insurance. Standard deviations among insuring farmers are significantly higher for corn, sorghum, and wheat at the 5 percent significance level (Corn 1, Sorghum 1, Wheat 1). The second regression for each crop in Table 2 considers H_5^* which adds insurance premiums as a regressor. These results are again similar to the case where premiums are not considered indicating that insurers have significantly higher risk for corn, sorghum, and wheat (Corn 2, Sorghum 2, Wheat 2). These results show that insuring farmers for these crops have higher standard deviations after accounting for all farm-specific FCIC insurance parameters (FCIC yield and premium). Thus, both H_4^* and H_5^* is rejected for all crops except soybeans.

As in Table 1, a striking result from Table 2 is that little of the unexplained variation is captured by adding insurance premiums to the regressions. These results imply that the initial FCIC assumption of constant relative risk is poor and that the attempt to adjust for non-constant relative risk with different insurance rates has not been successful. More importantly, the explanation of standard deviations by either regression is very low indicating that FCIC yields are a very poor proxy for risk. The R^2 statistics are all below .25. The very low explanation of standard deviations among farms in Table 2 is not surprising given the lack of attention by FCIC to assessing farm-specific yield variability. For example, better reflection of farm-specific variability might be expected if approved production histories were used to assess yield variability. These results are suggestive of a poor correlation between yield expectations and risk. Alternatively, perhaps specific consideration of the characteristics that determine distinct mean and variance effects will be necessary to capture variation in both.

Potential Distinct Mean and Standard Deviation Effects of Farm Characteristics

Tables 3 and 4 examine the potential for improving FCIC predictions of yield expectations and standard deviations using readily available data on farm characteristics. The first half of Table 3 considers the additional contribution of irrigation, farm size, and crop acreage to explaining farm-specific expected yields. The expected yield regressions in Table 3 reveal that the effects of these additional variables are largely as expected.[10] Regressions in the first half of Table 3 (Corn 1 and Sorghum 1) show that irrigation explains a significant part of the difference in expected yields and FCIC insurance yields for corn and sorghum (at the 10 percent one-sided sense in the latter case). Farm size explains a significant part of the difference for corn and wheat (Corn 1 and Wheat 1). Acreage of the insured crop explains a significant part of the difference for wheat (Wheat 1). These results suggest that statistically significant improvements can be made by tailoring FCIC insurance yields to more farm-specific characteristics. Furthermore, these additional characteristics are readily observable and do not require heavy information gathering costs.

The second half of Table 3 examines the extent to which variations in expected yields may have already been picked up in adjustments of insurance premiums to loss experience. Adding premiums to the regressions reveals that a significant part of the variation in expected yields among farms is corrected by local premium rates for all crops except sorghum (see the t-ratios of insurance premium). Farms with higher premiums tend to be farms with lower expected yields and thus higher expected indemnities, other things equal (Corn 2, Soybeans 2, Wheat 2). However, accounting for the additional variation explained by premiums does not appreciably reduce and in most cases increases the significance of adding irrigation, farm size, and crop acreage. Thus, an important part of the variation explained by these additional characteristics appears to escape current FCIC rate-making procedures.

Table 3 also implies, however, that most of the explained variation in expected yields among farms is captured by FCIC insurance yields. The t-ratios in Table 3 for FCIC insurance yield are all over 7. Furthermore, the adjusted R^2 statistics in Table 3 are not much higher than for the expected yield regressions in Table 1. Thus, accounting for readily observable farm characteristics may not be sufficient to reduce the adverse selection due to errors in FCIC insurance yields very much. From Table 3, about 40 percent or more of the variation in expected yields among farms is not captured by current FCIC insurance parameters even when improved by using the addition characteristics considered here. These results suggests that adverse selection will continue to be a serious problem for offerings of multiple peril crop insurance unless data bases on farm-specific characteristics are greatly enhanced beyond what is considered here. If better tailoring of the terms requires data that is not readily observable, then the additional costs of collecting the data must be weighed against the benefits of reducing adverse selection.

It may be surprising to some that expected yields are not well reflected in FCIC insurance yields given that the FCIC requires keeping farm-specific approved production histories upon which FCIC insurance yields are based. Several points are noteworthy here. First, if a farmer does not participate for a few years, then the farm's approved production history can get out of line with expected yields because of secular increases in yield levels. Second, when a sufficient farm-specific production history does not exist, county ASCS yields are used to establish FCIC insurance yields. Average yields vary considerably among farmers in the same county because of land quality, managerial ability, and production practices, so such approaches may be inaccurate. Non-participating farmers with relatively high average yields may never have incentive to participate and accumulate sufficient production histories so corrections will not occur. If these phenomena explain the poor correspondence, then important improvements may be possible by strengthening requirements for production record keeping without necessarily requiring participation.[11]

In effect, uniform requirements for production histories may play the role of a public good that can better facilitate private viability of crop insurance.

Table 4 turns to the potential for using farm-specific characteristics (irrigation, farm size, and crop acreage) to tailor assessments of yield variability to individual farms. Here irrigating farms are expected to have lower relative risk (lower standard deviation of yield for given expected yield) and possibly lower absolute risk because of reduced vulnerability to weather conditions. Larger crop acreage is expected to lead to a lower relative risk because the yield is averaged over a larger (and likely more widely distributed) acreage thus reducing vulnerability to localized weather and pest conditions. The effect of farm size (for a given acreage of the insured crop) is expected to be positive if it reflects less specialization and therefore less experience with the insured crop. The significant results in Table 4 are all consistent with these explanations although few coefficients are statistically significant.

