# FUTURE RESEARCH NEEDS ON FEDERAL MULTIPLE PERIL CROP INSURANCE

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Significant changes have been made in Federal Crop Insurance (FCI) in the last several years. There is good reason to believe that these changes will improve the program. However, there are still reasons for concern. This paper will develop those concerns in the context of previous research and future research needs. The primary focus will be on the pricing (or cost) of crop insurance to individual farmers. Pricing of insurance is critical on two related fronts: 1) the effect of aggregate response on the viability of FCIC, and 2) the farm level price and how it compares to expected indemnity payments. In considering the aggregate response, I shall focus on policy changes and the critical aspect of implementation. The farm level focus will concentrate on farm level rates and their use in prescriptive and predictive models.

## Changes in Federal Crop Insurance

The first federal crop insurance program was developed in 1938. During the next several years the program struggled and was eliminated for a short time. Upon being reintroduced in the mid 1940's, the program became experimental with protection provided on only a few crops in a limited number of counties. The Federal Crop Insurance Act of 1980 made crop insurance a permanent program. Since this act, the number of crops insured has been significantly expanded with FCI available in nearly every county in the U.S. The goal has been to replace low-yield disaster programs with crop insurance. In 1987 if a farmer can purchase FCI he will not be eligible for low-interest emergency loans. The 1985 Farm Bill made disaster payments discretionary for the Secretary of Agriculture. Still, there were payments in 1986 due to the drought in the Southeast. However, the basic message is that farmers will be expected to self-insure in the future and they can do so through FCI.

FCI is offered in two forms 1) as multiple peril insurance that covers a very wide range of unavoidable losses and 2) limited peril insurance which is typically fire and hail insurance. Analyzing that FCI in a multiple peril context means that research can concentrate on the distribution of crop yields. In addition to insuring yield shortfalls, FCI also insures quality for some crops.[1] Although FCI is available on a limited peril basis and for quality adjustments, I shall focus on the multiple peril dimensions and consider the research needs which require a better understanding of the probability distribution for yields.

Among the most significant changes in FCI in recent years has been the move away from protection based on area average yields to a method to provide coverage based on farm-level average yields. I will discuss this in the focus on farm-level rate making below.

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The Crop Insurance Act of 1980 also provided subsidies on premiums in addition to coverage of administrative costs. For most crops, three coverage levels are provided based upon a measure of farm level yield (explained below). The subsidies are 30% for the 50% and 65% coverage levels and roughly 19% for the 75% coverage (thus, the average subsidy is approximately 25%). Given a subsidy of 25% and fully covered administrative cost, the loss ratio for an actuarially sound insurance program should average 1.25. Thus, farmers should make 25 cents for every dollar invested in crop insurance. Still, participation in FCIC remains relatively low (roughly 20% of the eligible acres). I offer some possible reasons for the low participation below.

Another significant change in FCI is the increased role of the private insurance companies in marketing insurance. This move to privatize FCI has been facilitated through reinsurance agreements whereby the government and increasingly, the private financial sector provide the major reserves needed to protect against catastrophic losses. Since crop insurance involves losses across space as well as time, the issue of adequate reserves is critical. Unlike many other insurance plans, crop insurance exposes companies to the risk of major losses within the same period. Crop failures which occur over a wide area can devastate reserves of an insurance company. Thus, private institutions which take this risk would need to have insurance over a very wide area in order to pool risk. Historically, this has been the justification for government involvement in national crop insurance. Under perfect capital markets, these concerns may be mitigated somewhat. However, history has demonstrated that the private sector experience with multi-peril crop insurance has not been good. Once severe losses occur, the private sector typically has abandoned insurance in the area (Krammer). One could expect that private sector insurance would be offered in less counties and for less crops. Thus, in light of the current trends and the intention of the Reagan Administration to privatize FCI, a vital research question involves the ability and willingness of the private sector to take on the risk involved. Research that would provide some indication of how the availability of multi-peril crop insurance would change without government involvement is needed.

