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# The Role of Research in Producer Risk Management

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*Abstract*

Agricultural economists have for many decades concerned ourselves with gaining an understanding of individual behavior when confronted with risk, and developing tools to address decision-making under risk. This area of research has recently gained renewed attention for a variety of reasons. This paper attempts to provide a review of the current status of risk related research, to assess areas where we have made significant progress, and also areas where expected benefits of future work are greatest.

Theoretical advancements have contributed to our understanding of portfolio trade-offs, optimal input and output decisions, and the use of instruments such as futures and insurance. Advances in the ability to quantify risk with more robust methodologies also contribute to the information available for producers. Research has also contributed to the development of new instruments and provided evaluation of alternatives which confront producers.

There are, however, areas in need of further research. We identify five general areas which we believe merit further attention. Progress in these areas should contribute significantly to our understanding of risk management and the information that agricultural economics may provide to producers.

Keywords: Risk, Insurance, Research

# The Role of Research in Producer Risk Management [1]

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## Introduction

Agricultural economists for many decades have been concerned with gaining an understanding of individual behavior when confronted with risk, and with developing tools to address decision-making under risk. This is not surprising given the variability in weather, uncertainty in markets for both outputs and inputs, and various other risks confronting agricultural producers. This area of research has recently gained renewed attention for a variety of reasons. An obvious reason is the change in federal farm policy which eliminated federal policy makers' discretionary supply controls and ended the longstanding deficiency payment program which provided price protection to producers.

As we confront the realities of risk management in the present and future, it is reasonable to look back at what we have learned regarding agricultural risk management and to consider where our risk management research efforts would be most productively utilized in coming years. This paper attempts to provide a review of the current status of risk related research, to assess areas where we have made significant progress, and also areas where expected benefits of future work are greatest. To make this agenda at least somewhat tractable, we concentrate on research that most directly relates to producer decision-making.

## A Brief Review of Past Risk Management Research

A review of literature related to agricultural risk and risk decision-making shows an obvious progression in the economic theory, quantitative techniques and computational complexity that researchers are able to apply to agricultural risk issues. It gives an important sense of perspective to consider that our primary theory of decision-making when confronted with risk is based on the work of Von Neuman and Morgenstern which was published in 1944. The widely utilized portfolio or expected value-variance model was developed by Markowitz in the 1950's. The option pricing studies for which Merton and Scholes recently received the Nobel prize were conducted in the 1970's. Thus, it is not surprising that our understanding of risk management continues to evolve rapidly.

Expected utility models of the relationship between risks and the behavior of producers have advanced dramatically in recent years. Of particular relevance are the developments in understanding the relationship between risk and optimal decisions regarding input use and output levels. Understanding these relationships is central to understanding producer behavior when confronted by risk. It also serves as the framework in which risk protection mechanisms may be evaluated. The Sandmo model provided a workable approach for examining the implications of price risk. Yield risk has proven more difficult to evaluate as random factors such as weather enter into the production technology and potentially interact with other inputs. Models based on multiplicative production risk have generally been used to address yield risk and the more realistic case of both price and yield risk (Pope and Kramer, Newbery and Stiglitz, and Innes).
Another obvious progression of the literature relates to analysis of forward pricing. Much of the literature on producer hedging decisions has assumed non-stochastic yields and a single risk market - exchange traded futures contracts (Myers and Thompson). Hanson and Ladd, as well as Lapan and Moschini have addressed the market for options assuming deterministic yields. Lapan

and Moschini generalized from the assumptions of variance minimization to an expected utility framework and allow both futures and options to exist. Under their assumptions, options are dominated by hedging.

McKinnon and Grant have shown, in a variance minimization framework, that correlation between price and yield significantly affects the hedging decision. Where negative correlation exists then a natural hedge results in an optimal hedge lower than expected output. Sakong, Hayes, and Hallam, as well as, Moschini and Lapan introduced yield risk into the expected utility problem finding that options are no longer dominated in the choice set, particularly when expected correlation between yield and price is non-zero.