The first half of Table 4 examines the potential contribution of these additional characteristics after considering the explanation provided by FCIC insurance terms (the insurance yield and the premium) and the affect of insurance participation. The second half of the table considers similar possibilities that would be possible if the FCIC insurance yield correctly reflected differences in expected yields across farms. The first set of results reveal that farm size increases explanation significantly for wheat (Wheat 1) and corn (Corn 1) at a 10 percent one-sided significance level in the latter case, and crop acreage increases explanation significantly for wheat (Wheat 1). The second set of results show that much of the benefit of using farm size and crop acreage would be lost if expected yields could be measured more effectively. The irrigation effect on corn (Corn 2), however, becomes more significant against the lower unexplained variation of the second case.[12]

Turning to the R^2 statistics of Table 4, however, it is apparent that very little of the variation in standard deviations of yield among farms can be explained even adding the additional farm characteristics. None of the adjusted R^2 statistics exceeds .25 implying no more than 25 percent explanation. The adjusted R^2 statistics are considerably higher in the last half of Table 4 suggesting that assessment of yield variability could be significantly improved if assessments of expected yields could be improved. These results suggest that adverse selection due to risk is the major obstacle for multiple peril crop insurance. Over 75 percent of the variation in risk among farms is not taken into account by current FCIC methods. Even if FCIC insurance yields are improved to correctly reflect expected yields, over 55 percent of the differences in yield variability among farms cannot be taken into account with information investigated here. The results here imply that farmers will continue to have large differences in benefits from insurance that are not well reflected in premiums.

Finally, a comparison of estimated coefficients for irrigation, farm size, and crop acreage between Tables 3 and 4 is useful as a reflection on FCIC assumptions of rigid relationships between yield expectation and standard deviation. Under constant relative risk, the respective coefficients in Tables 3 and 4 should be identical (with log-linear specifications, identical coefficients imply identical percentage effects), whereas under constant absolute risk the coefficients in Table 4 should be zero even if the corresponding coefficients in Table 3 are not. Several characteristics appear to be risk neutral for several crops. For example, all three characteristics have insignificant coefficients in both regressions for soybeans and sorghum in Table 4 even though some corresponding coefficients in Table 3 are significant thus suggesting constant absolute risk effects. However, each of the characteristics have significant coefficients in at least one case in Table 4 for corn or wheat so constant absolute risk does not appear to hold uniformly. Comparing Tables 3 and 4, one finds little significant difference between coefficients for farm size and crop acreage using the first specification in Table 4 (test statistics not shown). This is consistent with intuition whereby farm size tends to increase both mean and standard deviation and crop acreage tends to reduce both.[13] However, intuition suggests that irrigation increases expected yield while increasing standard deviation less or even reducing it. Corn is a case in point. Testing the hypothesis that the irrigation coefficient for corn is the same between Tables 3 and 4 (using either specification for each Table) reveals a significant difference with t-ratios in the range of 1.93 to 3.40 (with 990 or 991 degrees of freedom) depending on specification. These various results thus imply that different characteristics have distinct effects on yield expectation and standard deviation. Whether the relationship between expected yield and yield standard deviation follows constant relative risk, constant absolute risk or some other relationship depends on which characteristics are varying. These results thus cast doubt on the ability of any simply relationship between yield expectation and yield standard deviation (such as those employed by the FCIC to proxy risk) to capture risk variation.

The Distribution of Indemnities

As a final step, we consider how well farm-specific FCIC parameters reflect the distribution of indemnities faced by individual farmers. While the foregoing analysis attempts to decompose potential adverse selection problems according to the frameworks of Figures 1 and 2, it is possible that some errors are offsetting. For this analysis, we replace the dependent variables of yield expectation and standard deviation with indemnity likelihood and expectation. The latter relationship is the most crucial in examining the adverse selection problem because adverse selection cannot occur when premiums are equal to expected indemnities for all farmers. Note that the expected indemnity is the actuarially fair premium. It is the premium level that makes a risk-neutral farmer indifferent to participation.

To investigate how well FCIC parameters reflect expected indemnities, data on expected indemnities must be constructed. Given normality of yields, the expected indemnity payment can be calculated as follows. Using results from Johnson and Kotz (pp. 81-83) where $y \sim N(\mu, \sigma^2)$, one finds

$$E(y|y \le \beta\bar{\mu}) = \mu - \frac{Z}{\Phi}\sigma$$

where

$$z = \frac{\beta\bar{\mu} - \mu}{\sigma}, \quad Z = (2\pi)^{-1/2} e^{-z^2/2}, \quad \Phi = \int_{-\infty}^{z} (2\pi)^{-1/2} e^{-x^2/2}\, dx.$$

Thus, noting that $\Phi = \Pr(y \le \beta\bar{\mu})$ is the probability of indemnity (elicited in the sample), the expected indemnity can be calculated as

$$E(I) = p_\alpha\Phi[\beta\bar{\mu} - E(y|y \le \beta\bar{\mu})] = (\beta\bar{\mu} - \mu)\Phi p_\alpha + Z\sigma p_\alpha$$

where p_α is the insured price selected by the farmer. For the regressions reported here, we use the probability of indemnitiy and expected indemnity at the 65 percent yield level and highest available insured price level. This contract accounts for almost two-thirds of the purchased insurance contracts in the data.

Table 5 presents regressions of Φ and E(I) on the same variables as included in Table 4 regressions. The question addressed by these regressions is how well can the FCIC approximate the variation in indemnity probability and expectation among farmers using available information. These dependent variables summarize the joint effects of errors in assessments of yield expectations and standard deviations in terms of how they affect the actual benefits received by farmers.

Again, the insurance participation coefficient demonstrate adverse selection because insurers receive higher benefits after accounting for differences in premiums. The effect on the probability of indemnity is significant for corn, soybeans, and wheat (10 percent level in the latter case), and the effect on the expected indemnity is significant for corn and sorghum (10 percent level in the latter case).