In addition to the issues surrounding reinsurance and protection provided by the private sector, the increased role of the private sector in implementation (selling) of FCI has raised some issues. In the move toward individualized protection, the FCIC has stressed the role of farm-level verifiable records as a critical information need. The private sector is responsible for obtaining these records in many cases. It is my impression that the efforts by FCI to obtain reliable records have been thwarted by the private sector. One wonders about an incentive system which involves an insurance commission for selling to a farmer when the salesman can influence the protection provided by accepting questionable records (this can be a problem for public insurance sellers as well). The current program mandates that the information system for farm level records be reliable.

## Moral Hazard

Two problems plague any insurance program: 1) moral hazard and 2) adverse selection (Lereah). A major problem that any insurance program faces is the behavior of the participants after they purchase insurance - -

what is called "moral hazard". Aside from the basic dishonesty that can occur, there are more subtle forms of behavior that may be encouraged by insurance. Clearly, those who chose to practice fraud by filing claims when they are unjustified will increase the cost of insurance for all. Although FCI has taken steps to protect against such behavior, one still hears of farmers who move grain from one farm to another in order to claim a loss and of farmers who alter their input useage in such significant ways that they are nearly assured of collecting on crop insurance. Perceptions of the significance of these problems vary. Given the state of the art in crop growth models it may be possible to devise techniques for identifying extreme outliers within a soil type area given the current year's weather. Techniques that could flag a claim within an area which was a specified number of standard deviations beyond the area mean could prove quite useful to FCIC in identifying farmers who present moral hazard problems.

FCIC has also taken steps to protect against losses that are due to poor farming practices. This is very difficult and expensive to monitor. The more subtle changes that may occur in farming practices are also a potential problem. For example, if a farmer has crop insurance, does this change his pest management program? Are insured farmers slower at preventive spraying that would protect against pests? In short, insurance can change behavior and increase the probability that a farmer will collect. Over time, this cost must be passed along in the form of higher premiums. In order to protect against this behavior, insurance programs become overburdened with legal language and restrictions that become troublesome to the bulk of farmers who are honest. This will continue to be a difficult problem which must be dealt with through legal processes and a better understanding of the subtle behavioral changes that occur when a farmer purchases crop insurance.

In fact, many of the moral hazard problems that exist in crop insurance are inappropriately named. As Pauly argues, insurance does alter the profit maximization environment and there are economic reasons that behavior will change. Of particular interest in today's environment is how farmers who are financially stressed may alter input useage. This combined with commodity programs which provide income enhancement which is invariant with respect to yield (deficiency payments are made on program yields) may encourage financially stressed farmers to reduce cost by reducing inputs. Allow me to demonstrate this through some simple budgets for a farmer who is participating in the 80/20 feedgrain program. Assume that the farmer expects corn price to be $2.00. With a target price of $3.03 he would receive $1.03 on his program yield. I also assume that program yield, expected yield and crop insurance coverage yields are all equal to 100 bushels. Price protection for crop insurance is $2.00. Deficiency payments will equal $103 and other gross receipts are driven by yields. There are two assumed cost for out-of-pocket expenses: 1) regular input use -- $150/acre and 2) cutbacks on input use -- $90/acre. In examining Kentucky corn budgets, it is possible to consider this type of reduction in input cost by elimination of potash and phosphorus fertilizers (which have residual build up in soils) and cutbacks on nitrogen and chemicals. Harvesting cost are adjusted as yield levels change. Possible yield levels with corresponding returns above out-of-pocket costs appear in table 1.

In this example, if the yield distribution with regular input use is normally distributed with a mean of 100 and a standard deviation of 20, then yields with regular input use would need to reach 118 bushels before returns above out-of-pocket costs are ever greater than the lowest returns (at 70 bushels) with cutbacks in input use. There is only a 16 percent chance under

**Table 1. Returns Above Out-of-Pocket Costs With Different Levels of Inputs When Participating in the Feedgrain Program and Federal Crop Insurance**

| Yield levels | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 120 | 140 |
|---|---|---|---|---|---|---|---|---|---|
| Input cost of $150 per acre | 56 | 52 | 48 | 44 | 46 | 60 | 75 | 104 | 128 |
| Input cost of $90 per acre | 112 | 108 | 104 | 100 | 106 | 120 | 135 | 164 | 188 |

normal input use that returns will exceed 118 bushels. Thus, what is needed is an understanding of how short-term (one or two years) cutbacks in input costs will change the yield distribution before a more complete model of risk management strategies could be developed. There are a number of farm model builders in this group that could design procedures for further examination of these questions. I believe some financially stressed farmers have adopted such short term strategies and that FCI and the commodity programs have provided them this opportunity. FCIC needs a better understanding of this type of moral hazard. When farmers do make such cutbacks they become higher risk for FCIC.