We have also made significant gains in our ability to empirically quantify risk. Because we are often dealing with the expectations of low probability events, a great deal of effort has been devoted to improving our ability to utilize limited data. An example of our increasing ability to quantify risk is in the approaches that have been taken to model the risk that producers face, such as yield variability. If we follow the progression of literature that relates to yield variability, we see that a very few years ago agricultural economists appealed to fairly simplistic and tractable distributional assumptions in almost all cases. Normality or triangular distributions were generally the norm. More recent research has modeled potential asymmetries and non-unimodality, finding substantial differences in outcomes. For example, the conditional beta by Nelson and Preckel and the more recent work of Goodwin and Ker represent advances in parametric and non-parametric yield modeling. Ramirez has recently developed improved approaches to capturing time-varying multivariate relationships. Aradhyula and Holt applied time-varying GARCH models to examine supply response.

A substantial area of past empirical research has endeavored to develop improved quantitative models of the producer's decision environment. Math programming techniques which modeled optimal decisions in the presence of risk have been widely used for both normative and positive analysis (Patrick and DeVuyst). Linear approximations to the Markowitz E-V model were developed (Hazzell and Tauer) and increased computational capabilities allowed increases in model complexity and direct optimization of the E-V quadratic programming problem. A contemporaneous line of research developed improved simulation models. Monte Carlo and other stochastic simulations have also developed and become more sophisticated over time. Empirical applications such as Babcock and Hennessey, Richardson and Nixon, Coble and Heifner, and many insurance-rate setting procedures utilize this approach.

Another area where research has had a practical and relevant application to producer decision making is in evaluating and designing the instruments that are available to producers. Agricultural economists have made a significant contribution to our understanding of and the development of the insurance instruments that are available. Because of the lack of independence in losses and other insurability issues such as asymmetric information, crop insurance has often been deemed privately uninsurable. Agricultural economists have made a significant contribution in terms of quantifying the problems with agricultural insurance (Coble *et al.*). They have also contributed to developing alternatives, such as an area yield insurance plan, and improvements in the federally supported programs that exist (Skees, Black, Barnett). Contributions range from pointing out program inequities, improving rate setting, and adapting the insurance programs to new crops and locations (Knight and Coble).

## The Interface of Risk Research and Risk Education

In an ideal world, agricultural risk analysis would involve quality research which would be quickly and effectively conveyed to agricultural producers. Castle argues that this is seldom reality due to a gulf between researchers and extension economists conveying information to producers. Conveying risk management research to producers may be a particularly problematic area given its statistical intensity. A recent paper by Anderson and Mapp suggests that extension educators are often highly dissatisfied with the risk analysis being done by the research component of their respective land-grant institutions. Castle refers to this as a 'communication gap' and argues for a blurring of the lines between research and outreach efforts. In effect he is appealing for more joint appointments between research and extension. Obviously, institutional arrangements may affect the working relationship between researchers and extension educators.

However, a related issue is also relevant. As a profession, agricultural economists appear to be in substantial disagreement regarding fundamental principles related to risk management. Pope and Hallam, and more recently Schroeder *et al.* show evidence of significant differences in the underlying perceptions or assumption regarding risk related issues. Pope and Hallam found researchers in significant disagreement with industry and extension personnel regarding the forecasting ability of futures markets. This finding was reaffirmed in more recent work by Schroeder *et al.* which found significant disagreement between extension and research economists on seven of 12 questions regarding marketing and risk management.

It would appear that a continuing and respectful dialogue needs to take place between researchers and educators working with lay audiences. Researchers need to have feedback and useful problems presented to them. Educators need information that is directly applicable to their clientele. However, fruitful interaction will likely only come about from in-depth discussions of the underlying assumptions and postulates made by various groups. This is not likely to occur in an environment where neither side understands the other's assumptions and evidence.

This task seems imperative given the need for accurate, objective, and unbiased assessment of risk management issues. Vendors of various risk management instruments present producers with an increasing menu of risk management choices. To balance the information set between potential buyers and sales representatives, producers will need information regarding the attributes of various tools and analysis of the implications of using those tools.

It may be instructive to consider the risk management mechanisms of many larger business organizations. It appears that risk management tends to be handled by professional staffs which have the expertise and tools to manage risk (Cummins, Phillips, and Smith). Farmers are seldom organized in such large units to internalize this level of risk management expertise. That expertise will then need to come from an external source. This suggests an opportunity for educational efforts. However, research in this particular area is often not easily generalizable, given the individuality of factors such as risk aversion, wealth, and subjective probability assessments.

