IMPACTS OF CROP INSURANCE AND CROP DIVERSIFICATION ON FARM INCOME AND EQUITY GROWTH IN NORTH CENTRAL OKLAHOMA

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INTRODUCTION

With the passage of the 1996 Federal Agricultural Improvement and Reform (FAIR) Act, came new decisions for agricultural producers. The new farm plan gave farmers more flexibility with respect to cropping choices. New crops can now be grown on farms previously not producing the particular crop without risking the loss of government payments, as would have occurred under the 1990 farm plan. The replacement of market deficiency payments with loan deficiency payments may increase agricultural producers exposure to income variability. Thus, the government has encouraged farmers to purchase crop insurance to limit their exposure to income risk. The new plan replaced agricultural market deficiency payments with declining transition payments. The FAIR Act and the 1994 Federal Crop Insurance Reform Act provided for an expansion of federally supported crop insurance.

The change in policy provides farm operators new risk management tools in the form of crop insurance. Several crop insurance pilot programs were developed and offered to farm operators in an attempt to provide income risk management tools in addition to all risk yield insurance. Several pilot programs have become successful insurance policies now available for most crops in most areas. The current government program offers incentives in the form of premium subsidies to increase farmer participation in the crop insurance program. Government payments currently received are a temporary income enhancement. The payments do not reduce income variability, but provide a financial stress buffer during the transition period. If these government payments cease, the only guaranteed government assistance will be subsidized crop insurance.

Agricultural producers are now producing new crops to enhance farm income. This is a response stimulated by the low commodity prices resulting from fewer setaside acres accompanying the FAIR Act and simultaneous high aggregate yield levels for several consecutive years. The downturn in prices has caused some producers to seek new crops that can meet the financial obligations and goals of the farm business. Agricultural producers who take advantage of the cropping flexibility allowed under FAIR have new risks to analyze. Foremost, production of a new crop will impact farm income both in magnitude and variability or risk. Production and price risk determine the variability of income associated with a crop.

Business risk is the aggregate of all uncertainties that influence the profitability of the firm, independently of the way in which it is financed. The business risk faced by a farm is a combination of production, price, human, and institutional risks. Production and price risks are the primary variable components of business risk influencing farm income. Production risk may be hard to estimate for a new crop. If the crop has not been grown in the immediate area for some time, it is difficult to ascertain the expected yield and yield variability of the new crop. Price risk results from the variability of commodity prices. Increased price variability results in increased income variability, ceteris paribus. If regional production of the crop is insignificant in aggregate production, the yield-price correlation may be near zero or positive, increasing the income risk relative to a location with strong negative yield-price correlation.

The financial structure of the firm determines the financial risk of the firm. The use of borrowed funds as a source of capital requires a share of the operating profits to be allocated to principal and interest payments. As leverage increases a higher percentage of operating profits are required to meet financial obligations. Thus, increasing leverage increases the probability of experiencing cash-flow difficulties or increases financial risk.

There are currently many risk management tools available to agricultural producers. The primary risks they face are production and price risk. Production risk may be managed with federally subsidized crop insurance, area yield futures contracts, and crop diversification. Price risk may be managed by hedging, forward contracting, purchasing futures options, revenue insurance, contracting production with processors, and simply by selling at several different times during the marketing year.

Other significant business risks faced by an agricultural producer include institutional risk and human risk. Institutional risks mainly consist of the government's role in agriculture. Typically, the government subsidizes production, price, or income in one fashion or another, depending on the farm bill at the time. If the business enterprise relies on government subsidies or payments to remain profitable, then the business faces significant institutional risk. The other primary component of institutional risk is the risk created by federal regulations and laws impacting the operations and ultimately the costs of production of the business.

Human risk faced by the farm operation includes the risk of death of the farm operator, but more important to the farms financial success are the decisions and abilities of management and employees. Machinery operators who are capable, dependable, and highly skilled are less likely to cause losses due to carelessness or "poor farming" than are less experienced or skilled machinery operators. The production decisions made by management impact the production risk of a farm through the effects of input or production decisions on yield.

Agricultural producers in North Central Oklahoma have began diversifying, producing new crops, such as soybeans and cotton, to enhance income, reduce risk, or both. Producers interviewed in the area had grown both cotton and soybeans. However, they indicated they would not continue soybean production. Producers are interested in knowing the potential impact of these crops on farm income. Producers also indicated they were uncertain if the benefits of crop insurance justified the purchase, but that capital suppliers desired the purchase of crop insurance.

Problem Statement

A number of agricultural producers in North Central Oklahoma have began producing cotton. Some of these producers and others considering cotton production are uncertain of its impact on the financial position of their business. Producers believe cotton has the potential to enhance income levels at expected yield levels. However, the relatively high variability of cotton yields results in uncertainty of its impact on the farm business. Expanding into cotton production requires producers to make a significant investment in new machinery, thus increasing financial obligations. As debt levels increase, net farm income levels are reduced due to increased capital costs and financial risk is increased. The increased level of financial risk requires the farm firm to reevaluate the levels of production and price risk it is willing and able to bear. Production risk may be managed with the purchase of crop insurance and crop diversification. Price risk can also be managed with revenue insurance, hedging, and options. Agricultural producers in this area need additional information on the effects of crop diversification and the impact of growing cotton on farm income. In addition, they need information on the effectiveness of available crop insurance policies in managing income and financial risk.

Objectives

The primary objectives of this study are to analyze the impact of growing cotton and crop diversification on farm income and to determine the ability of crop insurance to manage risk under given levels of financial stress. Specific objectives are to:

1. Determine the effects of crop diversification on expected income and income variability.
2. Determine the potential effects of crop and revenue insurance alternatives on farm income.
3. Evaluate the effectiveness of risk management alternatives under conditions of low and high farm financial stress.

Procedures

To analyze the effects of crop diversification and crop insurance on farm income the financial transactions of a case farm were simulated through time. To accomplish the analysis a simulation model was developed. The simulation model consists of a financial simulator and a yield and price simulator. The financial simulator uses simulated yields and prices to calculate the costs and returns of each enterprise. The costs and returns of each enterprise are then compiled and entered in financial statements that track the financial position of the farm through time. The yield and price simulator generates intra- and inter-temporally correlated random yields and prices drawn from subjectively specified triangular distributions. These yields and prices are used by the financial simulator to calculate costs and returns.

The analysis conducted examines the impacts of several risk management alternatives on income. Each scenario consists of a crop mix and crop insurance alternative and is evaluated under two debt scenarios. Farm income distributions are then compiled from the simulation output. The farm income distributions from alternatives within debt scenarios are then compared. The importance of the impacts of crop diversification and crop insurance on farm income distributions is evaluated by examining the impacts on equity growth distributions for the planning period. Truncations of farm income distributions are important only if they alter equity growth distributions.

Review of Literature

Weather, insects, diseases, fire, and catastrophic casualties are all sources of production risk. Variability of input and commodity prices leads to market and price risk. Debt acquisition creates a source of financial risk. Government regulations and policies present a source of institutional risk. The farm manager and the farm's employees represent sources of human risk. Thus, the risks faced by a farm operation are many and diverse.

Risk is the chance of adverse outcomes associated with an action, decision, or event (Nelson). Risk can be quantified as the variance of returns over time (McSweeny, Kenyon, and Kramer). Eliminating all risk is impossible due to the uncertainty of future events. Even if total elimination of risk were possible, it would not be desired, as profits associated with taking risks would be eliminated as well. Nelson states, "The key to success is to take on the right risks." The goal of risk management is to manage which risks and how much of each risk the business bears.

Risk is widely recognized as a key factor in farm enterprise choice problems. The focus of the problem is the trade off between expected income and income variability. Income variability is the result of price and yield variability or risks. The production and price risks faced can shift the supply schedule of the farm. The possible shift of the farm's supply curve requires production and price risk to be considered in the decision between enterprises. In this case profit maximization can be replaced with utility maximization (Tomek and Robinson). Tomek and Robinson suggest that with variability in yield and price, or in the presence of yield and price risk, profit maximization can be replaced with expected utility maximization. A farmers expected utility can be estimated by the weighted mean of returns over recent history with the most recent years being more heavily weighted.

Boehlje and Lins identify four mechanisms used to manage risk. Avoidance, reduction, assumption, and transfer are the methods they described. The method of managing risk depends on the nature of the risk involved and the ability of the business to bear that risk. Avoidance is accomplished through changing business structure and operations, so the risk does not exist. Reduction is accomplished by using available technology and knowledge to prevent or curb the effect of events such as pest or disease infestation. Transfer of risk is accomplished through contracts such as insurance, futures, and futures options that transfer the risk to a second party for a set price. Assumption of a risk is accomplished by bearing the risk without reduction, avoidance, or transfer.

Risk management is accomplished through understanding, at least in part, the risks the business faces and making decisions between alternative methods of dealing with those risks. To make decisions between risk management alternatives the decision maker must have some quantification of risk associated with the event. The decision maker's measure of risk can be based on past experience or completely subjective in the absence of historical data.

Barry and Robison propose a broad explanation of risk. They consider a situation risky when an empirical distribution of past outcomes from similar situations can be formulated. Thus, the decision maker has some quantification of the risk involved. However, Barry and Robison distinguish uncertainty as stemming from a lack of information from which to establish a probability distribution. In uncertain situations probability judgments must be made with little or no empirical support. Once the probability distribution of an uncertain situation is subjectively estimated the decision process is the same for uncertain and risky situations. Barry and Robison argue that uncertain events are only significant if they alter the decision makers well being. They propose that risky events interact to form a subset of uncertain events. The decision maker, being neutral towards non-risky uncertain events, is only concerned with risky events.

The decision maker must decide how much risk the business can bear, quantify the risk associated with each alternative, and evaluate the methods of reducing the risks faced by the business. Reducing risks can be accomplished by transferring risk through insurance, removing variability of price with contracts, and diversifying the business enterprises. Alternatives can be rated by risk efficiency when risk preferences of the decision maker are unknown. The optimal alternative can not be determined, but an efficient set of alternatives can be derived by eliminating all alternatives that have a lower mean and higher variance than any other alternative in the original set (Hardaker, Huirne, and Anderson).

King and Oamek surveyed Eastern Colorado dryland wheat farms, obtaining information on government program and crop insurance program participation. They concluded assuming producers to be everywhere risk averse would have been inappropriate. Thus, second degree stochastic dominance techniques for evaluating optimal strategies impose unrealistic assumptions. They reported that the elimination of disaster payments made crop insurance more attractive to producers. However, not all producers would necessarily choose to purchase crop insurance under rational decision analysis.

Zering, McCorkle, and Moore reported that some evidence they discovered would indicate crop diversification is a substitute for crop insurance. They found smaller producer's farms tended to have higher yield variances. Larger farms attain self-insurance through spatial or geographic diversity. They concluded that premiums need to be tailored to a farm's actual production history. Areas of high yields have a higher level of uninsurable production. Increasing uninsurable production increases the amount of risk that is unable to be transferred by crop insurance.

Wright and Hewitt reported that every multi-peril insurance program that has been widely available has been underwritten by a government. Attempts to underwrite multi-peril policies by private companies have all failed according to Wright and Hewitt. There are two common failures of insurance, moral hazard and adverse selection. Both are results of asymmetric information between the underwriter and the insured. Moral hazard is the maximization of one's own utility, while detrimentally effecting the utility of another, in situations when the agent responsible for increased loss does not bear the full consequences (Kotwitz). Moral hazard occurs when the insured does less to prevent losses than he would have if not insured, increasing expected indemnities.

Moral hazard can be prevented if the underwriter can incorporate the effects of moral hazard into the premium structure (Knight and Coble). Chambers concluded that crops may be uninsurable even if information between underwriters and insureds were symmetric, due to the high cost of providing the insurance relative to the risk-spreading benefits provided to farmers. Chambers concluded that moral hazard only decreased the ability of the market to be insured. Hyde and Vercammen reported that false yield reporting by farmers better explained the contract structure of multi-peril crop insurance than the asymmetric input information argument of Chambers. Adverse selection occurs when those with higher expected loss ratios purchase insurance relatively more than those with low expected loss ratios. Knight and Coble suggest adverse selection in crop insurance stems from differences in inherent farm risks, due to differences in resources and management.

Wright and Hewitt argue that the benefits of risk pooling exhibit decreasing returns as risk reduction is achieved through other risk management decisions. Crop diversification, spatial diversity of the farm, off-farm income, and dynamic reallocation of cash flows are indicated by Wright and Hewitt as risk reducing actions that reduce the benefit of insuring against a single year event. Wright and Hewitt's conclusions are consistent with Zering, McCorkle, and Moore's suggestion that diversification is a substitute for insurance.

Just and Calvin reported that actuarially sound premiums for those insured would be higher than for those uninsured of the corn and soybean farms analyzed. Thus, insureds realized a positive effect on expected income, while the uninsured would have realized a negative effect on mean income had insurance been purchased. Goodwin concluded that for sound premium rates to be calculated some measure of farm-level yield variability needs to be incorporated into the premium rate structure. Average farm yield is a weak predictor of yield variability, thus the current premium rate structure of MPCI allows for adverse selection (Skees and Reed).

Coble et al. reported that significant moral hazard existed in the crop insurance market. They found that levels of moral hazard increased in years that growing conditions were not favorable. This behavior is an important actuarial problem. The authors noted a long actuarial history is required to set fair rates that account for increased moral hazard in some years. This suggests moral hazard is an important cause of poor actuarial performance.

Relatively little research has been devoted to the impacts of growing a new crop in a region. This is likely the result of an era in which the farm program restricted the crops and the acreage of crops that could be planted, if the farm desired to receive government payments. The ability of a new crop to enhance farm income is likely due to some comparative advantage a region may have in producing a crop or lower costs of production or transportation.

Production of a new crop has been illustrated to increase farm income for an Indiana corn and soybean farm (Bruner, Dobbins, and Patrick). Their research utilized a combination of field-level yields from yield trial plots for corn and soybeans, while cucumber yields were represented by state average yield data. The variability of state-level yield likely underestimates, while the variability of field-level yield likely overestimates that of farm-level yields. Accurately representing the variability of yield is significant in analyzing the performance of farm-level crop insurance. Greater variability will result in a higher frequency of indemnity payments. Thus, the use of field-level yields will over estimate income variability, while state-level yields will under estimate income variability. Estimating farm-level yield distributions will more accurately represent yield variability of the farm than field or aggregate yield distributions.

