Crop Insurance Research Needs

by

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Introduction

Federal Crop Insurance has been available to American farmers since 1938. Throughout much of its history, though, the program has been viewed as experimental and farmer participation has been relatively low. Since passage of the Crop Insurance Act of 1980, however, coverage has been extended to hundreds of new counties throughout the country and to several crops not previously insured by the Federal Crop Insurance Corporation. During this same period substantial subsidies on federal crop insurance premiums were introduced to encourage more widespread program participation. With the elimination of the Disaster Assistance Program in 1982, federal crop insurance became the primary federally administered program for protecting farmers against the adverse effects of yield risk.

Researchers' interest in issues related to crop insurance has expanded along with the federal crop insurance program. Studies by Ahsan, Ali, and Kurian; Dean, et. al; Gardner and Kramer; King and Oamek (1981, 1983); Kramer; and Lemieux, Richardson, and Nixon are representative of the range of research undertaken in the past few years. At the outset of this regional research project on risk management strategies for agricultural production firms, it is important to examine crop insurance research needs for two reasons. First, crop insurance is an important risk management tool for agricultural producers and an important element of an overall agricultural policy at the federal level. As researchers, we need to develop effective ways to help farmers evaluate crop insurance alternatives as part of a total risk management strategy. We also need to develop effective methods for analyzing the impacts of alternative crop insurance program provisions from an agricultural policy perspective at a time when the role of government sponsored programs to reduce agricultural risks is being re-evaluated. An examination of crop insurance research needs is also important for a second reason: it brings to light a number of theoretical, methodological, and empirical issues that are of general importance in risk management research. These issues include the measurement and representation of risk preferences, the uses of subjective and objective probability distributions, and the identification and evaluation of alternative action choices in normative risk models. They also include problems of aggregation, response prediction, and determination of the

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distribution of impacts in policy analyses based on positive risk models.[1/]

My discussion is organized according to what I perceive to be three important areas of emphasis for crop insurance research: farm level decision analysis, policy analysis at the federal level, and effective program management within the Federal Crop Insurance Corporation. The first two areas are familiar to us all. The third one, effective program management, is sometimes neglected by agricultural economists but is essential if policies selected at the federal level are to be successfully implemented. My review of past research will be far from exhaustive, and my perception of key research issues will reflect my own experiences and biases. Hopefully, though, this paper will serve as a starting point for a broader discussion of crop insurance research needs.

Farm Level Analysis of Crop Insurance Alternatives

Farm level models designed to help producers evaluate crop insurance alternatives are considered in this section. Such models are normative. Farm level models may also be used to predict producer behavior. Models of this type are discussed in the section on policy analysis.

A normative risk model should help a producer make a good decision. But what is a good decision is a risky context? From an *ex post* point of view good decisions are relatively easy to identify. They are those that, when all the relevant information is in, result in an outcome the decision maker considers to be optimal. Decisions must be made in an *ex ante* context, though. Following Mack, a good *ex ante* decision minimizes the costs of uncertainty, be they financial, psychic, or otherwise. A normative risk model should help decision makers minimize these costs by structuring available information relevant to the choice situation, by providing a medium for integrating outside information into the analysis, and/or by reducing the number of alternatives to be considered. A number of relatively simple normative risk models have been developed to help farmers evaluate crop insurance alternatives. (e.g. Oamek, King, and Trock; Texas Agricultural Extension Service; and Walker, Jeter, and Mapp). As Walker notes, most of these use some form of a payoff matrix to structure information about the range of outcomes under different crop insurance alternatives. Some use a programmable calculator or microcomputer, while others are based on written worksheets. Regardless of the medium used to conduct the analysis, the output of such models needs to be simple if it is to be useful to farmers. Several difficult theoretical and methodological issues can, however, greatly complicate the analysis of crop insurance alternatives.

Most, if not all, of the models designed specifically as decision aids for farmers consider crop insurance decisions in isolation from other risk management decisions. This keeps the number of alternatives to be evaluated down to a manageable number and may accurately reflect the way

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1/ I use the term "normative models" to refer to those designed to prescribe an action and the term "positive models" to refer to those designed to predict an action.

farmers actually make decisions. If there are, however, important interdependencies between risk management tools -- e.g. between crop insurance and commodity program participation -- it may not be correct to separate out crop insurance decisions.