The estimated coefficients of insurance premium and FCIC yield are interesting because they indicate the extent to which farmer benefits of insurance are explained by variation of FCIC insurance policy parameters among farmers. Ideally, this explanation should be complete. For example, if the actual premiums were actuarially fair, then the coefficient of the insurance premium in the second half of Table 5 should be 1 and all other coefficients should be zero. The F-statistics that test for actuarially fair insurance premiums are 11.4 for corn, 20.1 for soybeans, 14.2 for sorghum, and 6.5 for wheat all of which are significant well beyond the .005 level. Thus, FCIC insurance premiums are statistically far from actuarially fair. More importantly, the low R^2 statistics in Table 5 imply that the benefits of crop insurance cannot be well explained by FCIC insurance policy parameters nor by additional readily observable characteristics. None of the adjusted R^2 statistics are above 35 percent and most are below 10 percent.

Conclusions

This paper examines the relationship FCIC insurance parameters to the yield distributions of individual farms. The data suggest a poor relationship which gives rise to a considerable degree of adverse selection. This adverse selection is largely related to a poor assessment of farm-specific risks implicit in FCIC premium structures (except for soybeans). Rigid relationships implicit in FCIC methods which proxy yield standard deviations by yield expectations do not hold and cannot be expected to hold because different characteristics with distinct risk effects vary among farms. Apparently, FCIC attempts to correct for heterogeneity of risk by varying insurance premiums by county on the basis of loss experience have done little to correct the problem. Regression results show that these premium variations do not account adequately for differences among farms. A statistically better correspondence of premiums to farm risks and insurance benefits is achieved by better tailoring premiums to farm size, crop acreage and irrigation.

However, only an additional 2 to 7 percent of the variation of expected yields and standard deviations among farms is captured by these additional characteristics whereas over 40 percent of the variation in average yields and over 75 percent of the variation of standard deviations among farms remains unexplained. Thus, the parameters of FCIC insurance policies as well as additional observable farm characteristics explain relatively little of the variation of expected insurance benefits among farmers—less than 10 percent for most crops and less than 35 percent for all crops. Apparently, adverse selection will continue to be a serious problem for multiple peril crop insurance unless the set of characteristics used to tailor policy parameters to individual farms is significantly improved—improved not only beyond what is currently used but beyond what is currently available in public data bases. Alternatively, insurance indemnities triggered by area yields may be necessary to address the problem of adverse selection in multiple peril crop insurance. It is noteworthy, however, that the FCIC has not yet tried to assess directly the variability of individual farm yields on the basis of approved production histories. A history of 10 years' average yields, if used to assess variability directly rather than indirectly through an assumed relationship between yield expectations and yield standard deviations, may allow a much better reflection of farm-specific standard deviations than captured in regression results here. Perhaps greater private viability of crop insurance is possible through a combination of this approach to risk assessment with rates set accordingly, and more uniform requirements for recording production histories among non-participating farms as well as participating farms. Given that farm-specific assessment of risk appears to be the major problem motivating adverse selection, this approach deserves attention.

Footnotes

1 Beginning with the 1990 Farm Bill, the FCIC began to adjust premiums by farm-specific loss experience but this approach takes time to adjust and adjustment does not occur for uninsured farms.

2 At the time of the survey analyzed here, only two or three price levels were available. With the 1990 Farm Bill, a range of insured price choices became available depending on the insured yield level.

3 The APH yield is a ten-year moving average of actual yields on the farm if records are available but can be as short as a four-year average. If fewer that four years of records are available, an FCIC insurance yield is assigned usually on the basis of the farm or county Agricultural Stabilization and Conservation Service (ASCS) yield.

4 To implement this assumption, the FCIC adopted a system of 9 rate levels corresponding to 9 ranges of APH yield levels.

5 Partially in response to this type of work, the FCIC has more recently begun to use a specific increasing-absolute/decreasing-relative risk formula where the rate varies with $(\mu_i/\mu_c)^{-1.5}$ plus another term reflecting local loss experience where μ_i represents the individual farm APH and μ_c represents the county FCIC yield. While this approach moves away from constant relative risk, it is just as rigid and therefore unable to capture the wide variety of effects that different characteristics may have on the relationship of mean and standard deviation of yield.

6 Moral hazard can also be represented as in Figures 1 and 2. For example, if a farmer reduces input use when insured, then the yield distribution shifts left increasing the probability of an indemnity just as represented in Figure 1. If fewer risk-reducing inputs are used when insured, then the spread of the yield distribution increases as illustrated in Figure 2. The crucial distinction is whether these differences are due to inherent characteristics of farm(er)s or a change in behavior in the event of insurance. Hopefully, for reasons discussed above, only inherent effects of characteristics are measured here.

7 Specifically, farmer expected yields and probabilities of various yield outcomes were obtained by survey following the 1988 crop insurance year. They were obtained as a description of the yield

distribution for 1989 (before 1989 crop insurance decisions and weather information). This may bias the results slightly due to technological change but should remove effects of moral-hazard-related behavior. We recognize that some may be skeptical of farmers' ability to estimate yields at particular probabilities. However, this is exactly what is required for a farmer assessing the potential of receiving an indemnity, and such an assessment is surely a crucial step in deciding whether to buy crop insurance. A complete discussion of these matters or of the specific wording of the instructions and questions is too lengthy to include here. Suffice it to say that NASS officials spent months crafting the wording of these questions using the latest information and experience to elicit the best information possible. Questions were prefaced by considerable instructions on describing chances so implied probabilities would not be misinterpreted.

8 A substantial number of observations had to be dropped from the data. Usable telephone responses could not be obtained for 27.4 percent of the sample, discrepancies in insurance data resulted in a loss of 8.1 percent of the sample, and an inability by NASS to identify corresponding FCIC records resulted in loss of an additional 9.6 percent of the sample.