Finally, the relationship between price protection levels offered and the expected market price can play an important role in moral hazard problem for FCI. When the price protection level is greater than the expected market price, it will encourage farmers to alter their behavior in very logical ways in attempts to collect crop insurance when they have yields that are going to be close to the coverage levels. In addition, since price protection levels are offered are the same throughout the country, there are very likely some regional difference in participation in FCI that can be attributed to the relationship between regional prices and national prices. Research that would investigate the role of price protection levels in encourage moral hazard and regional differences in participation in FCI is needed.

## Adverse Selection

Another major problem for insurance programs is adverse selection. It is impossible, to tailor an insurance program to each individual. Thus, it is typical to identify a class or group of individuals and develop a program for that group. Premiums are then based on the average characteristics of the group. If the potential participants recognize this and understand how they compare to the average, then the program will suffer from adverse selection -- individuals with above average chances of collecting will purchase insurance at the average cost and those with below average chances of collecting will

not participate. Over time, this will create severe problems for the insurance program - - average premiums may in fact be less than the indemnity payments made to the adversely selected participants. Premium rates will be continually adjusted upward to compensate for these losses and over time a smaller and more adversely selected market will remain.

Until 1982, the only FCI available for major commodities was based on area average yields. Farmers could insure crops for yields below a certain percent of the area average yield. Premiums rates were also developed with the use of area average information (see Driscoll for more details on the rate making procedures and history). Consequently, a farmer who had yields above the area average would pay for more protection than the area average plan provided. Likewise, farmers with yields below that area average could receive more protection than was justified by the area average premium. There is emerging evidence that farmers are reasonably accurate at estimating their expected yields. Thus, over time, this system was doomed to failure as higher risk farmers became the primary participants in FCI, indemnity payments exceeded premiums and FCI was forced to raise premiums to cover losses (Skees). Premium rates are now a result of a long history of adverse selection. This and moral hazard problems are major reasons that participation in FCI is low. These problems have resulted in overpriced FCI for a large segment of farmers. If these causes of adverse selection are correct, areas of the country where risks are more a function of the environment and less a function of management should have less of a problem and larger market shares. A useful research project would examine these issues for particular areas of the U.S.

One crop that has historically been based more nearly on individual farmer experiences has been tobacco. In the case of tobacco there is much larger participation than exists for other crops. For example 18.1% of the eligible acres of corn in the U.S. were insured in 1985 versus 44.9% of the eligible tobacco acres (see the Hearings of the House Appropriations Committee). Although there are other reasons for these differences, it is also likely that the differences in the historical design of the programs explains part of these differences. Research which might isolate the reasons for differences in participation levels between crops is needed.

If FCI can provide farmers protection that is tied to a relatively accurate measure of their average yield, many of the adverse selection problems discussed above would be eased. The current program which attempts to accomplish this is called Actual Production History (APH). Yield guarantees will be based on the farmer's individual records where three or more years of verifiable records (ASCS is used to verify receipts and stored grain) are available. When ten years of records are available, yield guarantees are based exclusively on these records. Indexing procedures which use available farm records and Statistical Reporting Service adjusted county averages are used when less than ten years of data are available. Finally, if the farmer has no records, he can still participate in the APH program as FCI uses what are called transitional yields to develop protection for these farmers. In fact, such transitional yields will be similar to area average yields in the short run. Over time, as these farmers begin to establish a history of yields, their APH yield should more nearly reflect their actual farm average yield. However, as long as FCIC makes no trend adjustments there will continue to be a problem in rate making (Skees and Reed).

It is the intent of FCI to provide APH coverage for all major crops and eliminate area average plans. Therefore, it is extension colleagues should encourage farmers to begin to verify yields - - even though they have no intention of purchasing crop insurance in the next few years. This will allow such farmers the option to purchase a better insurance policy (one that reflects their average yield more accurately) in the event they change their assessment of FCI.