There is significant crop insurance literature, mostly evaluating multiple peril crop insurance (MPCI) or yield insurance. Federal crop insurance corporation (FCIC) yield insurance was shown to reduce income variability and allow for more rapid financial growth than would have been possible without the purchase of MPCI for High Plains cotton producers (Lemieux, Richardson, and Nixon). They utilized a stochastic simulation model for yields and prices. A normal distribution was used to represent cotton yields, allowing the range of yields to be over estimated. Crop insurance actuarial adjustments have been made since this study was performed. The impact adjustments made to actuarial tables on the results of the study need to be analyzed. Also, results from other regions may not be directly transferable to the region under investigation in this study.

Carriker et al. found farm-level yield insurance to out perform area yield insurance and disaster assistance programs in income variability reduction. The effectiveness of farm-level crop insurance varied among crops. The authors also noted that farm-level crop insurance suffers from adverse selection and moral hazard. These behaviors could explain why the government subsidized farm-level insurance aggregate indemnity-premium ratio often exceeds 1.

Williams et al. report farmers prefer disaster assistance to crop insurance. This preference is likely due to disaster assistance being cost free. They found that as the variability of farm-level yield increased farm-level crop insurance becomes more attractive. This behavior is consistent with the risk aversion. As the level of risk increases, a risk averse decision maker is more likely to reduce the risk.

Monke attempts to explain why farmers often don't make changes or decisions to limit or minimize current year income risk. The author reports that the impact short-run decisions have on long-run income variability may outweigh the advantages of the rational solutions suggested by farm programming models. The dynamic impact of short-run decisions are not captured by models that analyze only the short run.

MPCI is an effective tool for limiting yield risk. However, MPCI does not limit price risk, which is the other key component of farm income risk. Rarely have revenue insurance policies, crop revenue coverage (CRC) or income protection (IP) been studied. Revenue assurance was found to be more effective in stabilizing farm income of Kansas wheat farms than policies provided in the 1990 farm bill (Gray, Richardson, and McClaskey). This revenue assurance program was not a form of crop insurance, but did have similarities to CRC. Crop insurance was reported to significantly increase minimum revenue, while reducing mean revenue only slightly for the average wheat farm in the Kansas farm database (Duhyvetter and Kastens). Increasing insured yield level as well as buying up to a revenue policy were illustrated to further increase minimum revenue. Duhyvetter and Kastens reported results based on the average farm in their database, using historical prices from 1973 to 1995. This limits the study, because it does not analyze outcomes resulting from price scenarios not seen during that time period. Furthermore, each farm has a unique yield distribution, resulting from unique management and farming practices. Thus, optimal solutions for the average farm may not be directly transferable to each individual farm.

Average indemnity payments for CRC were found to be larger than those for MPCI to corn farms in Iowa (Hart and Smith). This is consistent with the design of CRC allowing for increasing insured values. CRC premiums are based on MPCI premiums plus an additional premium for price flexibility allowed in the policy. It is important to consider the impact of revenue insurance policies as well as yield insurance policies on farm income and income variability, as the price flexibility of CRC may make it more effective than MPCI for managing income risk.

Revenue insurance was illustrated to be more efficient than the 1990 farm program, measured by producer welfare per dollar of government expenditure (Hennessy, Babcock, and Hayes). The efficiency of revenue insurance relative to the 1990 farm program makes revenue insurance attractive from a taxpayer standpoint. However, the impact on farm welfare, a function of revenue, rather than net income was addressed. Focusing on revenue rather than income fails to account for the variability of costs due to yield variability.

Crop diversification is much like diversification of investments in a portfolio. The ability of diversification to reduce risk is tied to the relationships between the enterprises. If two enterprises with similar individual mean returns and risk in terms of variance of returns are examined, the degree of correlation or covariance between the two alternatives determines the risk reduction attainable through diversification (Markowitz). Two investments perfectly positively correlated, thus both receiving their highest (lowest) returns in the same year results in essentially no risk reduction. As the degree of correlation decreases the risk reduction potential increases. Should the two alternatives be negatively correlated one would receive relatively high returns when the other received relatively low returns and vice versa (Barry, Hopkin, and Baker). This results in less variable returns without significantly reducing the expected level of returns.

With diversification the gains of risk reduction are achieved through the forgoing of any reductions of costs that would be attainable due to economies of scale (Barry and Robison). Thus, one gives up maximum returns in order to reduce the chance of receiving low returns, in essence accepting lower, less variable returns. In cases where alternatives are not strongly positively correlated it is possible to decrease the variability of returns without significantly reducing expected return through diversification (Barry, Hopkin, and Baker and Hirt and Block).

Past research on crop insurance for a diversified farm situation is limited. Often farm-level analyses have not used farm-level data. Yield data are often limited on a farm-level basis. Thus, the use of subjective farm-level yield distributions may be a satisfactory method of representing actual farm-level yield distributions. Existing historical data can be used to aid in the specifation of a subjective distribution estimate.

For the purpose of analyzing a new crop the distribution must be subjectively specified, since empirical data are not available. Most studies have focused on a single crop or a corn and soybean crop mix in the central corn belt. The results of these studies are not directly transferable to the North Central Oklahoma region. Each region should be analyzed separately, because each region has a different set of crops and the relationships between crops is unique. This study quantifies the effects of crop diversification, including a new crop, cotton, and crop insurance on farm income in the North Central Oklahoma region for low and high financial stress situations.

Chapter 2

Model Development

Simulation Background

Simulation models are an important tool used to analyze empirical questions, generate data that is not readily available, and analyze the impact of policy changes on businesses or the economy. Historical data are often limited in existence or availability. Simulation is a flexible tool that can evaluate the performance of alternatives under historical conditions or under possibilities not represented in historical data.

Anderson described a process of model design and implementation. The method began with a goal setting stage. What the model is expected to do must be determined before the model can be designed. The second stage is to determine the relevant structure of the environment to be modeled. All components and features, as well as interactions between components that need to be included in the model, must be identified. The third stage is synthesis of information. The information and ideas developed must be constructed into a coherent and logical structure. Stochastic specification of probabilistic events must be represented in the model. Furthermore, the structure and specification of the model must be programmable. The fourth stage is verification and validation of the model. Verification requires that the model is performing as you expect. Validation requires that the output be checked against historical data or expert opinion to determine the accuracy of the output. The final stage is model analysis. Model analysis consists of sensitivity testing with regard to parameters, model experimentation, and interpretation of results.

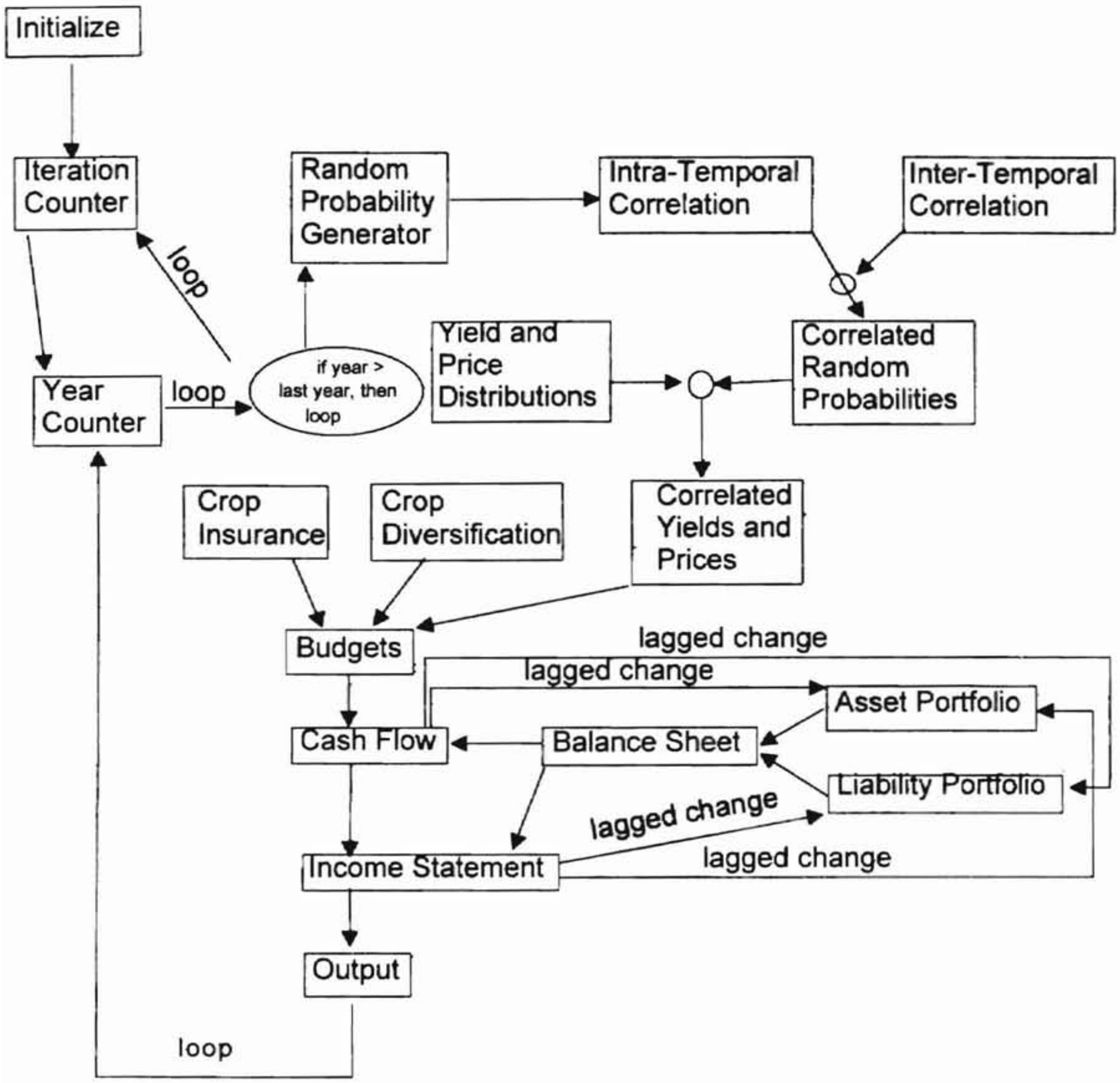
Model Conceptualization

Following the review of simulation literature, conceptualization of a computer model was completed. New and additional risks, from growing a new crop and a new farm plan, are being faced by farmers in North Central Oklahoma. Evaluation of risk management strategies selected in this study, crop diversification and insurance, require the analysis to adequately represent the impacts of risk and the risk management strategies. A model must be stochastic to represent yield and price variability or risk and dynamic to capture the effects of risk and risk management strategies on farm income and equity over time. Incorporating yield and price distributions to represent stochastic yields and prices must be accomplished. The model must record financial transactions and interactions through time to evaluate the impacts of risk and risk management strategies on financial performance.

The following stochastic dynamic farm-level simulation model was conceptualized. The model generates correlated random yields and prices, which are used in crop budgets to calculate costs and returns. The costs and returns calculated in the budgets are entered into the financial statements along with financial data of the farm scenario to calculate financial statements for each simulated year in the planning horizon. The simulation module generates intra- and inter-temporally correlated yields and prices that have approximately the same correlation and auto correlation indicated by historical data. At the end of the planning horizon the model resets all values to their original values (recursive), to simulate a specified number of iterations of the planning horizon. The output simulated by the model consists of annual financial statements and the correlated random yields and prices. The conceptualized model structure is diagrammed in figure 1.

The program completes financial statements for each consecutive simulated year of each iteration. The financial model is dynamic, capturing the immediate and lagged effects of revenue variability on farm income and equity growth. The use of a dynamic financial simulation model captures the effects of yield and price variability on the financial position and profitability of the farm over time. The dynamic interactions between yield and price variability and farm income are more accurately determined by a model that accounts for the effects of borrowing and saving over a planning period. Yield and price variability result in revenue and cost variability. Revenue and cost variability translate into income and equity growth variability. The resulting effects of yield and price variability on income and equity growth variability are impacted by the ability of farmers to spread income over multiple years through saving and borrowing activities. Furthermore, prices tend to go through cycles, adding to the dynamic nature of farm income.

Figure 1. Financial Model Flow Chart



Model Implementation

Financial Simulator

The underlying farm-level financial module is a spreadsheet based program that integrates user supplied information including assets, liabilities, budgets, and simulated yields and prices to construct the balance sheets, cash flow statements, and income statements for the farm scenario. The financial statements generated in the model were designed from those presented in Oklahoma State University Extension fact sheets and used in the Integrated Farm Financial Statements (IFFS) software package. The program generates financial statements that record the financial transactions and position of the farm firm as the model simulates a planning horizon. The effects of financial transactions during a simulated year are recorded when the ending balance sheet is calculated.

Budgets for each enterprise in the farm scenario are entered by the user. The budgets include per acre costs and per unit costs that vary with yield. Machinery operations are included in the budget and allow costs and returns to vary for different farming practices. Crop insurance selections are made in the budgets and the costs of the selected policy are calculated and entered into the budget for each year in the simulation. The correlated random yields and prices generated in the yield and price simulation module are used in the budgets. The revenues and costs from each enterprise resulting from the simulated yield and price scenario are entered into the cash flow in the appropriate month. The use of the simulated yields and prices in the budgets incorporates the effect of yield and price variability on farm income.

Information entered for assets and liabilities is used to construct the balance sheet. The balance sheet contains asset values, outstanding loan balances, accrued interest, contingent liabilities, and other liability values. The balance sheet is used to report the net worth of the business at a particular point in time. The cumulative effect of past financial transactions is quantified by the balance sheet, but it does not report how the financial position was achieved. The balance sheet records the value of all assets and liabilities, thus the liquidity and solvency of the financial position is captured on the balance sheet. Information provided for assets entered in the farm scenario includes cost, salvage value, useful life, and depreciable life if the asset is a depreciable asset. Machinery items are replaced during the simulation when their useful life expires. At the time of replacement a loan is created for the net cost of the machinery item with a 5-year repayment period. Asset purchases are assumed to occur at the beginning of each year. Tax basis and managerial depreciation is calculated for each asset. Managerial depreciation is entered on the income statement as an expense. Tax basis depreciation is used to calculate the cost basis column of the balance sheet, which is used in the calculation of contingent tax liability. Liability and loan information entered includes outstanding balance, interest rate, payment frequency, and number of payments remaining. This information is used to calculate the outstanding balances on liabilities and loans and accrued interest on loans. Liability payments are entered on the cash flow in the appropriate month. Changes in asset and liability inventories during the year are determined by subtracting balance sheet beginning values from ending values and entered on the income statement. Changes in asset and liability inventories are used as an accrual adjustment of the income statement.