9 Because the insurance participation coefficient is highly insignificant for 3 of the 4 crops in Table 1, it is not necessary to report separate regressions investigating H_1 and H_2.

10 Because of concerns of joint endogeneity of some of the regressors, Spencer and Berk endogeneity tests were performed to verify correct specification. Specifically, joint endogeneity of the insurance decision and crop acreage with the dependent variables of Tables 1-4 was tested. These tests were generally supportive of the specifications. For example, in the case of corn, of the eight endogeneity tests of the insurance decision and crop acreage (considered separately) with each of the four corn regression equations in Tables 3 and 4, only one was significant beyond the 35 percent level. For grain sorghum, only 1 of 8 tests was significant at standard significance levels. Tests for joint endogeneity of the standard deviation of yield with insurance participation and crop acreage were not significant for any of the crops. For soybeans and wheat, several of the tests for joint endogeneity of expected yield with insurance participation and crop acreage were significant (mostly just beyond the 10 percent level for wheat and just

beyond the 5 percent level for soybeans). For soybeans and wheat, the equations in Table 3 were rerun using instrumental variables for insurance participation and crop acreage. These results were similar with respect to estimates of exogenous variable coefficients. The major difference compared to results in Table 3 was that the estimated coefficient for insurance participation in wheat became negative and significant suggesting adverse selection. Because of similarities to Table 3, the results are not presented here.

[11] A more illusive problem is that farmers with both good and poor land can rotate two crops raising each on good land when uninsured and on poor land when insured. Thus, the APH yield for both crops will inappropriately reflect, in part, good land quality even though an insured crop is never grown on good land. This phenomena could be responsible for some of the poor correspondence between expected yields and FCIC insurance yields observed here. Addressing this problem may be impractical because it requires monitoring intra-farm (plot-specific) characteristics.

The distinction between adverse selection and moral hazard can be subtle when a farmer has multiple land qualities. If a farmer rotates crops for agronomic reasons, then insuring only poor land is a problem of adverse selection. On the other hand, if a farmer rearranges cropping patterns so as to use only poor land when insuring, then the problem becomes one of moral hazard because less productive inputs are used as a result of having insurance.

[12] Some of the crops have positive estimated coefficients on irrigation in Table 4 suggesting that irrigation increases the standard deviation. While these results appear to run counter to the intuition which characterizes irrigation as a risk-reducing input, note that all such results are insignificant. Furthermore, it is plausible that irrigation simply reduces relative risk rather than absolute risk. In this case, the logarithm of mean increases by more with irrigation than the logarithm of standard deviation. Comparing Tables 3 and 4, this condition is satisfied for every crop except wheat.

[13] Significant differences for both farm size and crop acreage are found when comparing results in Table 3 with the second specification in Table 4. Farm size has a significant relative risk reducing effect for both corn and wheat, and crop acreage has a significant relative risk increasing effect for wheat.

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Table 1. Regressions Reflecting Applicability of FCIC Mean Yield Assumptions

Crop/ Regression	Constant	FCIC Yield*	Insurance Participation	Insurance Premium*	R^2 ($\bar{R}^2$)
Corn 1	1.76	0.65	-0.004	[b]	.463
	(12.23)	(20.69)	(-0.17)		(.460)
Corn 2	1.98	0.63	-0.01	-0.09	.478
	(12.93)	(19.83)	(-0.37)	(-3.83)	(.475)
Corn 3		1.03	-0.02	0.02	.303
		(146.97)	(-0.60)	(0.86)	(.300)
Soybeans 1	2.65	0.29	-0.11		.228
	(28.15)	(10.23)	(-3.81)		(.224)
Soybeans 2	2.89	0.26	-0.12	-.14	.303
	(29.81)	(9.58)	(-4.26)	(-6.43)	(.298)
Soybeans 3		1.05	-0.14	0.11	-1.317
		(81.32)	(-2.64)	(2.95)	(-1.329)
Sorghum 1	1.09	0.79	0.09		.585
	(3.86)	(11.07)	(0.83)		(.576)
Sorghum 2	1.05	0.77	0.10	0.05	.586
	(3.52)	(10.96)	(0.85)	(0.40)	(.572)
Sorghum 3		0.99	0.10	0.18	.527
		(33.72)	(0.83)	(1.50)	(.516)
Wheat 1	0.56	0.87	0.001		.519
	(3.37)	(19.26)	(0.02)		(.516)
Wheat 2	0.65	0.87	0.02	-0.11	.530
	(3.88)	(19.38)	(0.35)	(-3.00)	(.526)
Wheat 3		1.04	0.05	-0.08	.511
		(130.14)	(1.09)	(-2.31)	(.508)

[a] The dependent variable is the logarithm of expected yield. Numbers in parentheses are t-ratios except in the case of R^2 where it is the adjusted R^2. An asterisk (*) denotes logarithmic specifications.

[b] Blanks indicate no coefficient estimated.

Table 2. Regressions Reflecting Applicability of FCIC Yield Variance Assumptions[a]

Crop/ Regression	Constant	FCIC Yield*	Insurance Participation	Insurance Premium*	R^2 ($\bar{R}^2$)
Corn 1	1.51	0.45	0.18	[b]	.121
	(5.37)	(7.32)	(3.33)		(.117)
Corn 2	1.82	0.42	0.17	-0.13	.134
	(6.07)	(6.68)	(3.20)	(-2.82)	(.129)
Soybeans 1	1.56	0.27	-0.01		.064
	(8.78)	(5.11)	(-0.21)		(.059)
Soybeans 2	1.66	0.26	-0.02	-0.06	.069
	(8.65)	(4.82)	(-0.27)	(-1.38)	(.061)
Sorghum 1	1.16	0.49	0.33		.232
	(2.75)	(4.70)	(1.89)		(.214)
Sorghum 2	0.97	0.48	0.34	0.25	.249
	(2.18)	(4.61)	(2.00)	(1.41)	(.223)
Wheat 1	0.04	0.70	0.12		.197
	(0.16)	(9.33)	(1.71)		(.192)
Wheat 2	0.09	0.69	0.13	-0.05	.199
	(0.32)	(9.30)	(1.80)	(-0.91)	(.192)

[a] The dependent variable is the logarithm of farmers' standard deviations of yield. Numbers in parentheses are t-ratios except in the case of R^2 where it is the adjusted $\bar{R}$. An asterisk (*) denotes logarithmic specifications.