Researchers and educators both have an interest in attacking the question of how to communicate risk analysis and risk management results more effectively. The use of statistical concepts that are essential to risk analysis are considered to be jargon and confusing to many non-professionals. For our work to be understood and useful we need to investigate how we can quickly illustrate and teach risk and probability concepts. For example, easy to use Monte Carlo Spreadsheet models may serve as an excellent teaching and illustration tool. As computer capabilities increase, we may be able to provide more graphical presentations such as those generated by new generation software like the AgRisk decision software. There, the basic methodology developed in a research application has been placed into a risk management decision tool that is now being made available to extension educators and to producers themselves.

## Where Do We Need to Concentrate Our Research Attention?

We see at least five major areas where important advancements in risk management research can be made. In this section we briefly describe each area and justify the need for continued research. Some areas may be considered to be relatively theoretical, while others are much more applied. Our selections are based primarily on our assessment of the potential for research in these areas to make a significant contribution to improved producer risk management decisions.

### Improved Characterization of Agricultural Risks

Wright and Hewitt pointed out a few years ago that much of the risk analysis that has been done has tended to be myopic. The context of their criticism was crop insurance demand and failing to recognize the whole-farm context of demand decisions. Recently, Glauber and Miranda conducted disaggregate analysis of deficiency payments and found many cases where little revenue risk reduction or even a risk increase occurred. This is in contrast to aggregate sector analysis which shows deficiency payments countering swings in aggregate commodity revenue. Both studies point out that risk analysis conducted using improper data may be grossly misleading. The dilemma is that the appropriate data is often not available. Often it becomes the binding constraint which limits empirical analysis. Table 1 illustrates this point. The table reports the ratio of a weighted average of farm yield standard deviations to the county yield standard deviation for the county where the farms are located. This analysis is based on work by Heifner and Coble and utilizes National Agricultural Statistical Service (NASS) and Risk Management Agency (RMA) data. The smallest ratio reported is 1.43. Thus, county yield standard deviations underestimate the average farm standard deviation and would severely bias analysis of yield risk.

Risk analysis is inherently data intensive. Estimation of higher moments or expected values of low probability events simply requires a much greater effort to collect quality data than do estimates of central tendency. Because risk analysis often utilizes time series data, this effort must be sustained over a number of years for it to truly be productive. Because of these difficulties, there remain some glaring and obvious gaps in the information that we have to analyze and address risk-related agricultural issues. A prime example is the lack of credible time series data on farm-level revenue. In recent months, policy proposals to insure schedule F income or allow farmer tax-sheltered savings have been suggested. Economists simply are hard pressed to analyze such designs because of a lack of credible data.

For risk analysis, poor quality data often is reflected in a limited number of observations on which to base estimates. This problem can be illustrated simply through comparisons of sample size used for estimation. Ker and Coble, in a study of alternative yield density estimators, compared the effect of sample size on the error in fitting a known distribution. Figure 1. shows the Mean Integrated Squared Error (MISE) resulting from maximum likelihood estimation of beta distribution parameters. Samples of size 15, 30, 45, and 100 were drawn from a known beta density. In the figure, the MISE is normalized relative to the sample size of 100. As sample size declines, the MISE increases rapidly. At a sample size of 15 the MISE exceeds 700 percent of the n=100 MISE. This illustrates the estimation error associated with the small samples even when we assume the underlying distribution is known. We concluded that contributions can be made both by developing improved data bases for risk analysis and by developing improved methods which are robust in small samples.

**Further Investigation of Producer Decision Making**

The expected utility hypothesis (EUH) has dominated conceptual thinking regarding risk decision making for many years. Mean-variance (E-V) analysis with its more restrictive assumptions has been widely used, but this use apparently stems from E-V's analytical tractability rather than beliefs that E-V assumptions are more robust than expected utility. The EUH is not without critics and evidence of inconsistences between observed behavior and the EUH has a long history (Bueshena and Zilberman). However, alternative models have not supplanted it. A key difficulty in using the EUH is the need for information regarding the degree of risk aversion and the relationship of risk aversion to wealth. Thus far efforts to empirically estimate risk aversion and test between forms of risk aversion have yielded decidedly mixed results (Saha, Shumway, and Talpaz). Anderson and Mapp question the fundamental decision modeling framework used to address risk issues. They argue that researchers treat decision making as an act and develop quantitative methods to improve selection of an alternative. They suggest that producers are more likely to view decision making as a learning process which they reevaluate until it is clear that one alternative tends to dominate the others.