The cash flow statement records the financial transactions of the farm business throughout the planning period. The amount and timing of all cash inflows and outflows are recorded by the cash flow statement. The cash flow statement calculates line of credit borrowing required to make cash payments incurred during the year when cash reserves will not cover those expenses. Thus, the cash flow records the additional interest expense incurred as a result of low revenue years. Furthermore, the cash flow records and carries the ending cash balance and outstanding line of credit balance forward to the beginning of the next simulated year. Thus, the cash flow captures the impacts of yield and price variability on the dynamic financial interactions of the farm business.

The income statement is a compilation of information contained on the balance sheet and cash flow statements. The income statement uses the information imported to calculate the profit or loss to management, unpaid labor, and equity. The farm income figure is the result of farm revenues less cash expenses, with accrual adjustments for depreciation and asset and liability inventory changes incurred during the planning period. The income statement incorporates beginning asset and liability values, cash transactions during the planning period, and the effects of those transactions on the ending asset and liability values to calculate profitability or income of the farm business during the planning period.

The interaction of the financial statements records the financial transactions of the business and their impact on financial position. The costs and revenues are calculated by budgets and are recorded on the cash flow. The cash flow records the timing of all cash inflows and outflows. When cash reserves are not great enough to pay cash expenses incurred during a period of time the cash flow calculates line of credit borrowing and interest expense. The ending cash balance and line of credit balance are recorded on the balance sheet. The balance sheet records the total accrued interest and remaining loan balances, as well as depreciation and asset acquisitions. The income statement then summarizes the cash flow and makes accrual adjustments of changes in asset and liability balances to more accurately report farm income.

To analyze the effects of crop insurance on farm income, the benefits and costs of crop insurance are calculated in the model. Thus, the actuarial tables for the insurance alternatives are entered into the model. The model uses the historical yield of the farm entered by the user and simulated yields and prices to calculate premiums and indemnities. Premiums and indemnities are calculated from equations published by the FCIC. Premiums fluctuate with historical yield and planting time harvest price estimates. To account for changing historical yield levels the model recalculates actual production history (APH) yields of the farm for every simulated year. A minimum of 4 years and a maximum of 10 years are used to calculate the APH yield. Farms with less than 4 years of yield data are required to use transitional yields established by the FCIC for years APH yields are not available. The crop insurance premiums and indemnities calculated in the program are entered directly into the cash flow statement. Thus, the dynamic effects of income stabilization attained with crop insurance are captured in the financial model.

Yield and Price Simulator

There are many ways of representing the distributions of yields and prices in simulation models. Procedures developed for specifying distributions such as the normal have been adapted to work for empirical and other non-normal distributions. Clements, Mapp, and Eidman illustrated a procedure for correlating random variables, but the procedure is limited to normally distributed variables. The procedure factors the upper triangular square root of the symmetric variance-covariance matrix. The upper triangular square root matrix is multiplied by a matrix of random normal deviates. The resulting correlated normal deviates are used to calculate the value of each variable from its respective normal distribution. The method they described for factoring the variance-covariance matrix is directly transferable to the correlation matrix.

Richardson and Condra proposed a procedure for simulating non-normal correlated random prices. Their methods built on the foundation work of Clements, Mapp, and Eidman, but used the correlation matrix rather than the variance-covariance matrix. The correlated normal deviates generated were converted to uniform(0,1) probabilities using the standard normal probabilities table. Correlated random variable values were then drawn from the cumulative distribution functions using the correlated uniform(0,1) probabilities. King reported a very similar procedure commonly known as the King Process Generator. The procedure described by Richardson and Condra drew correlated random variables from an empirical distribution, thus avoiding normality assumptions. Making normality assumptions and the assumption that yields and prices are random ignores unique aspects of agricultural firms including non-normally distributed yields and prices, intra-temporal correlation of yields and prices, and inter-temporal correlation of prices (Richardson, Klose, and Gray).

A method of adding inter-temporal correlation to the procedure published by Richardson and Condra was reported by Richardson, Klose and Gray. The method factors the square root matrix of the correlation matrix of each variable and its lagged values. This matrix is factored as described by Clements, Mapp and Eidman. The resulting square root of the inter-temporal correlation matrix of each variable is multiplied by a vector of intra-temporally correlated random standard normal deviates of each variable yielding the completely correlated standard normal deviates. The completely correlated standard normal deviates are used to calculate the uniform(0,1) probabilities. These probabilities are used to determine each variable's value from its cumulative distribution function (CDF). They used empirical distributions of each variable's deviations from the mean. Using completely correlated deviates allows the model to account for trends in yields and prices. Trends are entered into the model by adding the simulated deviate to the trend adjusted mean for each year simulated. This procedure allows for the simulation of variables through time in a manner consistent with historical auto correlation of prices. Both intra- and inter-temporal correlation relationships between variables are maintained. More realistic yield and price patterns are simulated than when using intra-temporal correlation procedures alone. The procedure outlined uses an empirical distribution for yields and prices. Thus, the procedure can be used with any distribution for which the CDF can be calculated.

Maintaining realistic correlation relationships between variables is important in simulating realistic yield and price scenarios. Heifner and Coble reported a method of estimating farm-level yield-price correlation coefficients. Adequate farm-level yield data are often not available. Thus, estimating farm-level relationships is often the best that can be done. Their method relied on the theory that the sum of the covariances of two variables with a third variable is equal to the covariance of their sum with the third variable. The three variables considered are farm yield, aggregate yield, and price.

Estimates of farm-level yield-price correlation coefficients are derived by multiplying aggregate yield-price coefficients by the farm-aggregate yield coefficient. The method relies on historical aggregate yield-price correlation coefficients which may have been influenced by farm policy. Heifner and Coble point out that ignoring farm-level yield-price correlation can result in setting revenue insurance premiums too high.

In this study, a simulation model was designed in Microsoft Excel utilizing the Visual Basic for Applications programming language and editor included in the software. The model uses a recursive non-parametric Monte Carlo simulation technique. It's recursive characteristic refers to each iteration simulating consecutive years, resetting user entered beginning financial values and simulating the next iteration. The model incorporates correlation between random variables (intra-temporal) as well as inter-temporal correlation of random variables.

Yield data available for cotton were sufficient to establish likely minimum and maximum yield values. However, the yield data available for cotton were too limited to accurately estimate an empirical distribution. When evaluating a relatively new crop in a region it is unlikely that existing yield data accurately represent the yield distribution. The empirical distribution created from observations in the first few years may not be representative of expectations due to the learning curve associated with growing a new crop and the extraordinary impact of individual years. The lack of farm yield data for a new crop in an area requires assumptions about the yield distribution for that crop. An empirical distribution requires several observations in order to accurately represent the underlying yield distribution. Assuming the yield to be normally distributed over estimates the probability of yields represented in the tails of distribution outside of the attainable maximum and minimum values indicated by historical observation. Thus, if a normal distribution is used it must be truncated. A triangular distribution effectively sets maximum and minimum yields. Thus, it does not over estimate the range of yields, as is likely with the normal. The triangular distribution lends itself well to being subjectively specified, which is required since farm level cotton yields are available for only three years. Historical yield and price distributions are typically skewed. The triangular distribution is easily specified, maintains the skewed property of the empirical, and fit the data well. The model developed for this analysis uses the methods of generating correlated variables reported by Richardson, Klose, and Gray. A triangular distribution is used for yields and prices in place of the empirical distributions ignoring trends in yields and prices. This alteration was made because farm-level cotton yield data were too limited to specify an empirical distribution consistent with extension specialists expectations. Every farm has a unique set of yield distributions, resulting from unique soil profiles, management concepts, agronomic decisions, and machinery operating abilities. It is important to use a distributional form that will represent unique farm-level yield distributions.

The random variable correlation process uses the upper triangular matrix of the symmetric correlation matrix (illustrated in equation 1) of yield and price variables to intra-correlate random deviates of the standard normal distribution. The correlation matrix is factored as illustrated by Clements, Mapp, and Eidman for a covariance matrix. The factoring process was applied to the correlation matrix by Richardson and Condra. The resulting triangular matrix is the matrix square root of the correlation matrix $(\rho^{.5}_{i_k, j_n})$. For this study three crop yields and three prices for each crop were simulated, requiring factoring of a 12 x 12 correlation matrix. A correlation matrix for each of the yield and price variables and its twice lagged values are factored in the same fashion.

(1) Intra-Temporal Correlation Matrix for Yield and Price Variables

$$\rho_{i_k,j_n} = \begin{bmatrix} 1 & \rho_{(x_{11},x_{12})} & \rho_{(x_{11},x_{13})} & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \rho_{(x_{11},x_{34})} \\ & 1 & \rho_{(x_{121},x_{13})} & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ & & 1 & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ & & & 1 & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ & & & & 1 & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ & & & & & 1 & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ & & & & & & 1 & \cdot & \cdot & \cdot & \cdot & \cdot \\ & & & & & & & 1 & \cdot & \cdot & \cdot & \cdot \\ & & & & & & & & 1 & \cdot & \cdot & \cdot \\ & & & & & & & & & 1 & \rho_{(x_{32},x_{33})} & \rho_{(x_{32},x_{34})} \\ & & & & & & & & & & 1 & \rho_{(x_{33},x_{34})} \\ & & & & & & & & & & & 1 \end{bmatrix}$$

(2) Inter-Temporal Correlation Matrix for each Yield and Price Variable

$$\rho_{i(t,t-1)} = \begin{bmatrix} 1 & \rho_{(i_t,i_{t-1})} & \rho_{(i_t,i_{t-2})} \\ & 1 & \rho_{(i_{t-1},i_{t-2})} \\ & & 1 \end{bmatrix}$$

The factored matrix (represented in equation 3) represents the square root of the symmetrical intra-temporal correlation matrix. Factoring large correlation matrixes can be difficult and an infeasible solution is may occur. An infeasible solution results when the calculation requires the square root of a negative number. Thus, intra- and inter-temporal correlation procedures are separated, requiring the factoring of several smaller matrixes rather than one very large matrix. Combining procedures requires factoring a matrix that includes each variable and its lagged values.

(3) Factored Intra-Temporal Correlation Matrix (12 x 12)

(3.1) $psqrt_{i_k j_n} = \rho^{.5}_{i_k,j_n}$

(4) Factored Inter-Temporal Correlation Matrix

$$(4.1) \quad psqrt_{i(t,t-1)} = \rho^{.5}_{i(t,t-1)}$$

An array of 12 independent random standard normal deviates (ISNDs) are drawn for each yield price scenario simulated (illustrated in equation 5). For 100 iterations of a 10 year period, 1000 vectors of 12 random deviates must be drawn. This is accomplished by using the "=NORMSINV(rand())" formula in Microsoft Excel for each random standard normal deviate.

(5) ISND vectors

y = year

i = iteration

$$(5.1) \quad VISND_{i,y} = \begin{bmatrix} ISND_{1,i,y} \\ \cdots \\ ISND_{12,i,y} \end{bmatrix}$$

Then the intra-temporal square root matrix is multiplied by the vector of ISNDs (VISNDs). The result is a vector of intra-temporally correlated standard normal deviates (CSNDs illustrated in equation 6). The standard normal deviate representing the user provided beginning value or the previous years value for each variable is then added to the CSND vectors. The vectors of CSNDs are then adjusted by the square root matrix of the symmetric inter-temporal correlation matrix of each individual variable.

$$(6) \quad CSND_{i,y} = VISND_{i,y} * psqrt_{i_k, j_n}$$

The process used differs slightly from the procedure reported by Richardson, Klose, and Gray. The procedure they describe factors an inter-temporal correlation matrix with the number of rows and columns equal to the number of years simulated in each period. Their procedure produces a random first year value for each of the yield and price variables. This may not be ideal if the objective is to examine the likely occurrences of a period of consecutive years beginning at a specific point in time. To allow for this modification starting values representing the previous years levels are entered in the model. The model calculates the standard normal deviate associated with each beginning value and uses those deviates as the first value in the CSND vectors. Instead of factoring an inter-temporal correlation matrix for each variable with the dimensions of the planning horizon, matrixes with lagged values representing only those orders of autocorrelation assumed to be significant are factored. The third and higher orders of autocorrelation are assumed to be zero for the variables. In this case it allows a 3x3 matrix to be factored instead of a 10x10 matrix. Next, matrixes are constructed that can be multiplied by the smaller inter-temporal square root matrix. A matrix is constructed for each variable for each simulated year. Each matrix consists of the CSND for that year and the two previous years. These vectors are then multiplied by the first row of the square root matrix of the respective inter-temporal correlation matrix. The result is an intra- and inter-temporally correlated standard normal deviate for each variable for each simulated year. The resulting intra- and inter-temporally correlated deviates of the standard normal are converted to uniform(0,1) probabilities, using a standard normal probability chart.

The correlated uniform probabilities generated are then adjusted by a linear equation (illustrated in equation 7) where the final uniform(0,1) probability is a function of the generated uniform(0,1). The purpose of this adjustment is to control the probability of receiving the maximum or minimum values specified in the triangular distribution. If the probabilities are not adjusted, the probability of reaching the maximum and minimum values known to be attainable is zero. The probability of reaching a maximum or minimum value has been set to approximately five percent, the probability indicated by historical data. The values obtained from the adjustment equation are truncated so that for F(p) the minimum and maximum attainable values are 0 and 1 respectively.

(7) $F(p) = -.055556 + 1.111111p$

The resulting adjusted uniform(0,1) probabilities are then used to calculate the value of each yield and price variable for the simulated year. The model uses a triangular distribution, which can be solved for the value of the variable given a probability (0<p<1). (illustrated in equation 8). The probability of each variable is inserted in the respective triangular distribution equation, which returns the value of the variable for the given probability.

(8) Triangular Cumulative Distribution Function

$$l = \text{lowest value}$$
$$u = \text{highest value}$$
$$m = \text{modal value}$$
$$p = \text{probability}$$

(8.1) If $p < .5$, Then $F(p) = l + [p(u-l)(m-l)]^{.5}$

(8.2) If $p > .5$, Then $F(p) = u - [(1-p)(u-l)(u-m)]^{.5}$

The outlined procedure generates completely correlated, intra- and inter-temporally correlated, random yields and prices used in the financial module. The financial module calculates the financial statements of the farm based on the revenue and costs associated with the simulated yields and prices. The simulated financial statements can then be used to summarize farm income and financial growth of the farm.

Model Verification and Validation

Once a working version of the model was programmed the actions and interactions of the model and its components were audited. The tests simply verified that the model was making calculations correctly and operating as intended. Following the verification process the model was validated. The validation process consisted of comparing simulated yields and prices with distributions and correlation matrixes entered in the model and comparing financial output to IFFS financial statements. A trial simulation was run to test the model. The trial simulated a three year period for a test case farm. The simulation output was analyzed and compared with expected yield and price distributions and historical correlation coefficients. The model generated yield and price distributions nearly identical to those entered in the model. Expected and simulated yield and price distributions are represented in table 1.