[b] Blanks indicate no coefficient estimated.

Table 3. Adverse Selection due to Expected Yield[a]

Crop/ Regression	Constant	Insurance Participation	Insurance Premium*	FCIC Yield*	Irrigation	Farm Size*	Crop Acreage*	R^2 ($\bar{R}^2$)
Corn 1	1.69	-.035	[b]	.614	.065	.046	-.003	.517
	(11.32)	(-1.31)		(18.94)	(2.57)	(3.27)	(-.21)	(.512)
Soybeans 1	2.59	-.117		.292	.061	.026	-.019	.238
	(23.74)	(-3.92)		(10.24)	(1.30)	(1.39)	(-1.11)	(.227)
Sorghum 1	1.36	.111		.698	.126	-.017	-.018	.600
	(3.03)	(0.96)		(8.28)	(1.53)	(-.36)	(-0.49)	(.576)
Wheat 1	.69	.058		.824	-.023	.084	-.099	.568
	(3.65)	(1.34)		(17.45)	(-0.53)	(4.36)	(-6.01)	(.562)
Corn 2	1.93	-.038	-.098	.593	.088	.052	-.015	.535
	(12.31)	(-1.46)	(-4.33)	(18.42)	(3.50)	(3.74)	(-1.03)	(.529)
Soybeans 2	2.83	-.124	-.140	.262	.027	.032	-.027	.311
	(25.60)	(-4.34)	(-6.37)	(9.49)	(0.60)	(1.80)	(-1.62)	(.300)
Sorghum 2	1.28	.127	.147	.673	.159	-.013	.018	.606
	(2.83)	(1.09)	(1.16)	(7.75)	(1.83)	(-0.28)	(0.49)	(.578)
Wheat 2	.72	.057	-.064	.818	-.004	.085	-.095	.571
	(3.80)	(1.32)	(-1.64)	(17.34)	(-0.10)	(4.46)	(-5.68)	(.564)

[a] The dependent variable is the logarithm of expected yield. Numbers in parentheses are t-ratios except in the case of R^2 where it is the adjusted R^2. An asterisk (*) denotes logarithmic specifications.

[b] Blanks indicate no coefficient estimated.

Table 4. Adverse Selection due to Standard Deviation[a]

Crop/ Regression	Constant	Insurance Participation	Insurance Premium*	FCIC Yield*	Expected Yield*	Irrigation	Farm Size*	Crop Acreage*	R^2 ($\bar{R}^2$)
Corn 1	1.63	.162	-.120	.433	[b]	-.047	.041	-.024	.139
	(5.03)	(2.99)	(-2.56)	(6.49)		(-0.90)	(1.41)	(-0.82)	(.129)
Soybeans 1	1.56	-.020	-.059	.262		.036	.041	-.027	.073
	(7.08)	(-0.35)	(-1.34)	(4.77)		(0.40)	(1.14)	(-0.84)	(.058)
Sorghum 1	0.99	.356	.284	.451		.053	.006	.002	.251
	(1.44)	(2.01)	(1.47)	(3.40)		(0.40)	(0.08)	(0.03)	(.197)
Wheat 1	0.48	.183	-.004	.605		.096	.057	-.101	.230
	(1.47)	(2.47)	(-0.06)	(7.50)		(1.22)	(1.75)	(-3.54)	(.217)
Corn 2	-.03	.192	-.040		.784	-.121	.003	-.017	.274
	(-0.08)	(3.84)	(-0.90)		(11.89)	(-2.49)	(0.12)	(-0.64)	(.265)
Soybeans 2	-0.39	.080	.040		.761	.005	.019	-.010	.186
	(-1.14)	(1.48)	(0.92)		(8.85)	(0.06)	(0.56)	(-0.33)	(.173)
Sorghum 2	.10	.270	.183		.678	-.058	.015	-.010	.401
	(0.18)	(1.69)	(1.06)		(5.95)	(-0.51)	(0.23)	(-0.21)	(.358)
Wheat 2	-.35	.145	.052		.818	.077	-.017	-.017	.434
	(-1.44)	(2.31)	(0.90)		(14.27)	(1.19)	(-0.59)	(-0.69)	(.424)

[a] The dependent variable is the logarithm of the standard deviation of yield. Numbers in parentheses are t-ratios except in the case of R^2 where it is the adjusted R^2. An asterisk (*) denotes logarithmic specifications.

[b] Blanks indicate no coefficient estimated.