Risk management decision-making is also conditioned on the decision maker's subjective assessment of the risks being confronted. A substantial body of literature has also arisen investigating the difficulty individuals have in assessing risk and how one may best elicit subjective distributions from individuals (Hardaker, Huirne, and Anderson). Eales *et al.* found that producers were fairly accurate in forecasting price levels, but made significantly smaller estimates of price volatility as compared to implied futures volatilities. Pease found evidence that producers' subjective yield distributions deviate from estimates derived from historical data. Findings such as these suggest that there is an opportunity to teach producers how to better subjectively evaluate the risks that they confront. Pingali and Carlson suggest that this kind of training can have a measurable impact on decision making.

It would seem that there are several plausible areas of research which may result in models that have superior capabilities. First, advances need to be made in integrating both stochastic and dynamic dimensions into our modeling exercises. For some problems the static framework that has dominated risk research appears to be a limiting constraint. For example, what is the economic relationship between intertemporal savings behavior and intratemporal risk strategies such as insurance? Traditionally, dynamic optimization across time has assumed risk neutrality, while static risk modeling incorporates risk preferences without accounting for the broader context of some decisions. Theoretical frameworks such as that of Kimball may allow us to address empirical issues such as tradeoffs between investments and insurance (Chen, Meilke, and Turvey). A related area of research that may in fact address some of Anderson and Mapp's concerns is to employ Dixit and Pindyck's contingent claims model which explicitly accounts for the option value of deferring decisions in an uncertain environment.

**Confront the Market Efficiency Debate**

In the area of agricultural risk decision-making, a critical issue related to risk management is the market efficiency debate. Whether markets are efficient or not appears to profoundly affect marketing strategies. To put it simply, if producers can earn consistent gains by obtaining superior market forecasts, even a relatively small gain per unit may exceed the utility gain from risk reduction activities such as hedging. Conversely, if there is little opportunity for farmers to 'beat the market' and risk associated with speculative positions, then price enhancement as a risk management strategy is a complete misnomer.

It appears that as a profession we are giving fundamentally inconsistent guidance to agricultural producers because of disagreements on the efficiency of agricultural markets. Although not perfectly correlated, the evidence suggests that the disagreement is significantly related to research and extension appointments. The aforementioned Pope and Hallam, and Schroeder *et al.* studies confirm that researchers are more likely to believe that producers are unable to earn positive profits from forward pricing strategies.

Zulaf and Irwin, and Brorsen and Anderson provide in-depth discussions of research in this area. Although empirically difficult to examine, research has generally shown crop futures and options markets conforming to Grossman and Stiglitz form market efficiency where information is costly, but not Fama's strong form market efficiency. Kastens and Schroeder recently tested market efficiency in the Kansas City wheat futures and found that it generally conformed to efficiency and outperformed econometric estimates. The results for livestock tend to be more mixed. Bessler and Brandt found expert forecasts outperformed the live cattle futures, but not the live hog futures.

Under the Grossman and Stiglitz model, informed traders can gain a return on the investment made in obtaining information. A legitimate question is whether producers have access to unique information and can act quickly enough to capitalize on that information. Zulaf and Irwin examine the evidence regarding various marketing strategies which have been suggested to enhance preharvest prices. Brorsen, Coombs, and Anderson investigated the strategy of always forward contracting wheat production. In general, their conclusions suggest pessimism about the ability of these techniques to enhance crop returns.

Researchers and educators need to give attention to this issue because it so fundamentally affects the content of what should be offered in risk management education. Such a difficult empirical issue is not likely to be resolved in the near future, but anyone who is involved in agricultural risk related research or extension education activities should be well acquainted with this debate and with the competing arguments that have been brought to bear on this issue. One of the real challenges related to this issue is evaluating alternative forecasts. Expert forecasts which are quite common and well received are also difficult to evaluate. Efforts such as the AgMas project which tracks the performance of advisory services may over a period of time offer insights into this issue.