Table 1. Expected and Simulated Yield and Price Distribution Statistics

	Expected				Simulated			
Variable	mean	maximum	minimum	modal	mean	maximum	minimum	modal
CT yield	552	1000	150	505	566	1000	150	547
CT season average price	0.55	0.77	0.40	0.49	0.56	0.77	0.40	0.50
CT plant futures	0.67	0.85	0.47	0.70	0.69	0.85	0.47	0.75
CT harvest futures	0.67	0.89	0.48	0.65	0.68	0.89	0.48	0.66
GS yield	74	150	27	46	72	150	27	39
GS season average price	2.39	3.44	1.49	2.23	2.33	3.44	1.49	2.06
GS plant futures	2.56	3.60	1.61	2.46	2.57	3.60	1.61	2.51
GS harvest futures	2.48	3.73	1.62	2.08	2.47	3.73	1.62	2.04
WW yield	40	66	18	37	42	66	18	42
WW season average price	3.33	4.75	2.25	2.98	3.29	4.75	2.25	2.86
WW plant futures	3.58	4.88	2.37	3.50	3.46	4.88	2.37	3.13
WW harvest futures	3.48	4.30	2.40	3.73	3.43	4.30	2.40	3.58

The intra- and inter-temporal correlation of random variables simulated was not identical to the correlation matrixes input into the model. However, the sign of all significant coefficients was consistent and the magnitudes of the correlation coefficients wwere similar to historical correlations of variables. The stochastic structure of the model prevents correlation matrixes of simulated variables from being identical to those entered in the model. Expected and simulated intra-temporal correlation coefficients are presented in table 2. The inter-temporal correlation procedure yielded correlation coefficients between lagged values of variables similar to those indicated by historical data. Expected and simulated inter-temporal correlation coefficients for season average prices are presented in table 3.

Table 2. Simulated and Expected Intra-Temporal Correlation Coefficients

Expected						Simulated				
	CT	CT Prc	CT plnt	CT harv			CT	CT Prc	CT plnt	CT harv
CT	1.00					CT	1.00			
CT Prc	-0.38	1.00				CT Prc	-0.27	1.00		
CT plnt	-0.02	0.30	1.00			CT plnt	0.02	0.28	1.00	
CT harv	-0.26	0.89	0.49	1.00		CT harv	-0.17	0.87	0.44	1.00

	Wht	Wht Prc	Wht plnt	Wht harv			Wht	Wht Prc	Wht plnt	Wht harv
Wht	1.00					Wht	1.00			
Wht Prc	-0.39	1.00				Wht Prc	-0.51	1.00		
Wht plnt	-0.03	0.46	1.00			Wht plnt	-0.47	0.55	1.00	
Wht harv	-0.13	0.81	0.63	1.00		Wht harv	-0.53	0.82	0.73	1.00

	GS	GS Prc	GS plant	GS harv			GS	GS Prc	GS plant	GS harv
GS	1.00					GS	1.00			
GS Prc	-0.32	1.00				GS Prc	-0.36	1.00		
GS plan	-0.22	0.46	1.00			GS plant	-0.27	0.43	1.00	
GS harv	-0.42	0.91	0.48	1.00		GS harv	-0.42	0.91	0.45	1.00

	Wht	GS	CT			Wht	GS	CT
Wht	1				Wht	1		
GS	-0.38	1			GS	-0.09	1	
CT	0.29	0.05	1		CT	0.02	0.01	1

Table 3. Expected and Simulated Inter-Temporal Correlation Coefficients of Prices

Expected				Simulated			
Lag	Wht Prc	GS Prc	CT Prc	Lag	Wht Prc	GS Prc	CT Prc
1	0.47	0.17	0.11	1	0.32	0.17	0.16
2	-0.23	-0.04	-0.08	2	-0.16	-0.07	-0.05

The financial statements of the model were compared to IFFS financial output. Simulated yields and prices were used in IFFS budgets to check the financial results of the model. Costs and returns calculated in the model were the same except for interest. The model assumes that line of credit payments are made at the end of the month and that line of credit borrowing occurs at the beginning of the month. IFFS assumes a mid-month timing of borrowing and repayment transactions for the line of credit. The differences in interest calculations were minuscule. All other figures on the balance sheet, cash flow, and income statement were consistent with IFFS output.

Chapter 3

Analysis

Farm managers have several risk management tools available. In the case of price risk, futures and options, contracting production, spreading sales over time, revenue insurance, and selecting low price risk enterprises are methods of reducing price risk. Production risk can be managed by transferring risk through insurance, diversifying with respect to enterprises, selecting low risk enterprises, using risk reducing production practices, and diversifying spatially. Thus, farm managers have many risk management tools they can employ to manage production and price risk. The current research project focuses on the use of crop insurance and crop diversification.

The analysis compares combinations of crop diversification and crop insurance alternatives. Three cropping strategies wheat, wheat and grain sorghum, and wheat, grain sorghum, and cotton are considered. Each crop mix is considered in the presence of five crop insurance alternatives and without crop insurance. The comparison is based on the distributions of farm income received from each crop mix and insurance scenario. Farm income distributions are derived from simulated financial output. The mean and variance of simulated farm income is compared among risk management scenarios.

Data, Methods, and Procedures

Since, there is no farm record association in Oklahoma and producer contacts are very limited, it is difficult to obtain farm-level yield data directly from agricultural producers. However, yield data from individual producers are recorded by crop insurance companies each year as required by the FCIC. Thus, field-level yield data were obtained from crop insurance agents in North Central Oklahoma for wheat, grain sorghum, and cotton. Ten, eight, and three years of yield data were available for wheat, grain sorghum, and cotton respectively. The available cotton yield data contained field-level yields that reinforced confidence in expert estimates of minimum and maximum yields, but was not sufficient to estimate reliable empirical distributions of farm-level cotton yields.

Available farm level yield data and subjective distribution estimates obtained from extension specialists were used to create subjectively specified triangular distributions for yields. Season average prices for Oklahoma were obtained from the National Agricultural Statistics Service (NASS) for the marketing years of 1980 through 1998. Futures price data were collected for the same period and planting and harvest price averages were calculated as published by the FCIC. The historical price data were then used to calculate triangular distributions for each of the price variables. The parameters of the triangular distributions used are summarized in table 1.

Correlation between yields and prices was estimated from county level data. Canadian County was considered to be the closest county with historical cotton yield data and similar yield patterns. County-level correlation coefficients were used to estimate farm-level coefficients, because farm-level correlation coefficients associated with cotton yield would be unreliable given the limited number of observations for cotton yield. The three years of cotton yield data available were not sufficient to accurately estimate the long run correlation of cotton yield with the other variables.

The appropriate budgets, asset and liability information, crop distributions, and correlation matrixes were entered into the computer model for each of the 44 scenarios.

100 iterations of a ten year planning horizon were simulated, yielding 1000 observations of farm income for each scenario. The simulated data were then used to evaluate each of the scenarios.

Scenarios

Three crop mix alternatives are analyzed for the farm scenario. A wheat only crop mix is used as the base case crop mix. A 2/3 wheat and 1/3 grain sorghum crop mix is the second alternative. This crop mix is the most common crop mix of diversified farms in the region. The final crop mix scenario includes 1/2 wheat, 1/3 cotton, and 1/6 grain sorghum. These crop mix alternatives allow the evaluation of crop diversification and growing cotton to enhance income or manage risk for a North Central Oklahoma wheat farm.

Three crop insurance policies are evaluated in this study. Multiple Peril Crop Insurance (MPCI), Crop Revenue Coverage (CRC), and Catastrophic (CAT) Insurance are evaluated. MPCI offers protection against low farm-level yields. MPCI offers comprehensive protection against low yields, poor quality, late planting, replanting costs, and prevented planting due to adverse weather, fire, hail damage, wind damage, plant disease, insect damage, earthquake, and wildlife. MPCI is available on more than 60 crops in primary production areas throughout the U.S.. MPCI is available at coverage levels from 50 to 75 percent (in 5 percent increments) of the approved yield for a farm. The indemnity price election for the insured crop can be selected from 60 to 100 percent of the Federal Crop Insurance Corporation's (FCIC) expected market price.

Catastrophic risk protection (CAT) is the completely subsidized level of MPCI. It offers coverage equal to 50 percent of the approved yield and an indemnity price of 55 percent of the FCIC expected market price. CAT coverage is essentially without cost to agricultural producers, requiring only a $60 administrative fee per crop per county.

Crop Revenue Coverage (CRC) is one of the insurance policies resulting from the new farm plan. CRC provides both price and yield coverage by insuring a revenue level. Farm operators are guaranteed a minimum revenue in the event of low yields, low prices, or a combination of both. CRC includes limited replacement cost as a benefit, through the increase of the minimum guarantee if the harvest price exceeds the base price of the contract. This allows replacement protection for meeting forward contract requirements in low yield years with prices rising from planting to harvest. The CRC minimum guarantee is established by multiplying the approved yield of the farm by the base price for the crop by the farm operators coverage level from 50 to 75 percent (in 5 percent increments) by the selected price level, either 95 or 100 percent of the base price. The base price is established by calculating a monthly average contract price prior to the typical planting time of the crop using the appropriate futures market. The harvest price is established in the same fashion. The final revenue guarantee is the greater of the minimum guarantee or the harvest guarantee which is calculated like the minimum guarantee with harvest price substituted for base price.

Each of the three crop mix alternatives are evaluated in the presence of six crop insurance alternatives. No insurance or self insurance, CAT coverage, and MPCI and CRC coverage both at the 55% and 75% yield coverage level are the insurance alternatives evaluated. All MPCI and CRC alternatives considered assume the 100%

price election is selected. Four additional cases constructed evaluate the purchase of MPCI and CRC at both levels of coverage for cotton, while purchasing CAT insurance for wheat and grain sorghum. Insuring only cotton, which is considered to be quite risky compared to wheat and grain sorghum, is examined to determine if crop insurance effectively limits the yield risk associated with cotton. If so, the purchase of crop insurance for cotton could allow income to be enhanced relative to producing wheat or wheat and grain sorghum without greatly increasing income risk.

A 10 year planning horizon is simulated for each of the 22 scenarios. The 10 year period is simulated for 100 iterations. This results in 1000 observations of farm income being generated by the simulation model. The financial output of the model is used to calculate summary statistics of farm income and equity growth for the case farm. The debt scenario of the case farm is altered to simulate the impacts of crop insurance and diversification on highly leveraged farms. By increasing the debt levels associated with the case farm, a high financial stress farm is developed. Each of the scenarios simulated for the original case farm are simulated for the high financial stress case farm. The results are presented separately for low and high financial stress cases. The base case is the uninsured case farm that produces only wheat. The base case is the standard by which the performance of all crop insurance and crop diversification alternatives are evaluated.

Case Farm

The farm scenario considered is a farm located in North Central Oklahoma. The farm operation considered consists of 3000 acres, comprised primarily of class one soil types. A large farm size was chosen to allow for efficient use of farm machinery with crop diversification. It is assumed two families are earning income from operating the farm and that one family is earning income from ownership of the farm. This structure represents a large size family farm still owned by the parents, but operated by their children. The scenario considered allows $75,000 of family living withdrawals from the business, while $40,000 of off-farm income is available to service farm expenses throughout the year.

The case farm has a beginning cash balance of $25,000. A line of credit is available to the farm business. No limit was placed on available credit eliminating asset liquidation to meet cash flow requirements. The interest rate associated with the line of credit is 10 percent. The case farm has a machinery inventory valued at $477,736 and real estate valued at $2,346,000. The farm has an outstanding land note with a $500,000 principal balance financed at 9 percent and 10 remaining payments. The beginning balance sheet of the case farm is presented in table 4. The asset and liability inventories of the case farm yield a debt to asset ratio of .25, which indicates low financial stress.

Table 4. Beginning Balance Sheet of Low Debt Base Case Farm Scenario

Current Assets	Market	Cost	Current Liabilities	Market	Cost
Cash&Checking	25,000	25,000	Accounts Payable	0	0
Hedging Account			Ad Valorem	0	0
Marketable Securities			Employee Withholding	0	0
Accounts Receivable			Income Taxes	0	0
Prepaid Expenses	0	0	Deferred Taxes	0	0
Cash Investment Growing Crops	134,270	134,270	Notes Payable	0	0
Marketable Livestock			Current Portion Term Debt	32,910	32,910
Stored Crops and Feed			Accrued Interest	0	0
Purchased Feed			Other Accrued Expenses	0	0
Supplies	15,750	4,500	Other Current Liabilities	0	0
Other Current Assets			Contingent Tax Liabilities	2,025	0
Total Current Assets	175,020	163,770	Total Current Liabilities	34,935	32,910
Non-Current Assets					
Breeding Livestock	0	0			
Machinery Equipment	477,736	175,843	Non-Current Liabilities		
Vehicles	33,700	16,800	Non-Current Portion Term Debt	467,090	467,090
Investment Capital Leases			Non-Current Deferred Taxes	0	0
Contracts Notes Receivable			Other Non-Current Liabilities	0	0
Investment Cooperatives	0	0	Contingent Tax Liabilities	260,423	0
Real Estate Land	2,346,000	1,218,000	Total Non-Current Liabilities	727,513	467,090
Cash Value Life Insurance					
Investment Other Entities					
Other Non-Current Assets	0	0	Total Liabilities	762,448	500,000
Total Non-Current Assets	2,857,436	1,410,643	Equity	2,270,008	1,074,413
Total Assets	3,032,456	1,574,413	Total Liabilities & Equity	3,032,456	1,574,413

To simulate a farm in high financial stress, the debt portfolio of the case farm is altered. The high stress situation has $1,300,000 of debts outstanding consisting of $1,000,000 land debt and $300,000 machinery financing. The land note and machinery note of the high financial stress situation have 10 and 4 annual payments remaining respectively. These debt levels give the high stress case farm a debt to asset ratio of .52, which indicates high financial stress.

Crops typically grown in the area consist primarily of winter wheat and grain sorghum, while cotton production is becoming more popular. Another enterprise somewhat common in the area is grazing stocker cattle on winter wheat pasture, prior to the physiological joint stage of the wheat plant. However, the farm scenario considered is within an area of productive soils, where farms are more likely to specialize in crop production than in other areas of the state.