The APH program has also changed the fashion in which rates (premiums) are developed. Discounts are available for farmers with higher APH yields. Thus, farmers with higher average yields can receive more protection, and in some cases, pay less than they would under the area average plan (see Skees and Reed for the justification for these yield span adjustments).

One significant problem with the APH concept is in areas where there is autocorrelation between years. During periods of good yields, the APH yield will be higher than the actual expected yield. Likewise, during periods of bad yields, APH will be lower than expected yield. The four state project (Black et.al.) found little evidence of autocorrelation in Kentucky, Michigan and Minnesota. However, in the arid regions of Kansas there was evidence. More research is needed to consider alternatives to APH for areas where autocorrelation is a problem.

## Problems with the Aggregate Response to Crop Insurance

Since 1982, the government has subsidized crop insurance rates. Currently, the Reagan administration is attempting to phase out these subsidies. In public hearings before the House of Representatives Agriculture, Rural Development and Related Agencies subcommittee of the Committee on Appropriations, the Manager of FCIC provided details of the expected effects on the phase out. Farm premiums per acre for all crops were $6.92 in FY 1985. Over the five year phase out these premiums would increase to $12.19 per acre -- a 76% increase. The FCIC subsidy in FY 1986 was 100% of the administrative and operating expenses and 25% of the premium costs. Administrative cost of the Federal Crop Insurance program averaged 43 percent of premiums collected from 1983-1985.

If these subsidies are eliminated, rates will increase substantially unless the actuarial nature of the program changes significantly. In 1985, 21.2 percent of the total eligible acres of the principal crops in the U.S. were insured. Expected increases in the price of insurance will undoubtedly reduce this percentage and very likely eliminate the possibility that farmer's with less risk will purchase insurance. Thus, it is highly unlikely that any changes in the composite group of farmers will result in lower rates.

The loss ratio for all programs for FCIC was 1.1 from 1948-80. From 1982-85 the loss ratio has averaged 1.59 -- this means that farmers received an average of $1.59 in indemnity payments for every $1.00 in premium. If premiums do increase by the planned 76% and FCIC could expect similar participation and losses as occurred in 1982-85, then the loss ratio would average around .88 for farms purchasing crop insurance.

Given the attractive loss ratio of 1.59 it is easy to understand why it is difficult to convince administrators of the crop insurance programs that their rates may be too high. Pressures from the Office of Management and Budget to raise rates in light of these loss ratios are real. One of the things that is needed is an understanding of the elasticity of demand for crop insurance. In fact, this is the most important research need I can think of given the current environment. My hypothesis is that price decreases are more than offset by the quantity increases. If long-run demand is elastic, then the current directions are misguided.

Gardner and Krammer developed estimates of the elasticity of demand for crop insurance using 1979 data from 57 counties. Results suggest that the elasticity is one. Given the move away from area coverage to farm-level coverage, what is needed is research which would replicate this study with more recent data (1985 or 86).

There is reason to argue that farmers should be more responsive to price changes when they can obtain insurance that is more closely tied to their farm yields. However, what is more significant for insurance is the type of farmer who is attracted if price is reduced. I would argue that the pool of farmers who now purchase insurance is currently composed of the majority of farmers who represent the highest risk. Therefore, lowering the price would very likely attract relatively more farmers who represent lower risk than high risk. A well-designed research project that would address this hypothesis is needed.

## The Farm-Level Response

Individuals purchase insurance if they believe they can trade a small financial loss (premiums) for protection against the possibility of a large financial loss. Insurance works best when individuals predict expected losses more poorly than does the insurance company. The move to farm-level protection is extremely significant. King's detailed study with a small sample of dryland wheat farmers in Colorado suggests that farmers are more responsive to yield guarantees than they are to changes in premiums. Basing yield guarantees on individual farm experience (the APH program) should attract farmers who have historically had yield expectations which were greater than the area average yields. If FCIC can develop procedures to price individual contracts more correctly, this will be another major step toward attracting more farmers and improving the actuarial structure of the program.

Any decision process that evaluates the insurance purchase option should focus on: 1) the willingness and/or capacity to accept risk by both the farmer and the creditor, 2) subjective frequency distributions of returns with and without crop insurance, and 3) the cost (premiums) of the program compared to the protection provided. These three criteria form the basis of the remainder of this paper and a future research agenda.