Sources of risk also need to be considered carefully in the design of a normative risk model. Because crop insurance has its primary impact on yield risk, price risk is often ignored in the analysis of crop insurance alternatives (e.g. Oamek, King, and Trock). This greatly simplifies the analysis, but it can result in a serious underestimation of the risks a producer actually faces.

A simple mean variance risk model is a good starting point for an assessment of the importance of these concerns. Consider a situation where a single crop is produced. Price and yield, P and Y respectively, are assumed to be independent, normally distributed random variables. P has a mean $\bar{P}$ and a variance $V_p(X_p)$, where X_p is some price risk reducing input or activity (such as hedging). Y has a mean $\bar{Y}$ and a variance $V_y(X_y)$, where X_y is some yield risk reducing input or activity (such as crop insurance). It is assumed that $V'_p(X_p)$ and $V'_y(X_y)$ are both negative and that $V''_p(X_p)$ and $V''_y(X_y)$ are both positive. It is also assumed that X_y and X_p have cost functions $C_y(X_y)$ and $C_p(X_p)$ that have positive, increasing slopes. The decision maker's objective function is

$$(1) \quad Z = \bar{P}\bar{Y} - C_y(X_y) - C_p(X_p) - OPC - (\lambda/2)\ (V_p(X_p)\bar{Y}^2 + V_y(X_y)\bar{P}^2 + V_y(X_y)V_p(X_p)),$$

where OPC is a constant level for production costs other than those for X_y and X_p and λ is a constant level of absolute risk aversion. The final expression on the right hand side of (1) is the variance of the product of P and Y. Setting the partial derivatives of (1) with respect to X_p and X_y equal to zero yields the following first order conditions:

$$C'_p(X_p) = -\ \lambda/2\ (V'_p(X_p)\bar{Y}^2 + V'_p(X_p)\ V_y(X_y))$$

$$(2) \quad C'_y(X_y)^2 - \lambda/2\ (V'_y(X_y)\bar{P}^2 + V'_y(X_y)\ V_p(X_p))$$

These indicate that both risk reducing activities are engaged in until their marginal cost is equal to the marginal reduction in the decision maker's risk premium (the product of $-\ \lambda/2$ and the marginal impact on the variability of net returns). Given the previously stated assumptions about the signs of first and second derivatives of the cost and variance functions, second order conditions for a maximum should be met.

This simple model could no doubt be improved considerably.[1/] It rather clearly suggests, though, that decisions about price risk reducing and yield risk reducing activities are not independent--even when prices and yields are uncorrelated--and that a decision about either of these activities depends on the degree of variability in both prices and yields. The key questions for researchers designing normative risk models concern the strengths of these interdependencies. I hypothesize that interdependencies between choices will only be important when an action can almost completely eliminate one kind of risk.[2/] On the other hand, I hypothesize that the need to consider both price and yield risk will be important whenever both prices and yields are highly variable. These are empirical questions, though, that can only be addressed through further research.

A third major issue in the design of normative risk models is that of the probability distributions used in evaluating alternative action choices. Should they be empirical or subjective? In addressing this question, I think it is important to separate prices and yields. It is also important to maintain a broad view of our goal -- to help farmers make "good" decisions.

Regarding product prices, all producers in an area face essentially the same price distributions.[3/] This simplifies matters, since it suggests that expert assessments of price probability distributions -- be they empirical, subjective, or some combination -- can be used by a number of farmers. If alternative marketing strategies are to be considered, though, the difficult question of which price distributions should be supplied must be addressed. With a multiplicity of marketing dates and arrangements comes the need to consider a multiplicity of price distributions. Having recognized the importance of this problem, though, I will leave it, since it is likely to lead us too far from the central issue of crop insurance.

Crop insurance is a tool for managing yield risk. While producers is an area all face essentially the same price distribution, the probability distribution of yields can vary significantly from one farm to another. In a study of Colorado dryland wheat farmers by King, yield distributions were found to differ considerably among farmers in a single area. Is this a common phenomenon, or is it only a problem for certain crops and/or particular regions? This, in itself, is an important research issue. When yield distributions do not vary greatly among farms in a specific locality (as is assumed in the procedures used by the FCIC to

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1/ One particularly serious shortcoming is the use of normal distributions, since risk reducing activities often skew probability distributions. Also the representation of crop insurance as a purchased risk reducing input may not be appropriate.

2/ See King and Oamek (1981) for an example which supports this hypothesis.