It is assumed that no additional machinery is needed for grain sorghum production beyond the machinery compliment of a wheat farm. However, for a wheat farm to expand into cotton production requires a significant investment in machinery. It is assumed that the farm scenario considered will require the purchase of a new row-crop planter, 2 cotton pickers, a module builder, a rotary hoe, and a cotton wagon. This would be an investment of approximately $495,000 with taxes and setup costs. Machinery purchases are assumed to be financed for a five year period at an interest rate of 10%. This capital purchase would increase the assets and liabilities of the balance sheet by $495,000. This increases the beginning Debt to Asset ratios of the low and high debt scenarios to .36 and .59 respectively for the scenarios including cotton in the crop mix. Thus, the additional debt increases the financial stress of the farm scenario, increasing financial and cash flow risk. The machinery and equipment inventory of the case farm with cotton equipment is presented in table 5.

Table 5. Machinery and Equipment Inventory

Machinery & Equipment	Current Value	Purchase Year	Useful Life	New Value	Salvage Value
Combine	$113,333	1995	15	$150,000	$40,000
Grain Truck	$35,000	1990	20	$60,000	$10,000
Fertilizer Tanks	$14,300	1999	20	$15,000	$1,000
SP Sprayer 60'	$28,189	1990	15	$68,200	$8,184
Grain Truck	$45,000	1994	20	$60,000	$10,000
Grain Drill 35'	$29,491	1997	10	$38,500	$8,470
Rotary Hoe 30'	$7,746	1997	15	$9,400	$1,128
Row Crop Planter 8 row	$17,544	1996	10	$25,500	$5,610
Springtooth Harrow 58'	$8,551	1995	15	$12,100	$1,452
Field Cultivator 60'	$32,226	1998	12	$37,400	$6,358
Chisel 37'	$11,313	1993	12	$21,200	$4,250
Disk-Rip 17.5'	$14,625	1994	12	$25,000	$4,250
Tractor 150hp	$33,650	1985	20	$91,400	$14,400
Tractor 310hp	$86,768	1996	12	$112,200	$35,904
Module Builder	$20,000	2000	20	$20,000	$1,000
Cotton Trailer	$12,100	2000	12	$12,100	$2,420
Cotton Picker 4 row	$195,000	2000	12	$195,000	$33,150
Cotton Picker 4 row	$195,000	2000	12	$195,000	$33,150
Half-Ton Pickup	$22,900	1998	10	$28,000	$2,500
Half-Ton Pickup	$10,800	1994	10	$24,000	$2,000

Farm operating expenses are a function of the crops produced, farming practices, management decisions, and yield. As yield increases costs incurred also increase on a per acre basis. Budgets used in the model are presented in tables 6, 7, and 8 for wheat, grain sorghum, and cotton respectively. The budgets illustrated are prepared using long run expected prices and yields. Variable costs represent the cost of all inputs, while fixed costs represent the overhead costs of land and machinery. Fixed costs are assumed to be $2.00 of real estate and personal property tax per acre in addition to depreciation on farm machinery. The model used in this analysis calculates depreciation based on the useful life of the machinery complement as entered in the program. Machinery operating costs are based on estimates published by the University of Minnesota. Yield dependent costs titled "car and truck expenses" in the budgets are the variable costs of transporting grain to the elevator. In the cotton budget used it was assumed that cottonseed was traded for ginning costs. This assumption allowed cottonseed yield and price variables to be excluded from the model.

Table 6. Wheat Budget with Expected Yield and Price

Production	Units	Qty.	Price	Total/Acre	Machinery Operations	Times Over
wheat	bu	41.5	$3.33	$138.20		
				$0.00	chisel	2
Value of Production				$138.20	field cult.	2
					combine	1
Costs					drill	1
Seed	bu	1.5	$6.00	$9.00	offset disk	1
Fertilizer	lbs	51.5	$0.12	$6.18		
Fertilizer	lbs	72.65	$0.17	$12.35	Totals	7
Equipment Rent	acre	1	$2.25	$2.25		
Labor	acre	1	$4.63	$4.63		
Fuel, Maintenance	acre	1	$8.50	$8.50		
Utilities	acre	1	$2.00	$2.00		
Car and truck	acre	1	$6.00	$6.00		
Car and truck	yield	1	$0.05	$2.08		
Total Variable Costs				$52.99		
land taxes			$2.00			
Total OH				$27.65		
Revenue				$138.20		
Total Costs				$80.64		
Returns/acre				$57.56		

Table 7. Grain Sorghum Budget with Expected Yield and Price

Production	Units	Qty.	Price	Total/Acre	Machinery Operations	Times Over
grain sorghum	bu	76	$2.30	$173.88		
				$0.00	disk-rip	1
Value of Production				$173.88	chisel	1
					harrow	1
Costs					plant	1
Seed	lbs	4	$0.90	$3.60	spray	2
Fertilizer	lbs	69	$0.17	$11.65	combine	1
Fertilizer	lbs	50	$0.12	$6.00	offset disk	1
Chemicals	acre	1	$34.33	$34.33		
Equipment Rent	acre	1	$2.25	$2.25	Totals	7
Labor	acre	1	$6.56	$6.56		
Fuel, Maintenance	acre	1	$10.58	$10.58		
Car and truck	acre	1	$6.00	$6.00		
Utilities	acre	1	$2.00	$2.00		
Car and truck	yield	1	$0.05	$3.78		
Total Variable Costs				$86.75		
land taxes			$2.00			
Total OH				$33.93		
Revenue				$173.88		
Total Costs				$120.68		
Returns/acre				$53.20		

Table 8. Cotton Budget with Expected Yield and Price

Production	Units	Qty.	Price	Total/Acre	Machinery Operations	Times Over
lint	lbs	555	$0.56	$310.80		
seed	cwt			$0.00	disk-rip	1
Value of Production				$310.80	chisel	1
					field cult.	2
Costs					harrow	1
Seed	lbs	12	$0.60	$7.20	plant	1
Fertilizer	lbs	60	$0.17	$10.20	rotary hoe	4
Fertilizer	lbs	35	$0.26	$9.10	spray	6
Chemicals	acre	1	$45.00	$45.00	cotton picker	1
Custom Hauling	yield	1	$0.01	$2.78	cotton trailer	1
Supplies	yield	1	$0.02	$8.33	module builder	1
Marketing Fees	yield	1	$0.02	$10.55		
Labor	acre	1	$19.21	$19.21	Total	19
Fuel, Maintenance	acre	1	$31.25	$31.25		
Car and truck	acre	1	$6.00	$6.00		
Utilities	acre	1	$2.00	$2.00		
conservation	acre	1	$12.50	$12.50		
Total Variable Costs				$164.11		
land taxes			$2.00			
Total OH				$76.91		
Revenue				$310.80		
Total Costs				$241.02		
Returns/acre				$69.79		

Chapter 4

Results

Simulated farm incomes were compiled and analyzed for crop insurance and diversification alternatives across financial stress levels. Equity growth for the simulated planning periods was also evaluated. Only equity growth for the entire planning period was analyzed. A discussion of farm income and equity growth results is organized by financial stress level. Summary statistics of farm income and equity growth are presented in tables following the presentation of results for each crop mix alternative. The following is a discussion of the outcomes and the results of the analyses performed. The impacts of crop insurance and crop diversification across financial stress levels on farm income and equity growth distributions are described.

Distributions of average farm income for the planning period were calculated and compiled for each scenario. Normality assumptions were tested for each of the average farm income distributions using the Kolmogorov-Smirnov (KS) test for normality. The p-value of the KS statistic for all of the average farm income distributions was $>.10$. Thus, the normality assumption could not be rejected. Statistical significance of the difference between mean incomes resulting from alternative scenarios was then determined with a paired sample t-test of means. The differences between mean incomes of insurance alternatives for each of the crop mixes were all statistically significant ($P<.05$) in the high and low debt scenarios. The significance of differences in means between crop mix alternatives varied across debt levels. The statistical significance between crop mix alternatives is presented in the following presentation of results.

Table 9. Statistical Significance of Mean Farm Income Differences Between Insurance Alternatives

	NO Ins	CAT	MPCI-55	MPCI-75	CRC-55	CRC-75
WW						
No Ins		*	*	*	*	*
CAT			*	*	*	*
MPCI-55				*	*	*
MPCI-75					*	*
CRC-55						*
WW and GS						
No Ins		*	*	*	*	*
CAT			*	*	*	*
MPCI-55				*	*	*
MPCI-75					*	*
CRC-55						*
WW, GS, and CT						
No Ins		*	*	*	*	*
CAT			*	*	*	*
MPCI-55				*	*	*
MPCI-75					*	*
CRC-55						*

Note: Asterisk denotes significant difference at the .05 level.

Table 10. Statistical Significance of Mean Farm Income Differences Between Uninsured Crop Mix Alternatives

	WW	WW-GS	WW-GS-CT
Low Debt			
WW			*
WW-GS			*
High Debt			
WW		*	*
WW-GS			

Note: Asterisk denotes significant difference at the .05 level.

Low Financial Stress

Base Case

For the low debt base case, farm income of the 1000 simulated years averaged $163,570 and had a standard deviation of $101,762 (Table 11). The minimum farm income received in the base case was -$64,525, while the maximum farm income received was $690,036. Thus, the range of values simulated for farm income in the base case was $754,561. Equity growth of the farm for the planning period is calculated by dividing the change in equity during the planning period by beginning equity. Average equity growth for the base case during the ten year planning period was 48.1%, with a standard deviation of 16.9% (Table 12). The minimum and maximum equity growth rates in the base case were 6.2% and 91.6% respectively. The wheat only crop mix yielded the highest average income level associated with either of the traditional crop mix alternatives, but was more variable than the wheat and grain sorghum crop mix.

Table 11. Summary Statistics of Farm Income for the Low Debt Wheat Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	$163,570	($64,515)	$690,036	$101,762	0.622
CAT	$163,549	($64,575)	$689,976	$101,713	0.622
MPCI-55	$158,393	($62,715)	$682,617	$100,715	0.636
MPCI-75	$151,855	($23,951)	$661,656	$91,360	0.602
CRC-55	$157,074	($54,972)	$680,441	$99,690	0.635
CRC-75	$150,207	($31,180)	$654,558	$88,343	0.588

Table 12. Summary Statistics of Equity Growth for the Low Debt Wheat Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	48.1%	6.2%	91.6%	16.9%	0.351
CAT	48.0%	6.1%	91.5%	16.9%	0.352
MPCI-55	45.8%	2.6%	88.7%	16.9%	0.369
MPCI-75	42.9%	0.1%	84.9%	16.2%	0.378
CRC-55	45.2%	1.1%	88.0%	16.8%	0.372
CRC-75	42.2%	1.0%	85.2%	16.0%	0.379

CAT Insurance. The purchase of CAT insurance for the wheat only farm decreased average farm income by $21, while decreasing the standard deviation by $49 compared to the base case. The reduction of average farm income is less than the $60

CAT premium indicating some risk transfer does occur. CAT insurance actually decreased minimum farm income from -$64,515 with the base case to -$64,575, while maximum farm income was also reduced by $60 (Table 11). Simulated farm incomes resulted in mean equity growth of 48% for the planning period. Equity growth ranged from 6.1% to 91.5% with a standard deviation of 16.9% (Table 12).

MPCI 55%. The purchase of MPCI at the 55% coverage level reduces average farm income to $158,393 and the standard deviation of farm income to $100,715. The lower level coverage of MPCI examined increases minimum income from -$64,515 in the base case to -$62,715 (Table 11). The slight increase in minimum income suggests that very little downside yield risk is insurable at the 55% coverage level. $682,617 was the maximum level of farm income received when MPCI-55% was purchased. Maximum income decreased $7,419, while minimum income increased $1,800. The relatively large decrease in maximum income relative to the increase in minimum income indicates that the costs of transferring risk with crop insurance are high. When MPCI was purchased at the 55% coverage level, mean equity growth over the 10 year planning period was 45.8%, ranging of 2.6% to 88.7% (Table 12).

MPCI 75%. Increasing the coverage level to 75% further reduced average farm income to $151,855 and the standard deviation of farm income to $91,360 (Table 11). The purchase of MPCI at the 75% coverage level resulted in mean equity growth for the 10 year period of 42.9%, with a range from .10% to 84.9% (Table 12). Increasing the coverage level from 55% to 75% increased minimum income from -$62,715 to -$23,951. The $40,564 increase in minimum income, relative to the base case, had an average cost of $13,363, measured by the decrease in mean income. The maximum income received was $28,380 less than in the base case. MPCI-75% reduced maximum income less per dollar of increase in minimum income than did MPCI-55%.

CRC 55%. Purchasing CRC insurance at the 55% coverage level resulted in an average farm income of $157,074 with a standard deviation of $99,690 (Table 11). The farm income levels associated with CRC-55% resulted in mean equity growth of 45.2% over the 10 year planning period (Table 12). Simulated equity growth levels ranged from 1.1% to 88%. Minimum equity growth for the planning period is higher for CRC than for MPCI at the 55% coverage level. The minimum and maximum farm incomes received with the lower coverage level of CRC are -$54,972 and 680,441 respectively. The minimum income level increases relative to the lower level of MPCI, indicating CRC provides increased income risk reduction relative to MPCI. With CRC-55% the decrease in maximum income and increase in minimum income are both about $10,000, while mean income is decreased $6496. The risk reduction of CRC-55% is cost effective relative to MPCI-55%, which reduced mean and maximum income more per dollar increase of minimum income.

CRC 75%. Increasing CRC coverage level to 75% resulted in decreasing average farm income to $150,207, while decreasing the standard deviation of farm income to $88,343 (Table 11). Farm income levels in the single crop case with the purchase of CRC-75% resulted in average equity growth of 42.2% during the 10 year planning period. Simulated equity growth for the planning period ranged from 1% to 85.2% (Table 12). Minimum equity growth is higher for CRC-75% than for MPCI-75%, opposite of the relationship at the 55% coverage level. Minimum income with CRC-75% is -$31,180, which is lower than with MPCI-75%, but $33,335 greater than in the base case.

Increasing insurance coverage in the wheat only scenario reduced income variability. The reduction of income variability with insurance increased the average costs of the farm, insurance premiums and interest costs, more than average indemnities received. Thus, crop insurance was not shown to be a source of additional profit for a wheat farm in North Central Oklahoma. Likewise, the reduction of income variability relative to mean income associated with crop insurance was not sufficient to increase average equity growth rates of the farm scenario.