**Analysis of New Strategies and Instruments**

We are currently in an environment where new risk management tools or strategies are being developed rapidly. Objective analysis of these alternatives is of great value as decision makers evaluate alternatives. For example, four new insurance designs have been offered in the U.S. since 1993. Relaxation of the agricultural trade options ban may allow a multitude of alternatives. Area yield insurance forced further examination of the relationship between systematic and independent risks. The more recent revenue insurance products have precipitated new attention on the relationships between price and yield at the disaggregate level. Some designs differ from existing instruments in such a fashion to require significant research efforts to collect data and construct models for analysis. It is reasonable to expect that the wave of new instruments will continue for the foreseeable future.

In part due to the development of new products, new research has begun to further address the interaction of risks and risk instruments. Heifner and Coble, Wang *et al.*, Dvuyvetter and Kastens, and Poirtras have recently investigated the implications of multiple risk instruments such as futures and various forms of insurance. These studies uniformly suggest that risk management choices are not necessarily separable in many empirical contexts. Figure 3. is taken from the work of Coble and Heifner and reports the optimal preseason hedge ratio given no insurance, MPCI, and the new Crop Revenue Coverage design for four locations. This chart illustrates two points. First, insurance and hedging do not appear independent and results vary across regions.

This line of research brings together veins of research which have tended to remain detached from one another in our literature. For example, the forward pricing and insurance literatures have tended to emphasize distinct issues and assume away issues central to the other line of research. Future developments in instruments are likely to demand further efforts which cross over the boundaries of what have been traditionally distinct subject matter specialties such as marketing, production and financial economics.

**Examination of New Technology, Contractual Arrangements, and Environmental Risk**

*Genetic Engineering*

To date, much of the agricultural economics literature on farm-level risk has focused on forward pricing strategies and crop yield and/or revenue insurance. But the technological, economic, and environmental context in which farm-level decision making occurs is changing rapidly. For example, in 1997 over 16 million acres of genetically engineered crops were grown in the U.S.[Marra *et al.*] Renkoski predicts that by 2005 a substantial portion of all crop seed will be genetically engineered. Crops genetically engineered to be insect or disease resistant would seem to promise significant reductions in yield and/or input cost risk (Robinson *et al.*).

The technology fee that farmers pay when purchasing genetically engineered crops is conceptually similar to an insurance premium. Yet most agricultural economics research to date has simply compared expected net returns between traditional and genetically engineered crop varieties in a budgeting framework. Models of farmers' adoption decisions with regard to genetically engineered crops are needed that explicitly incorporate risk. Certainly, the availability of genetically engineered crops should be included as a choice variable in future efforts to model farm risk management decision-making in a portfolio context.

Related research should also address the relationship between crop yield and revenue insurance and genetically engineered crops. For example, is the promised reduction in yield risk associated with insect or disease resistant crops sufficient to warrant reductions in insurance premiums?

Finally, it is important to note that transgenic technologies have not always performed well under the sort of unusual weather conditions that are also typically associated with yield losses -- witness the failure of *Bt* cotton to control cotton bollworm in parts of Texas during hot, dry weather in 1996 and the failure of some transgenic soybeans to resist herbicide application in the mid-South during cool wet weather in 1997. Much remains to be learned about the risk implications of genetically engineered crops.

*Production Contracts*

Agricultural economists also need to better understand how the continuing changes in market structures for agricultural commodities affect farm-level risk exposure. While, in our introductory agricultural economics courses we continue to teach that production agriculture approximates idealized competitive markets with homogeneous products, it becomes increasingly difficult to square that perspective with reality.

Much has been written about the "industrialization of agriculture." The phrase seems to defy a consistent definition but a common notion is that farmers -- including crop farmers -- are increasingly selling differentiated products through production contracts rather than homogeneous products in impersonal spot markets. On the demand side, much of this change is driven by consumers who insist on consistency in product quality and price. Food processors often require raw agricultural commodities with specific quality characteristics while spot and exchange markets deal only in homogeneous products. Spot markets also expose processors to input price risk and the risk associated with maintaining input flows so factories operate at peak efficiency (Boehlje). As a result, processors increasingly rely on production contracts to source raw agricultural commodities.