3/ Their subjective assessments of those distributions may, however, differ considerably.

establish rate and average levels) the problem of identifying appropriate yield distributions for normative risk models is similar to that of identifying appropriate price distributions. If interfarm differences in yield distributions are great, on the other hand, appropriate farm-specific yield distributions must be identified. My subsequent remarks will focus on this case. In particular, they will focus on the use of subjective versus empirical probabilities.

An empirical yield distribution can be most easily represented by a sample cumulative distribution function. Following Anderson, Dillon, and Hardaker (p. 42), N sample observations of a random variable are arranged in ascending order. The probability that the random variable will have a value less than or equal to the Kth observation is K/(N+1). Other points on the cumulative distribution function can be determined by linear interpolation between known points. This approach makes full use of all available sample information and imposes no restrictions on the form of the underlying probability distribution. Questions regarding its use center around the issues of how large the set of sample observations needs to be (Anderson) and how yield trends can be handled in such a framework. Small samples and strong yield trends may significantly limit the usefulness of empirical yield distributions.

Subjective probability distributions are not based directly on empirical data but reflect a decision maker's personal assessment of probabilities. Anderson, Dillon, and Hardaker; Hogarth; Musser and Musser; and Spetzler and Stael von Holstein are good sources of information on encoding procedures designed to help decision makers structure probabalistic beliefs and on some of the shortcomings of these procedures. Clearly there are potentially serious problems associated with the use of subjective probabilities.

Should we use subjective or empirical yield distributions in normative risk models designed to analyze crop insurance decisions? This is a difficult question for reasons that go beyond the obvious shortcomings of both approaches. Survey results reported by King suggest that the empirical yield distribution for a farm often differs markedly from the operator's subjective yield distribution. Though this has not been formally tested, I hypothesize that differences between subjective and empirical probabilities are affected by risk preferences. The expected utility hypothesis requires a formal separation of risk preferences from probabilistic beliefs, yet it seems unlikely that decision makers actually make such a distinction. This can be a sensible way to behave. If probability assessments are adjusted to reflect risk preferences, simple choice roles such as expected value maximization may be quite effective. This type of behavior can, however, cause serious problems in a structured normative risk analysis.

Consider first the case where a decision maker is presented a payoff matrix based on empirical probabilities. If he typically bases his decisions on informally structured, risk preference adjusted subjective probabilities, he may follow an expected monetary value maximizing rule and choose an alternative that does not really reflect his risk preferences.

Consider next the case where a decision maker is faced with a large number of possible actions -- more than could be evaluated in a payoff matrix. In such a situation, formal risk preference measurements are often used along with subjective probabilistic information to identify a preferred choice or an efficient set of choices. Let the decision maker be moderately risk averse. This risk aversion should be reflected in his preference measurement, but it may also be reflected in his subjective probabilities in the form of higher assessed probabilities for bad outcomes. If the preference measurements and probability assessments are used together, alternatives identified as "preferred" may actually be too conservative, since the decision maker's risk aversion has been "double counted."

This points to one of several serious shortcomings of the expected utility hypothesis, the basis for most of our theory of decision making under uncertainty.1/ This does not mean, however, that we should abandon expected utility as a tool for normative analysis. The fact that it does not explain the way decision makers actually behave does not mean that it cannot serve as a guide in determining how they should behave. If we accept expected utility as a basis for normative analysis, there is a need to refine methods for eliciting and structuring subjective information so that cognitive biases can be minimized, to improve the quality and increase the availability of empirically based probabalistic information, and to train decision makers to use risk analysis techniques more effectively. This will require cooperative efforts between economists and psychologists. Musser and Musser are pessimistic about the amount of progress that can be made in this area, but there seems to be no other alternative until a better normative theory for the analysis of uncertain decisions is developed.2/

To summarize, research directed toward the design of normative risk models should focus on determining the separability of risk management decisions, on identifying the sources of risk that need to be considered in a risk analysis, and on problems related to the elicitation, integration, and presentation of information that can help producers make better decisions. We need to keep in mind that the object of a normative analysis is not to predict choices but rather to provide structured information about the consequences of alternative actions. When this is our goal we are faced with the difficult problem of considering all relevant factors and alternatives while minimizing informational requirements and maintaining the simplicity of the output we provide to the decision maker.