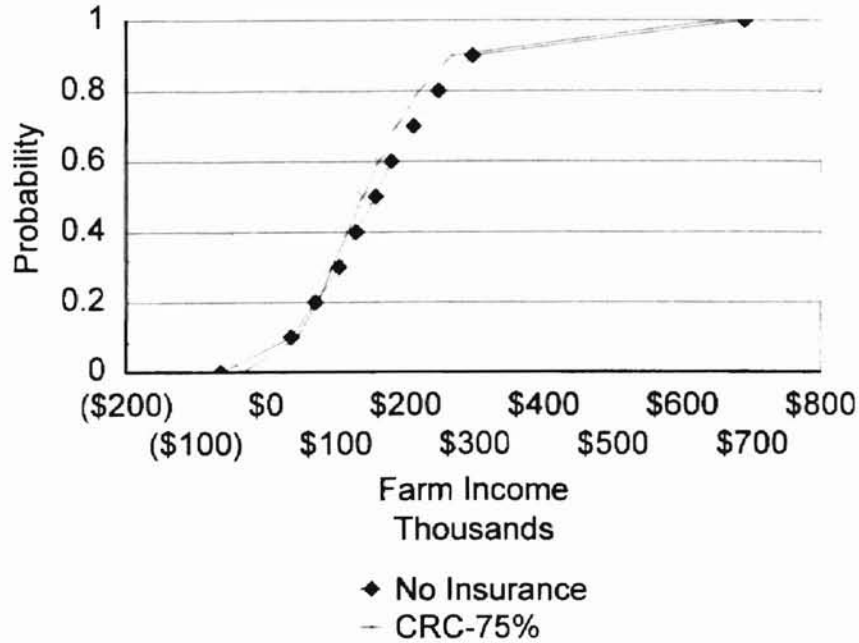
The coefficient of variation (CV) was calculated for both farm income and equity growth. The coefficient of variation is the ratio of standard deviation to mean. Thus, CV is a simple statistic that values the relative variability or the relative riskiness of an alternative based on its distribution. However, the CV statistic does not provide a statistic of absolute risk efficiency, but rather a relative statistic.

In the wheat only scenario the CV of farm income in the no insurance scenario was .622 (Table 11). When MPCI or CRC was purchased at the 75% coverage level the CV of farm income decreased. The lowest CV of farm income was with CRC-75% at .588. This indicates that when insurance is purchased at the 75% coverage level the standard deviation of farm income decreased relatively more than the mean of farm income. Thus, the addition of crop insurance at the higher level of coverage reduced relative variability of farm income. However, analyzing the CV of equity growth results in a different outcome. The purchase of crop insurance increased the CV of equity growth. Furthermore, as coverage levels were increased the CV of equity growth increased. The CV of equity growth was the lowest for the no insurance scenario at .351 and the highest for CRC-75% at .379 (Table 12).

With the wheat yield distribution used in the model a large portion of downside yield risk is uninsurable. Given the triangular distribution used for wheat there is only a probability of .13 that a low yield will trigger an indemnity payment at the 75% coverage level. Economic losses occur at yield levels that do not trigger an indemnity payment. As average yields increase, the portion of average yield that is uninsurable increases. The higher uninsurable yield may prevent crop insurance from effectively limiting economic losses at an acceptable level.

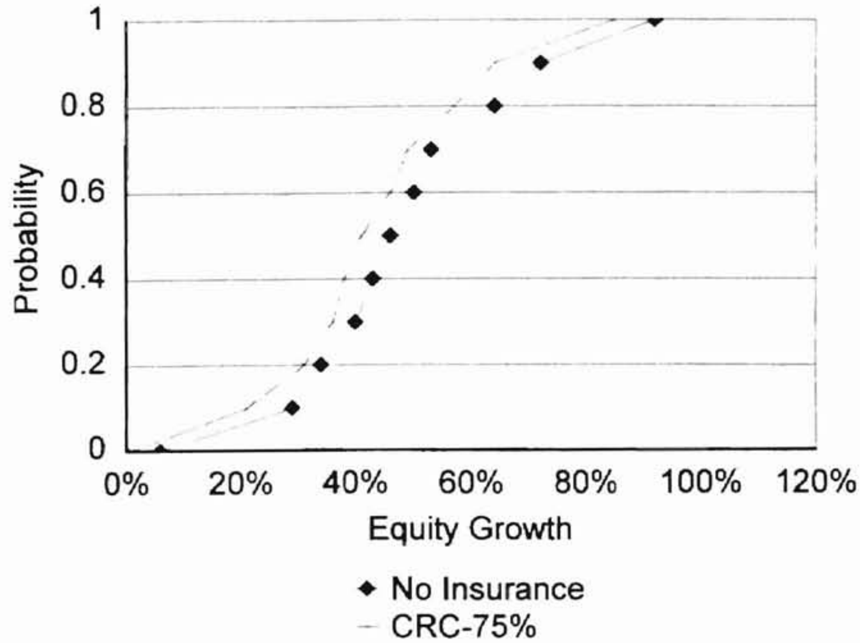
The lower minimum income associated with CRC relative to MPCI occurred when the futures price movement between planting and harvest was not large enough to increase the CRC indemnity relative to the MPCI indemnity by more than the premium difference between MPCI and CRC. The minimum incomes occurred during a year in which the planting time futures price was relatively low and yields were low. The effects of crop insurance on income for the base case were consistent with the results reported by Duhyvetter and Kastens for Kansas wheat farms. Farm income CDFs for the base case and the CRC-75% insurance alternative are illustrated in figure 2. The income redistribution benefits of crop insurance, represented by the area between the insurance and no insurance alternatives below the point at which their CDFs cross, are a small fraction of the cost of insurance, represented by the area between the alternatives above the point at which the CDFs cross (illustrated in figure 2).

Figure 2. Farm Income CDFs for the Low Debt Wheat Scenario with No Insurance and CRC-75%



The downside risk reduction of CRC-75% (illustrated in figure 2) was expected to be more important than results indicated. Results indicated that much less risk was transferred by MPCI and CRC than was expected. The reduction of income variability achieved with crop insurance, even though subsidized, was too expensive to increase the minimum equity growth rate. Figure 3 illustrates that, for all probabilities, equity growth was higher without CRC-75% insurance. The relationship illustrated is the same for all MPCI and CRC contracts analyzed.

Figure 3. Equity Growth CDFs of Insurance Alternatives for the Low Debt Wheat Scenario



Wheat and Grain Sorghum

The addition of grain sorghum to the crop mix in the uninsured case reduced mean income when compared to the base case, but not significantly (P = .27). The reduction in mean income was only $3,303 or about 2% of mean income in the base case, yielding an average farm income of $160,267 (Table 13). The standard deviation of farm income was reduced from $101,762 in the base case to $71,765 with crop diversification. The 2% reduction in mean farm income due to crop diversification yielded a 29% reduction in the standard deviation of farm income. The diversified scenario without insurance yielded a higher mean farm income with a lower standard deviation than did the single crop scenario with any level of MPCI or CRC insurance. Furthermore, the minimum income received was -$30,163, higher than the -$64,515 received in the base case. However, maximum income was only $473,227, much less than the $690,036 received in the base case. Simulated farm incomes yielded a mean equity growth of 46.6% for the diversified case. Equity growth for the planning period ranged from 15.7% to 78.4% with a standard deviation of 11.8% (Table 14). While mean income was higher in the base case, mean income was higher in the diversified case than in the wheat only case with MPCI or CRC at either coverage level. Furthermore, the standard deviation of farm income was less in the diversified case than in all of the single crop cases.

Results indicate that crop diversification was superior to MPCI and CRC in a simple mean variance analysis of farm income. Mean variance analysis eliminates scenarios that are inferior with respect to producer welfare, a function of income and equity growth. An alternative with a higher mean and equal or lower variance is dominant, while an alternative with a higher mean or lower variance alone is not dominant in a mean variance analysis.

Table 13. Summary Statistics of Farm Income for the Low Debt Wheat and Grain Sorghum Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	$163,570	($64,515)	$690,036	$101,762	0.622
WW-GS	$160,267	($30,163)	$473,227	$71,765	0.448
CAT	$160,560	($30,284)	$473,103	$71,788	0.447
MPCI-55	$154,149	($35,613)	$462,240	$71,498	0.464
MPCI-75	$145,062	($38,514)	$469,323	$70,651	0.487
CRC-55	$153,372	($38,533)	$467,092	$71,497	0.466
CRC-75	$146,329	($40,762)	$483,077	$70,617	0.483

Table 14. Summary Statistics of Equity Growth for the Low Debt Wheat and Grain Sorghum Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	48.1%	6.2%	91.6%	16.9%	35.1%
WW-GS	46.6%	15.7%	78.4%	11.8%	25.3%
CAT	46.7%	15.6%	78.9%	11.9%	25.5%
MPCI-55	43.9%	12.5%	76.4%	11.8%	26.9%
MPCI-75	39.9%	7.6%	72.9%	12.3%	30.8%
CRC-55	43.6%	11.0%	76.9%	12.0%	27.5%
CRC-75	40.5%	4.4%	73.0%	12.4%	30.6%

CAT Insurance. The addition of crop insurance in the presence of crop diversification reduced mean income similar to the base case, with the exception that CAT coverage increased mean farm income by $293 and the standard deviation of farm income by $23. Purchasing CAT coverage resulted in mean farm income of $160,560 with a standard deviation of $71,788 (Table 13). The minimum and maximum incomes received in the diversified scenario with CAT were -$30,284 and 473,103 respectively, actually lower than those received without insurance by about the amount of the CAT premium. Farm income levels yielded a mean equity growth of 46.7% with a standard deviation of 11.9%. Equity growth for the planning period ranged from 15.6% to 78.9% (Table 14).

MPCI 55%. Purchasing MPCI at the 55% coverage level resulted in mean farm income of $154,149 with a standard deviation of $71,498 (Table 13). Farm income ranged between -$35,613 and $462,240. Minimum farm income resulting with MPCI-55% was lower than with CAT, as was maximum income. The simulated farm incomes resulted in mean equity growth of 43.9% with as standard deviation of 11.8%, ranging between 12.5% and 76.4% (Table 14). The purchase of MPCI-55% reduces mean farm income and equity growth compared to those received with no insurance and CAT. MPCI-55% decreased minimum equity growth, mean equity growth, and maximum equity growth, however the standard deviation of equity growth was unchanged compared to no insurance. Thus, MPCI-55% offered no benefits with respect to equity growth.

MPCI 75%. Increasing the coverage level to 75% further reduced mean farm income to \$145,062 and the standard deviation to \$70,651 (Table 13). MPCI-75% further reduced minimum farm income to -\$38,514, while maximum income increased to \$469,323 relative to MPCI-55%. Simulated farm incomes resulted in mean equity growth of 39.9% with a standard deviation of 12.3%, ranging between 7.6% and 72.9% (Table 14). MPCI-75% resulted in decreased mean, minimum, and maximum equity growth and increased standard deviation of equity growth relative to MPCI-55%. Thus, increasing coverage levels of MPCI offered no benefits with respect to long term equity growth.

CRC 55%. Purchasing CRC at the 55% coverage level yielded a mean farm income of \$153,372 with a standard deviation of \$71,497 (Table 13). Farm income values ranged from -\$38,533 to \$467,092. Minimum farm income was reduced by purchasing CRC relative to MPCI at the 55% coverage level and with no insurance. Maximum income was increased relative to MPCI-55%, while the standard deviations of MPCI-55% and CRC-55% were about the same. Equity growth during the planning period averaged 43.6% ranging from 11% to 76.9% with a standard deviation of 12%

(Table 14). Mean equity growth was lower, while the standard deviation of equity growth was higher than with MPCI-55%.

CRC 75%. Increasing the coverage level to 75% resulted in mean farm income being reduced to $146,329 with a standard deviation of $70,617 (Table 13). The standard deviation of farm income was the lowest with CRC-75% for the diversified case, as would be expected. CRC is a revenue insurance product and has more income risk reduction ability than MPCI, a yield insurance product. Again increasing insurance coverage level in the diversified case decreased the minimum farm income received. Farm income ranged from -$40,762 to $483,077. Maximum farm income was higher with CRC-75% than with all other wheat and grain sorghum scenarios, indicating that either wheat or grain sorghum received an indemnity in the maximum income year. Simulated farm incomes resulted in mean equity growth of 40.5% during the planning period (Table 14). Equity growth simulated ranged from 4.4% to 73% with a standard deviation of 12.4%.

The standard deviation of farm income was reduced as the level of coverage was increased, but not in the magnitude experienced with the single crop scenario. Compared to the uninsured case standard deviation was reduced by $1,148, while mean income was reduced by $13,938 with the purchase of CRC at the 75% coverage level. The reduction in standard deviation relative to the reduction of mean income resulting from the addition of crop insurance was considerably less for the diversified farm than for the single crop farm. Thus, as crop diversification increases crop insurance provided less risk reduction.

Furthermore, with the addition of crop insurance to the diversified scenario the minimum income levels received were not increased as they were in the base case.

The CV of farm income in the diversified case was the lowest for CAT at .447 (Table 13). Purchasing higher levels of crop insurance resulted in higher relative variablity of farm income and equity growth. The CV of farm income was higher for 75% coverage levels than the 55% coverage levels, indicating that the higher levels of insurance coverage resulted in higher relative variability. Thus, in the presence of crop diversification crop insurance reduces the standard deviation of farm income very little relative to the decrease in mean farm income. Thus, it follows that the CV of equity growth was higher with insurance than without (Table 14).

Farm income and equity growth statistics indicate that crop insurance provided little to no downside risk transfer in the presence of crop diversification. The failure of crop insurance to increase farm income or equity growth in a below average income year is illustrated in figures 4 and 5 respectively. The farm income and equity growth with no insurance was higher than with CRC-75% at nearly all probabilities. Thus, the reduction of the standard deviation of farm income alone does not itself suggest that downside income risk was limited. In many of the scenarios standard deviation was lower simply because maximum income decreased more than minimum income.