Pricing crop insurance to individual farmers

Developing a pure insurance rate (where expected indemnity payments will equal premium payments) involves integration of the yield distribution below the yield guarantee level.

$$(1) \quad EL = \int_{-\infty}^{Y_g} (Y_g - Y)\, f(Y)dy$$

where EL is the expected losses (in bushels for grain); $Y_g$ is the yield guarantee (APH yield multiplied by the percentage level of protection); Y is the actual yield; and f(Y) is the probability density function (PDF) for yields. Pure insurance rates are simply the expected losses divided by the yield guarantee ($EL / Y_g$). Premiums are calculated from rate as follows:

$$(2) \quad \text{Premium} = Y_g\, P_g\, \text{Rate}$$

Thus, premium is equivalent to multiplying the price guarantee ($P_g$) by the expected losses.

Initially, FCI used procedures such as these to set rates under an assumed PDF. Over time these rates have been adjusted on the basis of losses within counties. Thus, today's rates are a function of experience, the original program design, and the composition of farmers attracted to the program.

From a farm level perspective, the essential information needed is the probability density function for yields. Once the PDF is known, all other information can be taken as given. This includes the yield guarantee. However, it should be noted that the relationship between the APH yield and the expected yield implicit in the PDF will have a great effect on expected losses and on a break even farm level rate. If APH yields are less than expected yields and rates are developed in the belief that APH yields and expected yields are identical, farm level rates will be higher than a break even value. This is the problem with ignoring trend in developing APH yields. As King demonstrates, farmers are more responsive to coverage that is based upon better measures of their expected yields. Therefore, if the APH yields do not reflect what farmers believe are their expected yields, this will be a constraint in farmer participation in FCI.

Research which would improve FCI's methods of developing APH yields is needed. If fact, since the thrust of the current FCI program is to identify farm-level yields, this is a strategic need. FCI must obtain reliable records on farm-level yields and have reliable procedures for developing APH. Farmers will recognize how their estimates of expected yields differ from APH yields and this will influence their understanding of expected losses.

It may be useful to illustrate the sensitivity of this relationship. Under the assumption of normally distributed yields it is relatively straight forward to calculate break even farm rates.[2] Given the mean and standard deviation and the yield guarantee, one can calculate break-even rates. The values below represent 75 percent protection levels and price protection of $2.00 per bushel. The expected yield was fixed at 100 bushels for each case. APH yields or coverage are changed to show how break-even rates would change.

**Table 2. Sensitivity of Relationship Between APH yield and Expected Yields on Rates and Premiums**

| APH Yield | Mean | Actual Coverage | Stand Dev. | Rate | Premium |
|---|---|---|---|---|---|
| 90 | 100 | 67.5% | 25 | .0169 | $2.28 |
| 100 | 100 | 75 | 25 | .0278 | 4.17 |
| 110 | 100 | 82.5 | 25 | .0433 | 7.14 |
| 90 | 100 | 67.5 | 35 | .0494 | 6.67 |
| 100 | 100 | 75 | 35 | .0651 | 9.77 |
| 110 | 100 | 82.5 | 35 | .0839 | 13.84 |

For example, the farmer with a standard deviation of 25 and an expected yield of 100 bushels who has an APH yield of 90 bushels would need to pay $2.28 per acre to break even. This compares to $4.17 when his APH yield is equal to the expected yield. Given this degree of sensitivity, it is little wonder that farmers are quite responsive to coverage offered. To the extent that FCI sets rates in the area that are consistent with the average differences in actual mean and APH yields, the actuarial problems will be reduced.

We can also use the normality assumption to examine what happens to rates when adverse selection from an area plan occurs over time. If rates were developed for the area based on 100 bushel yields and a SD of 25, a break even rate would equal .0278. If only producers with yields of 90 bushels and SD's of 22.5 (for a coefficient of Variation equal to the original design) were attracted they would still receive payments for less than 75 bushels and the break even rate should be .0453. Thus, over time rates would need to increase by 60% with this type of adverse selection. Such a rate increase would very likely discourage the farmers with yields of 100 bushels or more forever. I am arguing that this is precisely what happened due to the area plan and that FCI rates still reflect this type of adverse selection.