Policy Analysis of Crop Insurance Program Design Alternatives

In analyzing crop insurance program design alternatives from a policy perspective, the goal is to predict the actions of a large number of decision makers so that the aggregate impacts and distributional effects of

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1/ See Schoemaker for a broad critical review of the expected utility model.

2/ Several alternatives to expected utility theory have recently been proposed, most notably prospect theory (Kahneman and Tversky). In general, though, these are designed for positive rather than normative analysis.

policies can be determined. This information can then be used by policy makers to evaluate policy alternatives. Risk models for policy analysis can focus on impacts at the farm level, or they can be designed to predict aggregate effects. Often, both types of models are used to analyze a set of policy alternatives, but most of the recent policy analysis of crop insurance has focused at the farm level (e.g. Dean, et. al.; King; King and Oamek (1983); and Lemieux, Richardson, and Nixon). In many respects this is justified. Findings reported by King suggest that interfarm differences in the attractiveness of federal crop insurance coverage are considerable. The attractiveness of coverage may also vary considerably across regions and crops. For example, King and Oamek (1983) and Lemieux, Richardson, and Nixon report very different impacts associated with the elimination of the Disaster Assistance Program and subsidization of crop insurance premiums. Colorado dryland wheat farmers were hurt by this change, while Texas cotton producers were made better off. There is also a need, however, for models that can accurately predict aggregate impacts.

In this section, I look first at farm level models designed for policy analysis. I then consider approaches for analyzing the aggregate impacts of alternative crop insurance policies. Throughout this discussion emphasis will be placed on identifying ways that positive risk models can be modified to provide better information to policy makers.

Farm level models are useful for policy analysis because they can provide detailed information about how a set of policies will affect resource allocation and financial performance within a farm firm. A comprehensive farm level model, such as Richardson and Nixon's FLIPSIM, can be used to model intertemporal adjustments in crop mix, farm size, and financial position. Both price and yield risk can be considered, and income tax decisions can be modeled in detail. In addition, such a model can be flexible enough to consider a wide range of policy instruments. As such, farm level models can be of considerable value, but they are also subject to a number of serious limitations.

A possible lack of predictive power is undoubtedly the most serious limitation of farm level models. Typically they are driven by some optimization technique based on expected utility or an approximation of it. Is this a valid basis for prediction? Evidence cited in Schoemaker suggests it may not be. King reports a fair degree of success in using an expected utility model to predict the crop insurance decisions of twelve dryland wheat producers, but much simpler models performed equally well. If prediction is the primary purpose in an analysis, then, there may be better methods. This is an area where more research is needed. One possible direction for future efforts will be introduced later in this section.

A second limitation of farm level models for policy analysis is their high cost. If the impacts of alternative crop insurance policies differ considerably across farms, crops, and regions, a farm level model must be run for a large number of representative firms. This requires a great deal of data and considerable computing resources. In addition, the output from each run can be voluminous. In reducing this to a manageable amount for further analysis, many of the benefits of using a farm level model are lost. In addition, our ability to meaningfully aggregate the results of such an analysis is questionable.

Despite these shortcomings, there is still a need for farm level models. They can help us understand the processes by which policy changes affect farm firms and linkages between policies. They are, however, case study laboratories rather than vehicles for generating data that will accurately reflect aggregate impacts, and future research efforts should focus on making them more useful in this context. Farm level models should be particularly useful in the design and evaluation of provisions for an income insurance program.

Research by Gardner and Kramer on the demand for crop insurance suggests a more fruitful direction for research on the aggregate impacts of changes in crop insurance program provisions. They used data from a cross section of 57 U.S. counties to estimate a county level demand function for crop insurance. As expected, the percentage of acreage insured in a county was found to vary directly with the expected rate of return on crop insurance investments and inversely with the standard deviation of this rate of return. Their model can be used to predict changes in acreage insured associated with policy changes such as the introduction of premium subsidies. County level expected rates of return can be adjusted to reflect a policy change, while other explanatory variables remain unchanged. This new set of independent variables can then be used to predict the percent of acres insured in each county. These predictions can be weighted by the total acreage in each county and aggregated.

The use of county level data for an analysis of crop insurance demand can be somewhat limiting, however, especially if there is considerable variation in the rate of return on crop insurance within a county. Gardner and Kramer's model cannot be used to evaluate the impact of program previsions designed to reduce interfarm differences in expected rates of return, such as the individualized yield coverage (IYC) program. In addition, it may be difficult to predict aggregate expected FCIC loss ratios (the ratio of indemnities to premiums) with such a model, since it says nothing about how loss rates will change as the acreage insured increases or decreases.