For farmers, production contracts reduce some risks while increasing others. Most production contracts allow farmers to forward price their commodities. Some even provide a degree of yield risk protection. However, production contracts also frequently include considerable penalties for commodities that do not meet specified quality characteristics. Furthermore, production contracts for characteristic-specific commodities link farmers much more closely to volatile consumer markets than has been the case with traditional markets for homogeneous commodities (Boehlje).

How does this shift away from spot markets alter the risk environment of production agriculture? Answering this question will require more than simply applying our existing models to the new market structures. We must learn to analyze what Boehlje calls "relationship risk." The relevant issues will not lend themselves to analysis based on an assumption of relatively costless risk-sharing markets. The theory of the firm will provide a better conceptual base than efficient market theory. The new market structures will involve principal-agent relationships characterized by significant transactions costs. The insights of Williamson and North will be every bit as important as those of Stiglitz and Markowitz.

Much remains to be learned about how production contracts affect a farmer's exposure to risk. What are the interactions between production contracts and more traditional risk management instruments? Might optimally diversified portfolios include both spot marketed and contracted agricultural commodities? How can farmers effectively manage relationship risk?

*Environmental*

Knutson *et al*. recently reported risk perceptions from a series of focus group meetings held in Texas and Kansas with farmers, agricultural lenders and agribusiness representatives. The participants listed price risk, yield risk, and input cost risk as the three most important sources of risk with which they were faced. Agricultural economists have conducted extensive research in each of these areas. Following closely behind the first three sources of risk were changes in environmental regulations (number 4) and unforeseen litigation (number 5). We have contributed much less to a body of knowledge on these issues.

In recent years, changing environmental legislation and regulations have had a tremendous effect on farmers. From the Endangered Species Act to various wetlands protection laws, farmers have seen increased federal restrictions placed on their farming activities. Most states have also imposed restrictions such as those related to the storage and handling of petroleum products. Even now the Environmental Protection Agency (EPA) under the authority of the Food Quality Protection Act is reassessing all pesticides labeled for use in the U.S. As a result, many expect a significant curtailment in pesticides labeled for agricultural use. Under the authority of the Clean Water Act, efforts are underway to collect and digitize information on every watershed in the United States. This information will, no doubt, be widely used in future environmental litigation.

For farmers, the once external cost of negative environmental impacts (either intentional or accidental) is increasingly being internalized. The potential costs, either in fines imposed by regulatory agencies or court judgments resulting from litigation, are tremendous. In an enterprise that requires such close interaction with soil and water, even careful and environmentally-conscious farmers are faced with the potential for serious mishaps. How can farmers protect their business enterprise from environmental liability risk? Will the environmental liability insurance products that have evolved for the nuclear power or hazardous waste disposal industries one day be applied to agriculture? Due to joint liability concerns, will the agribusinesses to which farmers are tied through, for instance, production contracts one day require those farmers to carry environmental liability insurance? As has happened previously in our history, will we see farmers form insurance cooperatives to provide needed insurance protection? Will the behavioral signals sent by private sector environmental liability insurance reduce the need for command-and-control government regulation -- or is the relationship complementary? These, and many similar questions, have important implications for the long-run business risk facing farm enterprises. We have much work to do on these issues.

If our research results are to remain relevant to agricultural producers we can no longer focus strictly on yield and production risk associated with traditional commodities traded in spot markets or futures exchanges. We must better understand the risk implications of genetic technologies and the relationship risk inherent in production contracts. We must also understand environmental liability risk. Finally, we must struggle with how to include all of these items into a broad portfolio-based analysis of farm-level risk exposure.

## Conclusions

We believe that past research into agricultural risk management issues has made a significant contribution to understanding producer risk management. Theoretical advancements have contributed to our understanding of portfolio trade-offs, optimal input and output decisions, and the use of instruments such as futures and insurance. Advances in the ability to quantify risk with more robust methodologies also contribute to the information available for producers. Research has also contributed to the development of new instruments and provided evaluation of alternatives which confront producers.

There are, however, areas sorely in need of further research. This stems from issues that have not been fully addressed in the past and because new issues continue to arise. We identify five general areas which we believe merit further attention.