As Driscoll points out, FCI historically developed rates around the assumption that relative risk were constant across farms. Skees and Reed challenged that assumption and demonstrated that for a set of farms with Farm Business Analysis records from Kentucky and Illinois the assumption that standard deviation varied as expected yields increased could not be supported. If standard deviation is constant, then farms with higher expected yields have lower relative risk (CV's). This is the justification for the yield span relationships that FCI uses. Area average rates are adjusted by a factor developed from the ratio of APH yields to area yields raised to -1.25:

$$\text{Farm rate} = (\text{APH/area yield})^{-1.25} * \text{area rate}$$

Once again, examining the sensitivity of rates at various yield levels provides insight. If we assume that the area yield is 100 bushels and that the SD is 25, then a break-even area rate would be .0278. Rates for yield span adjustments and break-even rates for various yields appear in table 3.

**Table 3. Comparing Yield Span Rates to Break-Even Rates Under the Assumption of Constant Standard Deviation**

| Farm Yield (APH equal expected yield) | Yield Span Rate | Premium | Break-Even Rate With Constant SD of 25 |
|---|---|---|---|
| 80 | .0367 | $4.40 | .0510 |
| 90 | .0317 | 4.28 | .0372 |
| 100 | .0278 | 4.17 | .0278 |
| 110 | .0247 | 4.08 | .0208 |
| 120 | .0221 | 3.98 | .0156 |

As these data illustrate, if standard deviation is constant as farm yields increase, then the yield span relationship currently used by FCIC has not gone far enough in making adjustment in rates. The yield span exponent would need to be around -2.6 to obtain rates which are consistent with constant SD as expected yields increase. Research in additional areas is needed to address how SD changes as expected yields increase and to test the exponent needed for yield span relationships.

Another crucial issue for FCIC has been the definition of a farm unit. Currently, farmers who farm land in the same county must consider all owned land as one unit and purchase insurance on all acres of the crop grown (rented land is considered a single unit). As farm size increases, there is the common aggregation issue that we face when using county data rather than farm-level data for developing a measure of dispersion (see Carter and Dean). Farmers who farm larger units should have lower measures of dispersion and may, therefore, be less likely to purchase insurance. The four state study (Black et. al.) did not discover a relationship between acres farmed and measures of dispersion. It may be that these problems are not serious until the units become very large. Additional research is needed to address these issues.

The discussion up to now has focused upon the assumption of normality. There is evidence that yields are negatively skewed (Gallagher; Black et. al.) Such skewness means that break-even rates need to be greater than those developed above. FCI loads rates by adding 1 percentage point to the pure rate and increasing the resulting totals by 10 percent (Driscoll). Adding 1 percent to a rate develop from a normally distributed curve is equivalent to assuming that there is a one percent change of a zero yield. Making the 10 percent adjustment is a way to provide an additional belief that negative skewness increases as relative risk (CV) increases.

Returning to the yield span relationship, if yields are negatively skewed and more so as expected yields increase, then the exponent currently being used would be more appropriate than the -2.6 suggested above. Research that examines farm-level PDF's is desperately needed to better address the rate-making issues raised above. These issues were addressed in the four state project which used Farm Business Analysis records. In addition, farm-level break-even rates were developed using a number of procedures. For Kentucky, these rates averaged three times lower than the lowest area rates (which are subsidized) in the grain producing region of the state. This suggest that

this non-random sample of farmers with relatively high yields would face a loss ratio of .3 if they purchased crop insurance. A very small percentage of these farmers purchased insurance (less than 3 percent). The experience in Michigan and Minnesota was not quite as dramatic. Despite the non-random nature of the sample, it does strongly support the argument that the current rate structure is a product of the adverse selection of the area plan and that a desirable segment of the market will continue to be uninterested in crop insurance.

Prescriptive models for crop insurance decision making

The focus on rate-making should make it clear that rates are extremely sensitive to the underlying PDF and the relationship of APH yield to expected yield. Researchers who plan to develop farm risk models which incorporate insurance should keep this in mind. One must understand the relationship between pure rates and the rate being charged before beginning the research process. Farm level loss ratios reflect this relationship. This has been a sorely neglected piece of information in far too much research on crop insurance (Lemieux, et. al.; Plueger and Barry; Jetter). Without such knowledge it is difficult to develop inferences or prescriptions regarding crop insurance.