Table 5. Adverse Selection due to Heterogeneity of Insurance Benefits[a]

Crop	Constant	Insurance Participation	Insurance Premium*	FCIC Yield*	Irrigation	Farm size*	Crop Acreage*	R^2 ($\bar{R}^2$)
Dependent Variable: Indemnity Probability								
Corn	36.23	5.14	-.383	-5.00	-4.77	.97	-.91	.065
	(3.87)	(3.28)	(-0.28)	(-2.59)	(-3.15)	(1.17)	(-1.05)	(.054)
Soybeans	9.66	3.08	2.96	-0.10	1.71	.106	.11	.024
	(1.51)	(1.87)	(2.33)	(-0.06)	(0.66)	(0.10)	(0.11)	(.009)
Sorghum	49.73	5.55	4.55	-9.19	-2.59	.30	-.18	.165
	(2.67)	(1.16)	(0.87)	(-2.57)	(-0.72)	(0.15)	(-0.12)	(.106)
Wheat	40.87	2.89	2.76	-6.44	1.42	-.65	-.54	.057
	(5.23)	(1.61)	(1.72)	(-3.31)	(0.75)	(-0.82)	(-0.78)	(.040)
Dependent Variable: Expected Indemnity								
Corn	-2.51	3.08	-0.06	2.27	-1.05	-0.65	-0.03	.062
	(-0.54)	(3.95)	(-0.33)	(2.37)	(-1.39)	(-1.57)	(-0.07)	(.051)
Soybeans	-40.64	1.08	2.98	10.92	1.46	-0.34	0.18	.343
	(-9.64)	(1.02)	(12.09)	(10.42)	(0.89)	(-0.51)	(0.30)	(.333)
Sorghum	-8.70	2.52	0.24	2.51	-1.77	0.58	-0.34	.070
	(-1.16)	(1.30)	(0.31)	(1.72)	(-1.22)	(0.73)	(-0.57)	(.003)
Wheat	-1.99	0.41	0.64	1.75	1.64	-0.87	0.51	.095
	(-0.67)	(0.60)	(2.38)	(2.39)	(2.26)	(-2.94)	(1.97)	(.079)

[a] The dependent variables are, respectively, the probability of an indemnity multiplied by 100 and the expected indemnity when insured at the 65 percent level and middle price level. Numbers in parentheses are t-ratios except in the case of R^2 where it is the adjusted R^2. An asterisk (*) denotes logarithmic specifications except in the case of insurance premium which is logged only in the indemnity probability regressions.

June 16, 1995

Professor Ted C. Shroeder
Department of Agricultural Economics
Walters Hall
Kansas State University
Manhattan, Kansas 66506-4011

Dear Professor Shroeder:

Enclosed you will find three copies of a revision of manuscript 650, "Adverse Selection in U.S. Crop Insurance: The Relationship of Farm Characteristics to Expected Indemnities," which we are resubmitting for publication in the *Review of Agricultural Economics*.

We have revised the paper in response to your comments and those of the referees. We have detailed our responses in the various enclosures. We hope you now find the paper acceptable for publication.

Thank you in advance for your further consideration.

Sincerely,

Richard E. Just
Distinguished University Professor and Chair

Responses to Comments of the Editor on Ms. 650
"Adverse Selection in U.S. Crop Insurance:
The Relationship of Farm Characteristics to Expected Indemnities"

1. Writing style: The paper has been extensively rewritten following the reviewer comments. The introduction is clear from the first paragraph about the objectives of the paper and on the delineation of moral hazard and adverse selection issues. The two sections entitled "Farm Characteristics and Adverse Selection" and "Measurement of Adverse Selection" have been rewritten and reordered in response to reviewer comments. Much of the qualifying and explanatory material that had been placed late in the paper is now included earlier following reviewer comments. (Some of this material responded to reviewer comments but much later in the paper than where the questions arose.) We now lay out the methodology and develop the models before presenting results. Here we were perhaps trying too hard to be brief in the presentation.

2. Regression equations: Regressions are now labeled in the tables and referenced in the text. A new section has been added to clearly lay out the specific hypotheses to be tested in advance which also indicates how each equation was specified. Most of the tests are direct tests of whether the FCIC is capturing what needs to be captured in insurance rate making in order to avoid adverse selection generally. As the section defining hypotheses now develops clearly, we look for adverse selection in two stages. First, we show that participants have lower expected yields or higher risk. Then we show that these factors which cause greater indemnity expectations are not paid for with higher premiums. We also now indicate that our major objectives rather than showing adverse selection is (i) to investigate how well farm-specific yield distributions are captured by farm-specific FCIC insurance parameters and (ii) to investigate the potential of using readily available data on farm characteristics to better match premiums to expected indemnities. Adverse selection is shown as a by-product.

3. Literature review and insurance contract definition: Additional references are now added including some which use farm-specific data (but are restricted to localized areas). We also discuss the references and issues raised by Reviewer 4 in his comment 8. The problem with insurance contract definition is one of timing. The confusion here is that the previous manuscript described the crop insurance contract in force at the time the data were generated, i.e., gave only the information relevant to interpreting the data. Reviewer 4 describes only the crop insurance contract as it is today. We now give a more general statement of the crop insurance contract and indicate recent changes in footnotes. We indicate the greater flexibility in insured price that has subsequently become available and make clear that the limited choice of price options was in effect at the time the data were generated. This does not reduce the applicability of the results but simplifies the analysis necessary because only a few price options need be considered.

4. Moral hazard versus adverse selection: Because Reviewer 4 comments suggest that the delineation of moral hazard from adverse selection must occur early in the paper, we have now addressed the moral hazard issue in the introduction. This allows us to clearly delineate the problem upon which we focus in the paper and indicate how we isolate adverse selection from moral hazard effects. We separate adverse selection from moral hazard based on the farmer specific yield distributions which are obtained independent of the crop insurance year of the sample. Specifically, farmer expected yields and probabilities of various yield outcomes were obtained by survey following the 1988 crop insurance year as a description of the yield distribution for 1989 (before 1989 crop

insurance decisions). This may build in a slight amount of yield inflation associated with technological change but hopefully removes moral hazard considerations. Thus, a comparison of FCIC parameters to farmer yield distributions gives a clear indication of the asymmetry of information associated with adverse selection whereas a comparison of actual yields with the farmer yield distributions would reflect moral-hazard-related behavior. While some bias could conceivably occur in this delineation, the reader can evaluate the results accordingly. We now also indicate in the introduction that the ability to overcome adverse selection depends on better correlating expected indemnities with premiums (upon which we focus) whereas the ability to overcome moral hazard depends on monitoring or other structuring of the contingency which is a much different problem. The part of this information which relates specifically to how the questions were asked in included in a footnote. We are also more careful throughout the paper in identifying when adverse selection "can" occur as opposed to when it "does" occur.