- Improving the quality of data and techniques to evaluate risk issues
- Further investigation of producer decision making
- Work to reconcile disagreements regarding market efficiency
- Conduct analysis of new strategies and instruments
- Examine the risk implications of new technology, contractual relationships, and environmental liability.

Progress in these areas should contribute significantly to our understanding of risk management and the information that agricultural economics may provide to producers.

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Table 1. Comparison of Selected Farm and County Yield Standard Deviations

| Location | Standard Dev. of farm yield / Standard Dev. Of county yield | Standard Dev. of farm yield |
|---|---|---|
| | Corn | |
| Iroquois County, Illinois | 1.336 | 28.30 |
| Anderson County, Kansas | 1.43 | 31.23 |
| Lincoln County, Nebraska | 2.36 | 22.9 |
| Pitt County, North Carolina | 2.15 | 35.04 |
| | Soybeans | |
| LaSalle County, Illinois | 1.49 | 8.36 |
| Wright County, Minnesota | 2.17 | 11.22 |
| Yahoo County, Mississippi | 2.01 | 9.57 |
| DeKalb County, Missouri | 1.68 | 10.23 |
| | Wheat | |
| Madison County, Illinois | 1.71 | 19.03 |
| Logan County, Kansas | 1.60 | 13.52 |
| Alfalfa County, Oklahoma | 1.99 | 11.51 |
| Hunt County, Texas | 2.37 | 15.22 |