Figure 4. Farm Income CDFs for the Low Debt Wheat and Grain Sorghum Scenario

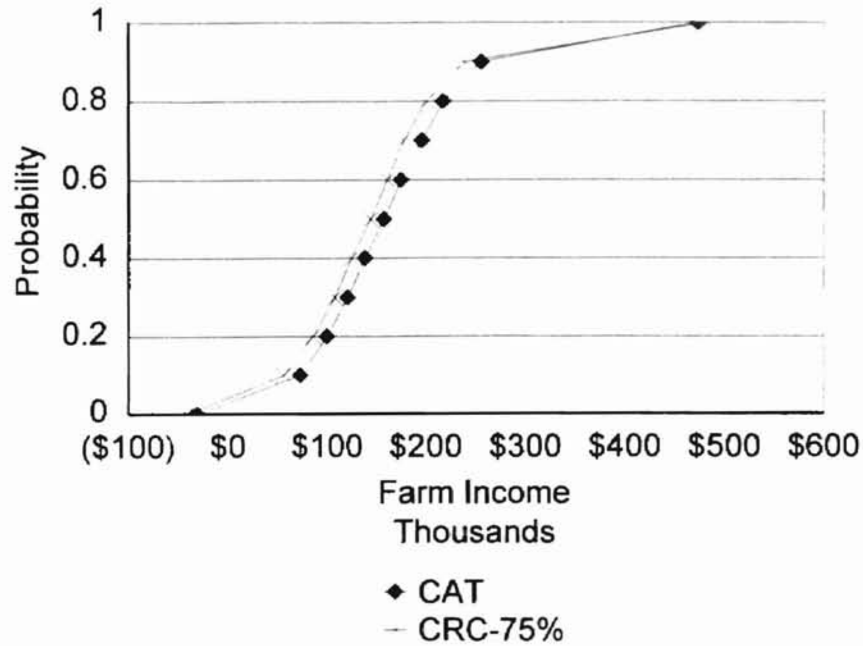
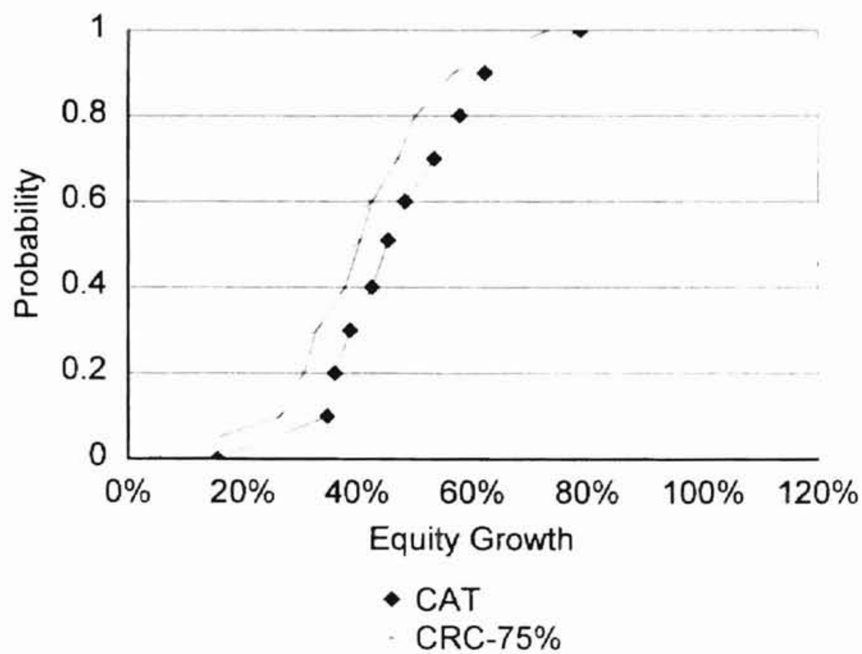


Figure 5. Equity Growth CDFs for the Low Debt Wheat and Grain Sorghum Scenario



Wheat, Grain Sorghum, and Cotton

Including cotton in the crop mix increased mean income relative to either alternative crop mix scenario considered. The increase in mean income was statistically significant ($P < 0.001$) in comparison to the base case yielding a mean farm income of \$175,914. The addition of cotton to the crop mix increased the standard deviation of farm income to \$124,983 (Table 15). The increase in standard deviation of farm income indicates that cotton is a relatively risky crop in comparison to wheat and grain sorghum. Farm incomes ranged from -\$138,251 to \$595,271. The range of farm income is narrower than that of the base case. The standard deviation of income for the three crop scenario without insurance is the highest of all scenarios. Since mean farm income and equity growth and risk and equity growth are directly related, the increase in mean and standard deviation of farm income is also seen in equity growth. Mean equity growth during the planning period was 52.5% and the standard deviation of equity growth increased to 15.8% (Table 16). However, the standard deviation of equity growth is still below that of the base case. Equity growth for the period ranges from 19.2% to 105.6%. While the minimum income when cotton is included in the crop mix is low, the minimum, maximum and mean equity growth during the planning period are the highest of any diversification scenario. Thus, long term, including cotton in the crop mix yielded the best expected, worst case, and best case results.

Table 15. Summary Statistics of Farm Income for the Low Debt Wheat, Grain Sorghum, and Cotton Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	$163,570	($64,515)	$690,036	$101,762	0.622
WW-GS-CT	$175,914	($138,251)	$595,271	$124,983	0.710
CAT	$178,834	($138,432)	$595,091	$121,314	0.678
MPCI-55	$166,432	($149,737)	$577,587	$116,430	0.700
MPCI-75	$136,513	($149,595)	$528,818	$105,908	0.776
CRC-55	$164,925	($142,400)	$572,214	$113,976	0.691
CRC-75	$134,307	($142,342)	$513,517	$102,122	0.760
MPCI-55CT	$170,938	($146,026)	$581,748	$116,490	0.681
MPCI-75CT	$148,720	($138,273)	$544,987	$106,507	0.716
CRC-55CT	$170,163	($136,846)	$578,062	$114,235	0.671
CRC-75CT	$146,333	($126,724)	$535,073	$102,960	0.704

Table 16. Summary Statistics of Equity Growth for the Low DebtWheat, Grain Sorghum, and Cotton Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	48.1%	6.2%	91.6%	16.9%	0.351
WW-GS-CT	52.5%	19.2%	105.6%	15.8%	0.301
CAT	53.8%	19.9%	105.8%	15.5%	0.288
MPCI-55	48.2%	11.4%	99.0%	15.5%	0.322
MPCI-75	35.0%	-7.9%	80.5%	16.6%	0.474
CRC-55	47.6%	9.3%	97.2%	15.7%	0.330
CRC-75	34.1%	-10.6%	75.3%	17.3%	0.507
MPCI-55CT	50.3%	14.6%	100.2%	15.9%	0.316
MPCI-75CT	40.5%	-0.1%	84.5%	15.4%	0.381
CRC-55CT	49.9%	13.8%	98.7%	15.3%	0.306
CRC-75CT	39.4%	-4.5%	80.3%	15.9%	0.403

CAT Insurance. The performance of crop insurance alternatives for the three crop scenario was consistent with that for the two crop scenario. The purchase of CAT coverage with cotton in the crop mix increased mean revenue $2,920 resulting in mean farm income of $178,834 with a standard deviation of $121,314 (Table 15). The increase in mean income coupled with a reduction in standard deviation of $3,669 in comparison to no insurance makes CAT coverage quite attractive, especially given CAT coverage is essentially free to agricultural producers. However, the minimum and maximum farm incomes received with CAT were slightly lower than without insurance. Mean equity growth simulated for the planning period was 53.75%, the highest of any scenario (Table 16). Equity growth for the period ranged from 19.9% to 105.8% with a standard deviation of 15.5%.

MPCI 55%. Purchasing MPCI at the 55% coverage level reduced mean farm income to $166,432 with a standard deviation of $116,430 (Table 15). Simulated farm incomes ranged from -$149,737 to $577,587. The minimum income received with MPCI-55% is about $11,000 lower than with CAT. Likewise, the maximum income received is about $18,000 lower than in the base case. Mean equity growth for the planning period was 48.2% ranging from 11.4% to 99% with a standard deviation of 15.5% (Table 16). Minimum, maximum, and mean farm income and equity growth were decreased with the purchase of MPCI-55% relative to CAT. The standard deviation of farm income was decreased, while the standard deviation of equity growth remained unchanged relative to CAT.

MPCI 75%. Increasing the coverage level to 75% reduced mean farm income to $136,513 well below the base case, but the standard deviation of $105,908 was still greater than in the base case (Table 15). Minimum farm income received was -$149,595, slightly higher than with MPCI-55%, while maximum farm income of $528,818 is significantly lower than with MPCI-55%. Simulated farm incomes resulted in average equity growth of 35% ranging from -7.9% to 80.5% with a standard deviation of 16.6% (Table 16). Increasing the coverage level of MPCI selected with the three crop diversification scenario resulted in little short term income risk reduction.

CRC 55%. Purchasing CRC at the 55% coverage level resulted in a mean farm income of $164,925 with a standard deviation of $113,976 (Table 15). Mean farm income and the standard deviation of farm income were lower with CRC-55% than with MPCI-55%. The minimum farm income received with CRC-55% was -$142,400, which was higher than with either MPCI alternative. The maximum income received was $572,214, which was lower than with the MPCI-55% alternative. Mean equity growth during the 10 year planning period was 47.6% ranging from 9.3% to 97.2% with a standard deviation of 15.7% (Table 16). Mean, minimum, and maximum equity growth levels were below those associated with MPCI-55%.

CRC 75%. Increasing the coverage level to 75% reduced mean farm income to $134,307 with a standard deviation of $102,122. Farm income ranges from -$142,342 to $513,517 (Table 15). The minimum farm income received was only $58 more than with CRC-55%, while the maximum income was $58,697 less than with CRC-55%. Increasing the level of coverage of CRC truncated the income distribution similar to increasing the level of coverage of MPCI. As the level of coverage is increased, maximum income is reduced much more than minimum income is increased. Simulated farm incomes yielded an average equity growth of 34.1% during the planning period. Equity growth for the planning period ranged from -10.6% to 75.3% with a standard deviation of 17.3% (Table 16). The effects of CRC-75% on farm income and equity growth are presented in figures 6 and 7, respectively.

Figure 6. Farm Income CDFs for the Low Debt Wheat, Grain Sorghum, and Cotton Scenario

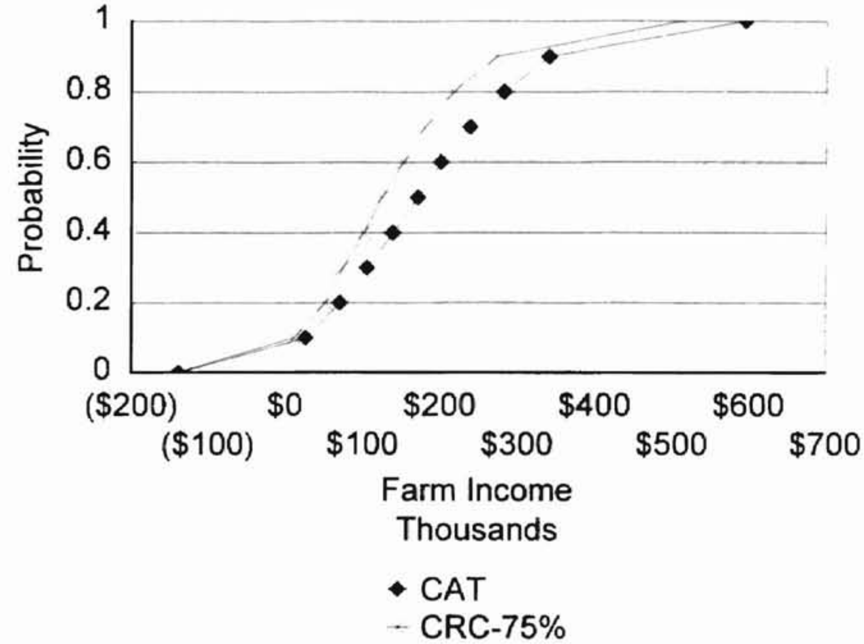
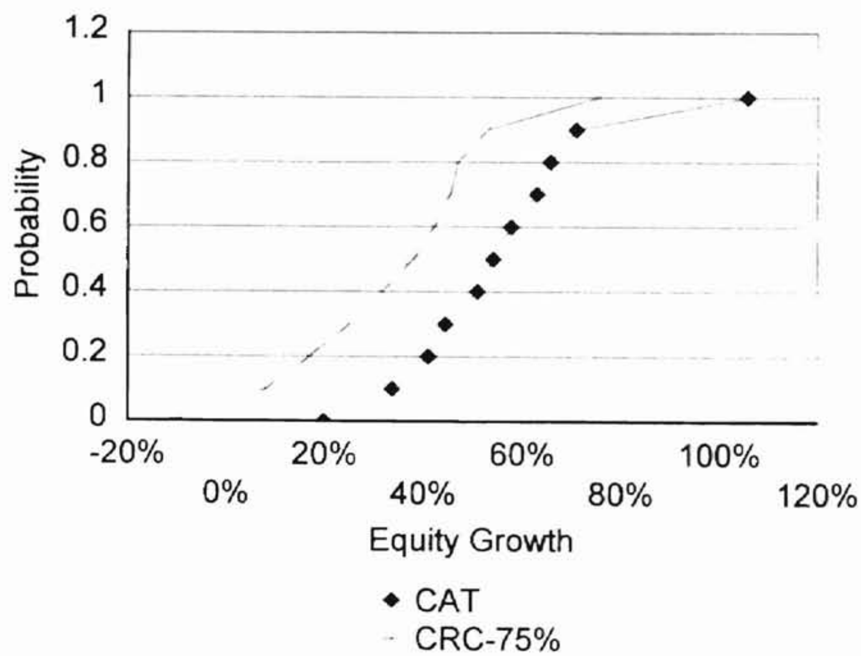


Figure 7. Equity Growth CDFs for the Low Debt Wheat, Grain Sorghum, and Cotton Scenario



MPCI 55% CT. Insuring only cotton at levels above CAT, while wheat and grain sorghum were insured with CAT, was examined to determine if farm income could be enhanced by including cotton in the crop mix, without grossly increasing financial risk. Insuring cotton with MPCI-55% resulted in mean farm income of $170,938 with a standard deviation of $116,490 (Table 15). Farm income ranged from -$146,026 to $581,748. Mean, minimum, and maximum farm income were higher than when all crops were insured with MPCI-55%. The standard deviation of farm income was also larger when only cotton was insured with MPCI-55% than when all crops were insured with MPCI-55%. Simulated farm incomes resulted in mean equity growth of 50.3% for the planning period. Equity growth rates for the period ranged from 14.6% to 100.2% with a standard deviation of 15.9% (Table 16). Mean, minimum, maximum equity growth and the standard deviation of equity growth were higher, than when all crops were insured with MPCI-55%.