These problems can be remedied, not least in part, by using farm level cross sectional data in a discrete choice model. Here the probability that crop insurance will be purchased, P, is considered to be a function of the farm level expected loss ratio, ELR, and a set of farmer characteristics such as age, education, etc. The parameters of this function can be estimated using Logit or Probit analysis.[1/]

The major obstacle to the implementation of such a model is the determination of ELR for each farm. For price and yield guarantees P_g and Y_g,

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1/ See Kinsey and Pindyck and Rubenfeld for good discussions of qualitative choice models. See Chambers and Foster and Garcia, Sonka, and Mazzacco for recent applications of such models.

ELR is defined by the following expression:

$$(3)\quad ELR = \left(\int_0^{Y_g} P_g F(y)\, dy\right)/PR,$$

where F(y) is the cumulative distribution function of crop yield per acre and PR in the crop insurance premium per acre. F(y) can be constructed from historical data, as was discussed in the section on normative risk models. Alternatively, it can be based on elicitation of subjective probabilities. Both kinds of distributions can be obtained in a mail questionnaire. Numerical integration techniques outlined in King can then be used to calculate ELR for each set of price and yield guarantees. The maximium value of ELR could then be used in the discrete choice model.

Such a model could be used to predict acreage responses to across the board changes in program provisions and to changes designed to reduce interfarm differences in the attractiveness of crop insurance averages. If empirical yield distributions are used, changes in aggregate FCIC loss ratios can also be predicted. This information is essential for budgetary planning. Results reported by King suggest that changes designed to reduce interfarm differences can have a dramatic impact on overall program performance through an alleviation of adverse selection effects. It is particularly important, then, that such changes in program provisions be studied.

The Analysis of Crop Insurance Program Management Alternatives

Program management is a third major area for crop insurance research. Walter has identified three research issues directly related to program management: valuing lost production, setting rate and coverage levels, and integrating crop insurance and marketing management. In my discussion I will emphasize the second of these.

Ahsan, Ali, and Kurian note that companies or agencies which supply agricultural insurance are faced with a particularly difficult problem in setting rate and coverage levels. Yield risks vary greatly across farms. Inequities are reduced and adverse selection problems are minimized if these differences are reflected in the coverage levels and premiums offered to each farm, but reliable farm level information on yield risks is costly to obtain.

At the present time, the FCIC uses historical county level data on past federal crop insurance experience to set rate and coverage levels.[1/] If past experience in a county has been bad -- i.e. if indeminities have been high relative to premiums -- premium rates are adjusted upward. If past experience has been good, they are lowered. Clearly, if adverse selection is a already problem, this procedure can make it worse. Upward adjustments in premiums in response to high loss ratios will cause participating farmers with the least yield risk to drop out of the program, making subsequent loss ratios still higher.

1/ See Yeh and Wu for a discussion of the procedures used.

In response to this problem the FCIC has established procedures for adjusting premiums based on farm level experience. They have also instituted the IYC program, which allows farmers to adjust coverage levels to reflect their historical average yields. The effectiveness of these measures can be questioned, though.

One possible alternative to these procedures is the target loss ratio approach suggested by King. Under this approach, premiums or yield guarantees are set at levels that make the expected loss ratio defined in (3) equal to some desired level.[1/] This requires historical yield data, which would be updated annually - information that is already required for participation in the IYC program. Research is needed to determine how this and other possible sets of provisions perform relative to current procedures for setting rates and coverages.

Related to this issue is a set of important questions about how reliable yield information can be collected, stored, and used by the FCIC. These questions are particularly difficult for feed crops for which yield information is difficult to obtain and verify.

Concluding Remarks

In closing, I think there is a need to maintain our sense of perspective about the importance of crop insurance research. Research is needed in all three of the major areas I have identified. In addition a considerable amount of effort will go into studies on income insurance for agricultural producers in the next few years. Much of my discussion here also pertains to these efforts. The most important thing to be gained from on assessment of research needs in this area, though, is an appreciation of the amount of general research on risk management that remains to be done. Research on crop insurance forces us to consider a number of these general issues. In this sense, it is important in a much broader context.

1/ A computer program written for this purpose is given in King.

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