If the probability distribution is known, it is relatively straight forward to develop rates and desired loss ratios. (For example, if a loss ratio of 80 percent is desired the pure rate is multiplied by 1/.8 or 1.25). If normality is not used developing theoretical rates is more difficult. However, numerical integration can be used as the FORTRAN subroutine in footnote 3 demonstrates. These techniques will be particularly important in simulation models which attempt to capture the risk environment with and without insurance. Any research that uses typical farms and representative PDF's for these farms along with the current rate structure would be well advised to check the loss ratio with these procedures and report that information. Due to the problems discussed above, FCI rates typically do not reflect the representative PDF within an area. In nearly all cases, performing research in this manner will assure that loss ratios for subsidized insurance are less than one.

Nutt and Skees demonstrate the sensitivity of pricing crop insurance in a whole farm risk environment over a ten year horizon. The research reveals that no factor is more important than the loss ratio in explaining the effects of insurance. Further, given an environment where farmers are paying more for short term borrowing than other borrowing, the pricing of insurance will be most sensitive for farmers with high debt. In fact, this work suggests that farmers who are most financially stressed would gain the most if crop insurance is priced at levels close to break-even. However, at loss ratios of .8 or lower these farmers are made relatively worse off when they purchase crop insurance. These results raise serious questions regarding creditor behavior which forces farmers to purchase crop insurance. Creditors need to recognize that cost of crop insurance relative to the expected payoff is crucial in the determination of whether it provides a real risk reduction option or actually increases risk. More research of the nature conducted by Pflueger and Barry is needed. However, such research must recognize the role of pricing and ask creditors about their perceptions of this relationship to

risk (i.e, do creditors consider loss ratios). The survey conducted by Pflueger and Barry shows that creditors do (on average) provide better credit terms to farmers who purchase crop insurance. Creditors must understand that risk protection does come at a cost and that if that cost is too high it will result in a more risky environment.

Farmers need to be able to asses their yield risk relative to the cost of FCI. Research is needed which would aid farmers in developing subjective loss ratios. No variable is more important in the farm decision than the expected loss ratio. I can envision decision tools which would help farmers consider the downside risk and then develop a farm-level rate which could be compared to the rate being quoted by an insurance salesman. A well-designed research project is needed to assess alternative elicitation procedures which would focus on the downside risk.

Finally, I believe we need to understand more about what farmers may be willing to pay for risk protection. The issue of privatization of crop insurance raises concerns about the loss ratio that individual decision makers may face. With administrative cost in excess of 40 cents per dollar of premium, the average loss ratio would be less than 60 percent. In some preliminary work in which I am involved the expected utility hypothesis is used for several different assumed utility functions. This work suggests that only extremely risk adverse farmers would be willing to pay for insurance that would be expected to return less than 60 cents on a dollar. Most decision makers would cease to purchase crop insurance at loss ratios of around 85 percent. If these results are reflective of the majority of decision makers, they clearly suggest that unsubsidized crop insurance will simply not work. This group could contribute a good deal to both our understanding of crop insurance and other risk management strategies by focusing on the concept of expected loss ratio and willingness to pay by various risk classes of decision makers.

## Summary

This paper has raised a number of research questions which must be addressed if multiple crop insurance is to provide a viable risk management option for a larger number of U.S. farmers. Given the current policy environment (spring 1987), I believe that work which investigates the price elasticity of demand for crop insurance is most important. Changes which have been made in FCI should make crop insurance more attractive to larger numbers of farmers. Yet, the transition has been difficult. The heritage of previous program designs which encouraged adverse selection has created tremendous problems and much confusion. Information which was generated under the area coverage plans should not be used in today's rate making. If my suspicions are correct and farmers do purchase proportionally more crop insurance as prices decline (i.e., the price elasticity of demand is greater than one) then current efforts which would eliminate subsidies and increase rates will kill the program.

In addition to research into the demand for crop insurance, researchers need to be concerned with how the pool of farmers changes as price of crop insurance changes. I have argued that price reductions would attract a class

of farmers who have lower risk. Research which would isolate demand for FCI by crops and regions would provide further information in this regard. Moral hazard and adverse selection will continue to be problems for FCI. Improved farm-level information systems and farm-level rate making for FCI is the best approach to these problems. FCI needs procedures to identify individual farmers who may present moral hazard problems within an area. Researchers need to provide more information on the relationship between moral hazard and commodity programs and the price protection level offered by FCI.