Responses to Comments of Referee 2 on Ms. 650 "Adverse Selection in U.S. Crop Insurance: The Relationship of Farm Characteristics to Expected Indemnities"

1. The introduction has been rewritten to focus only on the second objective you suggest. We now state the objectives of the paper in the first paragraph before any review of the literature. We clearly cast this objective in terms of improving the relationship of expected indemnities to premiums (potential adverse selection) which is clearly related to the regression specifications used later. The specific characteristics we investigate are clearly mentioned.

2. Pages 2-8 were significantly reduced in a number of ways. However, to provide the clarification and move some material from later in the paper to earlier in the paper as required by another referee, the section again grew to about its previous size.

3. Because the other referee's comments suggest that the delineation of moral hazard from adverse selection must occur much earlier in the paper, we have now moved part of the moral hazard footnote you reference into the introduction. This allows us to clearly delineate the problem upon which we focus in the paper. We then indicate how we isolate adverse selection from moral hazard effects. While some bias could conceivably occur in this delineation, the reader can evaluate the results accordingly. Further details are given later when we discuss the specific survey questions in a footnote. We are not aware of research that identifies how much of the problem is moral hazard versus adverse selection. However, as we now try to motivate in the introduction, the ability to overcome adverse selection depends on better correlating expected indemnities with premiums (upon which we focus). The ability to overcome moral hazard depends on monitoring or other structuring of the contingency which is a much different problem.

4. The objective is now stated this plainly in the introduction of the paper. This suggestion makes the focus of the paper much sharper.

5. These two sections have been rewritten and reordered in response to your comments. The confusing paragraph has been completely rewritten. Indeed, one of the major questions of the paper is similar to asking whether premiums are actuarially fair. We answer this question directly in the last section but decompose the problem by mean and standard deviation effects earlier. We now emphasize a clear objective from the introduction through to the conclusions. Reference to the regressions is delayed.

6. The bottom of page 8 was reduced to a small footnote.

7. We have now revised this paragraph so it simply describes the data available rather than how it was used. How is was used for standard deviation estimation is left solely to the next section.

8. It is important to bear in mind that we are not trying to explain farmer behavior and insurance choices but rather to determine how well the FCIC can do in predicting farmer yield distributions and expected indemnities with the available information they have. For this purpose, farm-specific yield expectations and standard deviations are used as the dependent variables because this is what the FCIC needs to explain. We agree that the regression analysis should be regarded as a correlation analysis rather than a causal model. It would not become a causal model unless the

FCIC chose to adopt the prediction equations. When the dependent variable becomes expected indemnities, this regression gives direct information on whether various factors are sufficiently reflected in premiums. These considerations are now discussed in a section that clearly defines the hypotheses to be tested.

9. In reality, it is not surprising that irrigation increases the standard deviation because it increases mean yield by much more. Standard intuition that irrigation is risk reducing is still appropriate in the sense that the coefficient of variation is reduced by irrigation implying that the risk premium declines for a decision maker with constant relative risk aversion. We now add some discussion of this interpretation.

10. We have now added discussion about how the FCIC assumed constant relative risk in setting premium rates at the time of this sample as well as how this assumption has been changed subsequently. We also point out how different farm characteristics can have different risk implications (e.g., some may be risk increasing while others are risk reducing) just as production inputs can be either risk increasing or risk reducing. This is an additional motivation for examining the different impacts of farm characteristics on the mean and standard deviation of yields as in Tables 3 and 4.

Responses to Comments of Referee 4 on Ms. 650
"Adverse Selection in U.S. Crop Insurance: The Relationship of Farm Characteristics to Expected Indemnities"

1. We have now rewritten the introduction stating the purpose of the paper in the first paragraph so that all review of literature builds around the purpose of the paper.

2. The literature review is necessarily brief to save space. The literature is too voluminous to include all relevant citations in the 'References' section. Nevertheless, we have added more references to farm-level data studies and to recent results that show adverse selection to be important.

3. The confusion here is that the previous manuscript described the crop insurance contract in force at the time the data were generated, i.e., gave only the information relevant to interpreting the data. We now give a more general statement of the crop insurance contract and indicate recent changes in footnotes. We indicate the greater flexibility in insured price that has subsequently become available and make clear that the limited choice of price options was in effect at the time the data were generated. This does not reduce the applicability of the results but simplifies the analysis necessary because only a few price options need be considered.

4. This paragraph has been restructured so as to eliminate the introductory statement which was not complete.

5. We now open the paragraph with this statement which is more clear and to the point. We are also more careful in identifying when adverse selection "can" occur as opposed to when it "does" occur. The issue of moral hazard is now addressed in the introduction. We attempt to separate adverse selection from moral hazard based on the farmer specific yield distributions which are obtained independent of the crop insurance year of the sample. Specifically, farmer expected yields and probabilities of various yield outcomes were obtained by survey following the 1988 crop insurance year as a description of the yield distribution for 1989 (before 1989 crop insurance decisions). This may build in a slight amount of yield inflation associated with technological change but hopefully removes moral hazard considerations. Thus, a comparison of FCIC parameters to farmer yield distributions gives a clear indication of the asymmetry of information associated with adverse selection whereas a comparison of actual yields with the farmer yield distributions would reflect moral-hazard-related behavior. This information is now included in a footnote.