Source: Coble and Heifner

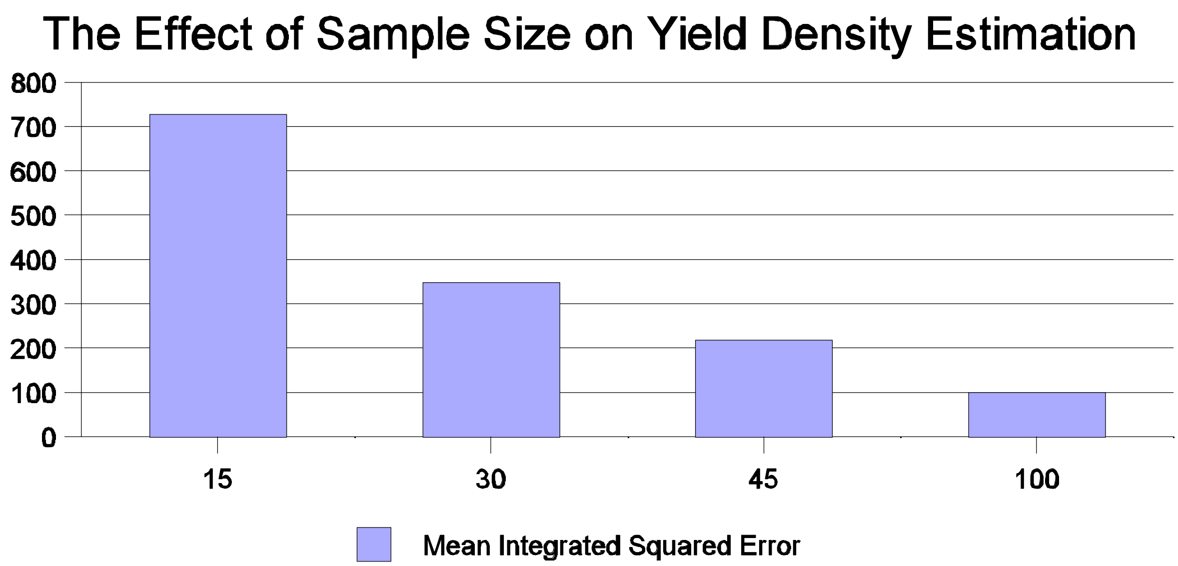


Figure 1. Source: Ker and Coble

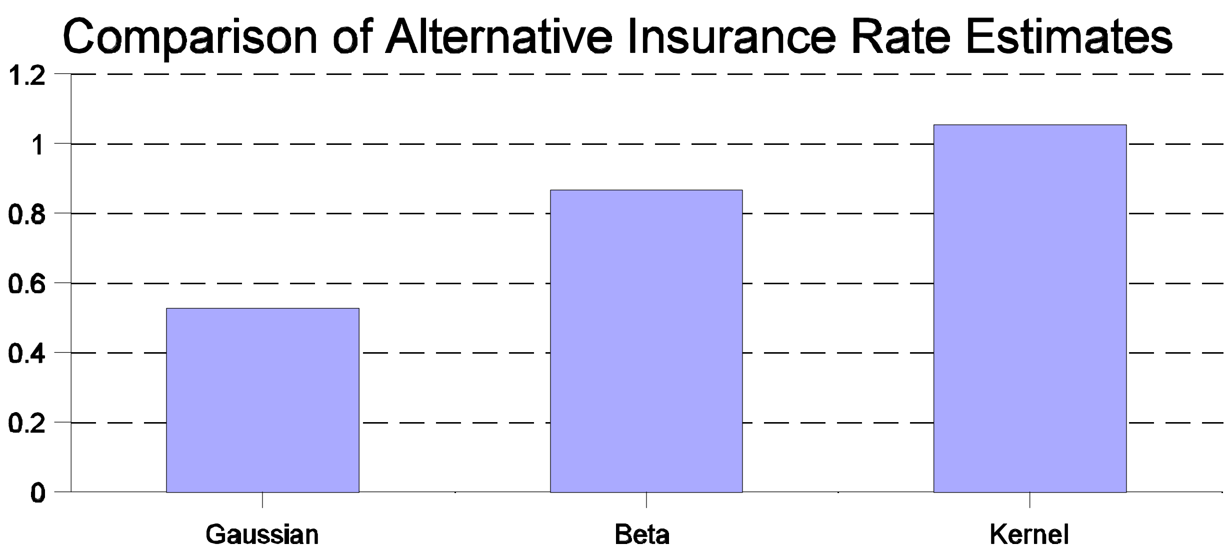


Figure 2. Source: Ker and Coble

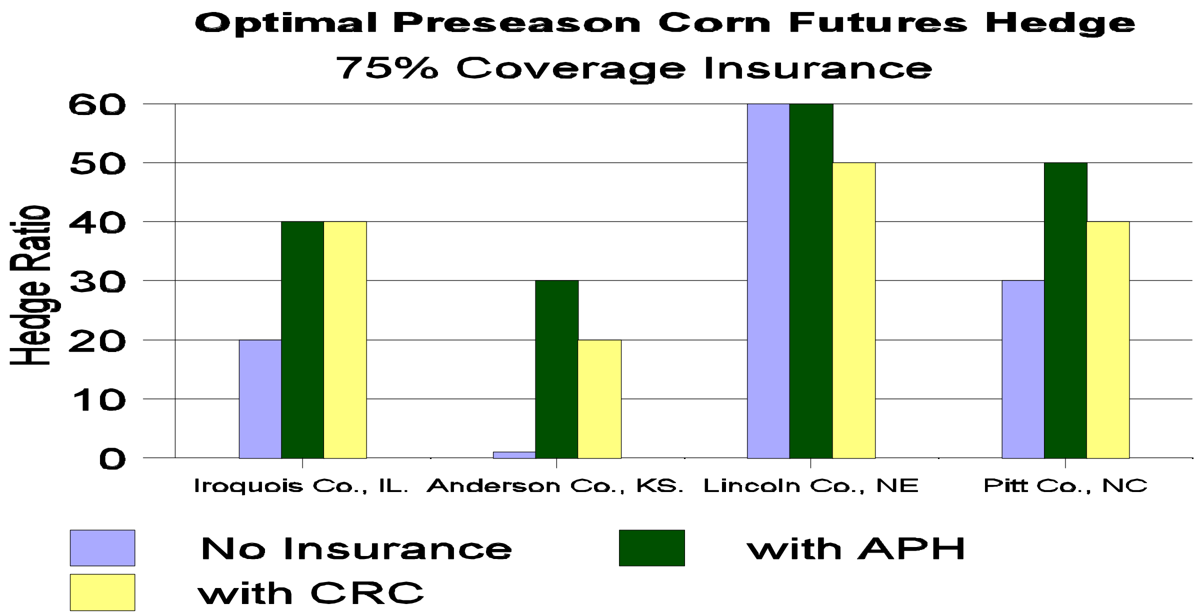


Figure 3. Source: Coble and Heifner