From a farm-level perspective, we need to continue to concern ourselves with the PDF's for farm-level yields. Rate-makers in FCI need better information on the likelihood of catastrophic events (this relates to negatively skewed yield distributions). They also need to understand how yield trends effect the relationship between APH yield and expected yield. More work is needed to develop improved yield span adjustment procedures. It is likely that these procedures should vary by crop and regions. Information on PDF's for more crops and regions will be needed to assess how yield span adjustments should vary. Farmers need procedures which will assist them in evaluating their farm's expected loss ratio. This would require improved methods for subjective yield elicitation. There is no information which would be more useful for farm-level decision makers when evaluating the crop insurance purchase decision. This information needs to be coupled with information on how much farmers with different risk preferences are willing to pay for crop insurance. Creditors also need to be made aware of how the expected loss ratio will affect the efficacy of crop insurance.

The research needs for crop insurance are indeed great. Researchers involved in S-180 should have a comparative advantage in performing much of this research. Further, much of the work needed would enhance ongoing and related efforts by S-180 researchers.

## Footnotes

[1] I will not be addressing the quality issues although there is a clear need for research on the distribution of quality for some crops. For example, the quality of corn will effect test weight and there is a high correlation between drought and low test weight on corn. These types of relationships make development of rates particularly difficult. In addition, in the work I have done with FCIC it has come to my attention that the information system records quality adjustments only at the local level -- Kansas City does not have this information. In Kentucky, we tracked some of the local information and discovered that a large percentage of the payments made for wheat losses were due to quality adjustments in price as a result of garlic in the wheat. Research that would isolate the quality adjustments and the yield shortfalls would aid in our understanding of rates.

[2] Using work by Botts and Boles and the polynomial function for integration of a normally distributed density function produces a more specific formulation for estimating expected losses from a truncated normal distribution:

(1)
$$Z = \left[\frac{1}{\sqrt{2\pi}}\right] \cdot e^{-1/2 \cdot \left[\frac{(EY - Y_g)}{SD}\right]^2},$$

(2)
$$T = \frac{1}{1 + b\left(\frac{EY - Y_g}{SD}\right)},$$

(3)
$$P = Z(a_1 T + a_2 T^2 + a_3 T^3),$$

(4)
$$EL = P(Y_g - EY) + Z \cdot SD,$$

where b=.33267, $a_1$=.4361836, $a_2$=-.1201676, and $a_3$=.937298 (Abramowitz and Stegun). Other variables include: EY - expected value, SD - standard deviation; P - probability of collecting in any given year; and the variables defined above or through intermediate calculations (Z and T). Expected losses are then used to calculate rates: R=(EL/YG). And rates are used to calculate premiums: PR=R $Y_g$ $P_g$ ($_g$ is the price guarantee). For the corn produced by farms in this analysis, the coverage level is 90 bushels (120 times 75 percent protection). Thus, with the price protection level of $2.35 per bushel (the expected price used for the price distribution) the premium for the data set where CV = .35 is calculated as follows:

PR = (6.51 * 90 * 2.35) * .01

= $13.77 per acre

[3] What follows is a FORTRAN Subroutine which uses random yields to develop break-even insurance rates:

```
      SUBROUTINE RATE(Y,ND,APH,PER,LOSS,RATE)
      DIMENSION Y(1000)
C
C     Y is an array of up to 1000 randomly developed yields
C     ND is the number of random yields
C     APH is the actual production history yield
C     PER is coverage level choosen to be multiplied by APH for yield
C         guarantee
C     LOSS is the desired loss ratio -- 1 will give break even
C     RATE is the break even rate
C
      XND=ND
      C=APH*PER
      ELSUM=0.
      DO 10 I=1,ND
      IF (Y(I) < C) ELSUM=ELSUM+(C-Y(I))
 10   CONTINUE
      EL=ELSUM/XND
      RATE=EL/C
C
C     The break even rate is expected loss divided by coverage
C     Rates are now adjusted to give the desired loss ratio
C
      RATE=RATE*(1/LOSS)
      RETURN
      END
```

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