6. We have reworded this material taking into account your comments.

7. We have reworded this material taking into account your comments.

8. These issues are made much more clear in the revised discussion. References have been added and the problem of asymmetric information which leads some to suggest area-yield insurance has been discussed more fully. A central point of this paper is simply to compare producers' subjective yield distributions with FCIC parameters to see how well FCIC parameters reflect individual farmers' situations. The primary problem is that yield risk is not well captured by FCIC parameters. Note, however, that in making this comparison, the subjective distributions do not unfairly represent FCIC abilities to take into account pre-season weather related events because

the subjective distributions are measured sufficiently far in advance of the growing season. This is now pointed out in a footnote.

9. Apparently, your adverse selection chart is the same as our Figure 2. Your moral hazard chart is a combination of our Figures 1 and 2. We submit that your moral hazard chart could also be used to represent adverse selection and that moral hazard can also be represented as in our Figures 1 and 2. For example, if a farmer reduces input use when insured, then the yield distribution shifts left increasing the probability of an indemnity just as represented in our Figure 1. If fewer risk-reducing inputs are used when insured, then the spread of the yield distribution increases as illustrated in our Figure 2. The crucial distinction is whether these differences between insuring and non-insuring farmers are due to inherent characteristics of farm(er)s or a change in behavior occurring with the event of insurance. Hopefully, for reasons discussed above, only inherent effects of characteristics are measured here. We have added explanation of these considerations in a footnote.

10. Sections have been reordered and rewritten to accommodate this suggestion.

11. Sections have been reordered and rewritten to accommodate this suggestion.

12. We have rewritten these statements in a much clearer way.

13. We now include these three paragraphs earlier as you recommend.

14. We recognize that some may be skeptical of farmers' ability to estimate yields at particular probabilities. However, this is exactly what is required for a farmer assessing the potential of receiving an indemnity, and such an assessment is surely a crucial step in deciding whether to buy crop insurance. A complete discussion of survey reliability or of the specific wording of the instructions and questions is too lengthy to include in the paper. Suffice it to say that NASS officials spent months crafting the wording of these questions using the latest information and experience to elicit the best information possible. Questions were prefaced by considerable instructions on describing chances so implied probabilities would not be misinterpreted. We have now included this discussion in a footnote.

15. We did not eliminate farmers who did not participate. Otherwise we could not include participation variables in Tables 1 through 5. (Presumably you found this out later in the paper.) The discussion at this point in the paper has been greatly modified to prevent future readers from being similarly misled. We included non-participants whether or not they had ever purchased crop insurance. To do this, we used the same procedure as the FCIC would use to determine an insurance yield if no APH were available. Moral hazard could be examined by comparing yield distributions in the event of insurance with those that apply in the event of non-insurance. Given the description of how yield distributions were measured (now in the paper), this is clearly not a comparison that would apply.

16. Regressions are now labeled in the tables and referenced in the text. A new section has been added to clearly lay out the specific hypotheses to be tested which also indicates how each equation was specified. Most of the tests are direct tests of whether the FCIC is capturing what needs to be captured in insurance rate making.

17. Those who purchase insurance are compared to those who do not by means of the participation variable. As the section defining hypotheses now develops clearly, we look for adverse selection in two stages. First, we show that participants have lower expected yields or higher risk. Then we show that these factors which cause greater indemnity expectations are not paid for with higher premiums. We also now indicate that our major objectives rather than showing adverse selection is (I) to investigate how well farm-specific yield distributions are captured by farm-specific FCIC insurance parameters and (ii) to investigate the potential of using readily available data on farm characteristics to better match premiums to expected indemnities. Adverse selection is shown as a by-product.

18. Refer to 16.

19. One of the points of the paper (now made clear) is that higher yields may or may not be associated with higher variability.

20. Refer to 16.

21. This discussion is now much earlier in the paper.

22. For reasons discussed in 5 above, these results are not due to moral hazard except under the unlikely failure of the assumption separating moral hazard and adverse selection effects.

23. We agree that a larger and better data set is (almost) always preferred. However, we submit that if this hypothesis holds within all individual regions, then is must hold across regions after accounting for other differences. These other differences in FCIC methodology are the underlying premium rates which vary among regions and yield levels which vary among farms. Thus, the tests and inferences we draw here are valid. In fact, we suggest that a data set that cuts across regions is needed to investigate the adverse selection problem appropriately. If Montana dryland wheat farmers have a large probability of 50 percent yield losses and a California desert irrigated wheat farmer almost never suffers more than a 15 percent yield loss, then the current program structure causes an adverse selection problem such that the desert farmer will never participate and the Montana farmer will always have a higher indemnity probability/expectation.

24. The revision of the introduction now contains this objective clearly in the first paragraph.

General Comments:

1. The paper is now reorganized, specific objectives are laid out and developed from the very beginning of the paper including more conceptual discussion. Procedures and models are developed more clearly and completely prior to presentation of results. We appreciate your comments and hope you feel the paper has been improved accordingly.

2. The way in which adverse selection is isolated from moral hazard is now clearly laid out beginning from the introduction and explained in detail in the description of the data. The necessary assumptions are identified. The differences in corrective actions for the two problems is mentioned briefly in the introduction. As with any paper, if the assumptions are not applicable, then the results may not apply.

3. Whether the data is sparse is a relative issue. Whether sparse or not, the data used here is the most extensive nationwide, farm-specific data set available for examining these crop insurance issues. We suggest that once the moral hazard issue is addressed and laid aside, then this general comment is of less concern because it is basically related to confusing moral hazard and adverse selection among regions. With respect to the heterogeneity issue, we would strongly argue that this is a major contribution of the paper. One of the biggest issues in crop insurance is how well heterogeneity is captured by parameters of FCIC insurance contracts. To adequately address this issue requires a data set that adequately represents the heterogeneity encountered by the FCIC on a nationwide basis both among regions and within regions.