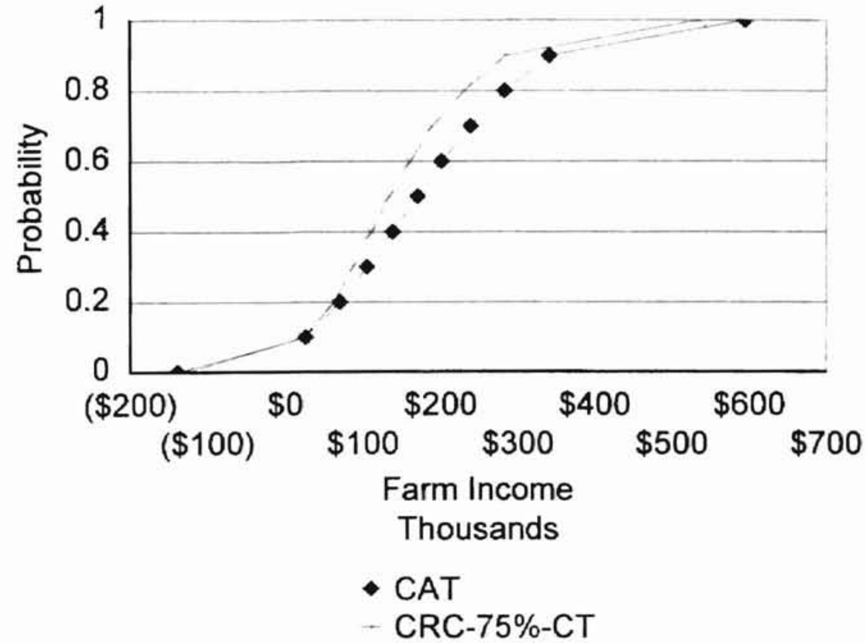
MPCI 75% CT. When cotton was insured above the CAT level with MPCI-75% farm income averaged $148,720 (Table 15). Mean farm income was about $12,000 higher than when all crops were insured with MPCI-75%. Farm income ranged from $-138,720 to $544,987 with a standard deviation of $106,507. Equity growth averaged 40.5% ranging from -.1% to 84.5% with a standard deviation of 15.4% (Table 16). Mean farm income and equity growth were less than in the base case, while the standard deviation of farm income and equity growth were larger than in the base case. Thus, the MPCI-75%-CT strategy was dominated by the base case in a mean variance analysis of farm income and equity growth.

CRC 55% CT. Insuring only cotton above the CAT level with CRC-55% increased mean farm income relative to insuring all crops at the same level. CRC-55%-CT resulted in mean farm income of $170,163 with a standard deviation of $114,235 (Table 15). Farm income values received ranged from -$136,846 to $578,062. Minimum and maximum income were higher than those received when all crops were insured with CRC-55%. Mean equity growth was 49.9% ranging from 13.8% to 98.7% with a standard deviation of 15.3% (Table 16).

CRC 75% CT. Insuring only cotton with CRC-75% resulted in mean farm income of $146,333, which was well below the mean income of the base case. Farm income ranged from -$126,724 to $535,073 with a standard deviation of $102,960. Equity growth during the planning period averaged 39.4% ranging from -4.5% to 80.3% with a standard deviation of 15.9%.

The CV of farm income in the three crop scenario was higher when all crops were insured than when only cotton was insured. The CV of equity growth indicates that CAT insurance resulted in relatively less variable equity growth than all other insurance alternatives for the three crop scenario. Farm income statistics indicated that insuring only cotton above the cat level reduced risk slightly. The risk reduction of CRC-75%-CT is illustrated in figure 8. The risk reduction is represented by the area between the alternatives, where income was greater for the insurance alternative. The income risk reduction in this case was minuscule compared to the costs. Thus, like in the single crop scenario the truncation of the income distribution by insurance was not capable of reducing downside equity growth risk.

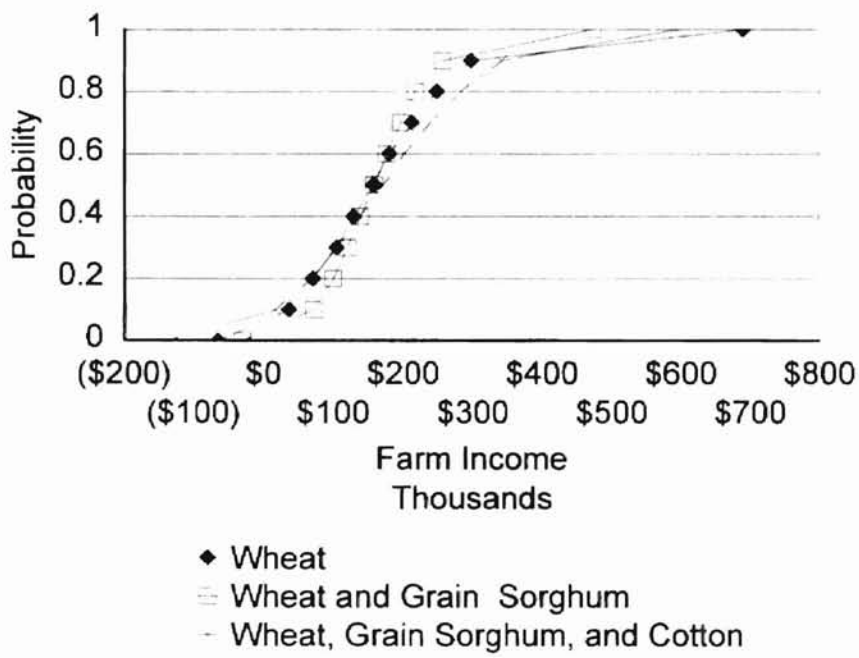
Figure 8. Farm Income CDFs Only Cotton Insured Above CAT Level



The crop mix alternatives considered had significant effects on farm income risk. The wheat and grain sorghum crop mix reduced income variability without significantly reducing mean income (P=.27). Wheat and grain sorghum have relatively similar average returns and yield and price variability. Since, the returns of wheat and grain sorghum production are not highly positively correlated, diversifying the crop mix results in significant income risk reduction without greatly impacting mean income levels. However, when cotton is added to the crop mix income risk is increased. When cotton is included in the crop mix the high variability of returns associated with cotton relative to wheat and grain sorghum caused the income variability of the farm to increase. The inclusion of cotton in the crop mix significantly enhanced income levels ($P<.001$). Thus, the trade off to higher income levels associated with cotton production was increased income risk.

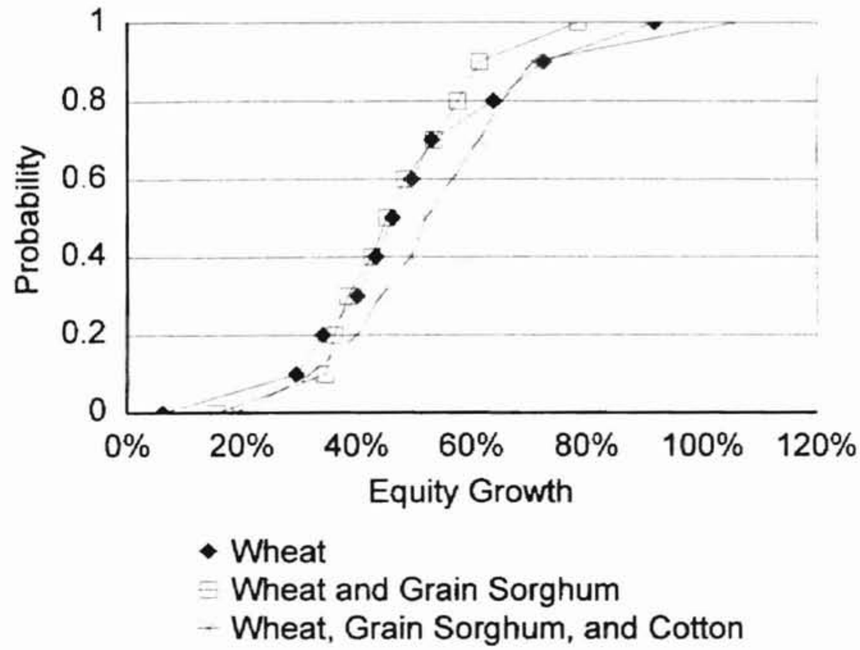
The income risk reduction of crop diversification is illustrated in figure 9. The downside risk reduction of diversification is represented by the area between two alternatives below the point at which they cross. Likewise, the costs of diversification are represented by the area between alternatives above the point at which they cross. In this case wheat and grain sorghum have the least downside risk, while including cotton yields the most downside risk.

Figure 9. Farm Income CDFs for the Low Debt Crop Mix Strategies With No Insurance



When equity growth is the focus, including cotton presents the least downside risk. While wheat only resulted in the most downside risk. As indicated in figure 10 the three crop alternative provided the highest equity growth at nearly all probability levels below .90. Thus, cotton production is a viable alternative crop if the business wants to increase equity growth and is not already in financial stress.

Figure 10. Equity Growth CDFs for the Low Debt Crop Mix Strategies With No Insurance



High Financial Stress

Under higher levels of financial stress income levels were lower due to increased borrowing costs. The effect of crop insurance on mean and standard deviation of farm income for the high debt scenario was consistent with the results of the low debt scenario. The reduction of income variability by crop insurance and crop diversification were very similar across debt levels. However, both reduced mean income more in the high debt scenario than in the low debt scenario.

Base Case

The base case under high financial stress yielded a mean farm income of $92,973 with a standard deviation of $106,526 (Table 17). The mean was considerably less than that received in the base case under low financial stress, while the standard deviation was slightly higher than that resulting in the low financial stress scenario. Farm income ranged from -$151,449 to $621,331, which was a wider range than in the low debt scenario. Minimum income was decreased more than maximum income. The impacts of increased leverage are illustrated by equity growth. Mean equity growth for the base case in high financial stress for the planning period was 26.6%. Equity growth during the planning period ranged from -75.7% to 119.8% with a standard deviation of 40.4% (Table 18). The percentage increase of standard deviation of income and equity growth were 4.7% and 139% respectively in comparison to the low debt base case. The increase in relative variability is indicated by the increase in CV. Thus, with increased leverage the variance of equity growth increases. .

Table 17. Summary Statistics Farm Income High Debt Wheat Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	$92,973	($151,449)	$621,331	$106,526	1.146
CAT	$92,925	($151,583)	$621,260	$106,484	1.146
MPCI-55	$84,937	($160,632)	$612,739	$105,605	1.243
MPCI-75	$73,783	($149,598)	$587,658	$97,039	1.315
CRC-55	$82,677	($158,679)	$609,993	$104,680	1.266
CRC-75	$70,794	($153,440)	$578,356	$94,224	1.331

Table 18. Summary Statistics Equity Growth High Debt Wheat Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	26.6%	-75.7%	119.8%	40.4%	1.519
CAT	26.5%	-75.8%	119.8%	40.4%	1.525
MPCI-55	21.1%	-81.9%	115.1%	40.7%	1.929
MPCI-75	13.4%	-86.5%	108.4%	40.2%	3.000
CRC-55	19.5%	-84.4%	114.0%	40.7%	2.087
CRC-75	11.1%	-84.4%	108.4%	40.0%	3.604

CAT Insurance. Purchasing CAT coverage for the single crop farm in high financial stress reduced mean farm income to $92,925 relative to the uninsured case (Table 17). The decrease in mean farm income was less than the $60 CAT premium indicating that some risk transfer does occur, but very little. The standard deviation of farm income was $106,484, slightly less than in the base case. Equity growth for the planning period averaged 26.5% slightly less than the base case (Table 18). The minimum equity growth rate of -75.8% was .1% less than in the base case and the maximum and standard deviation of equity growth were the same as the base case at 119.8% and 40.4% respectively.

MPCI 55%. The purchase of MPCI-55% further reduced mean farm income to $84,937 with a standard deviation of $105,605 (Table 17). Farm income ranged from -$160,632 to $612,739. The minimum and maximum farm incomes generated were both less than with CAT coverage. The purchase of MPCI-55% resulted in average equity growth of 21.1% during the planning period. Equity growth ranged from -81.9% to 115.1% with a standard deviation of 40.7% (Table 18). Mean equity growth was less than in the base case and the standard deviation of equity growth was larger than in the base case.

MPCI 75%. Increasing the coverage level of MPCI to 75% resulted in further reducing mean income and equity growth. Mean farm income was $73,783, less than family living withdrawals which are $75,000. The minimum farm income received, -$149,598, was higher than with MPCI-55% (Table 17). Likewise, the maximum income received, $587,658, was lower than with MPCI-55%. The standard deviation of farm income, $97,039, was lower than with MPCI-55%, CAT, and the base case. Simulated farm incomes resulted in mean equity growth of 13.4% for the planning period (Table 18). Equity growth ranged from -86.5% to 108.4% with a standard deviation of 40.2%. The standard deviation of equity growth was about .5% less, while mean equity growth is 7.7% less than with MPCI-55%.

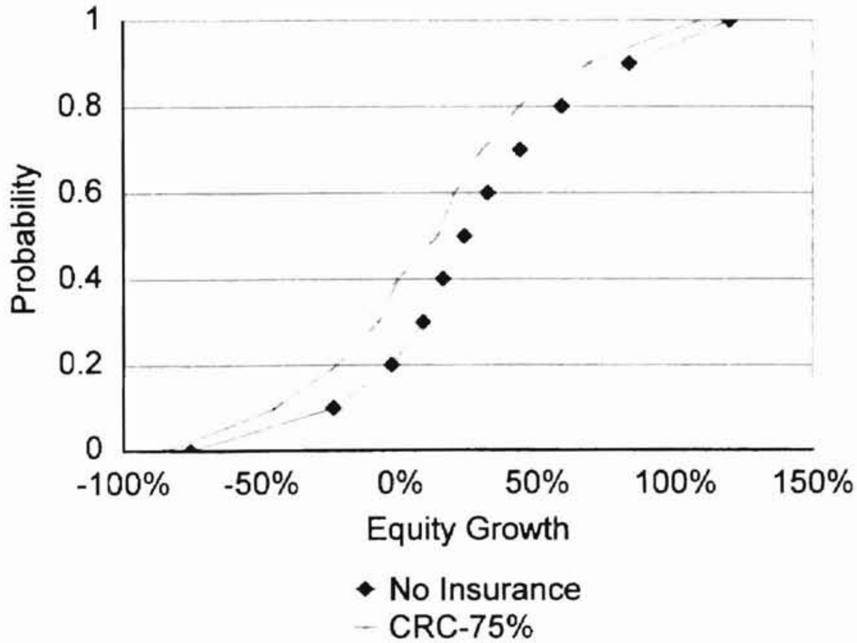
CRC 55%. Purchasing CRC-55% yielded an average farm income of $82,677 with a standard deviation of $104,680. Farm income ranged from $-158,679 to $609,993 (Table 17). The range of farm income was slightly narrower with CRC-55% than with MPCI-55%. Simulated farm incomes resulted in mean equity growth of 19.5% ranging from -84.4% to 114% with a standard deviation of 40.7% (Table 18). CRC-55% yielded a higher minimum revenue than MPCI-55%, but the average equity growth of the planning period was reduced with CRC-55%.

CRC 75%. Increasing the level of coverage to 75% with CRC resulted in decreasing mean income, while increasing minimum income. Farm income averaged

$70,794 with a standard deviation of $94,224 (Table 17). Farm income ranged from -$153,440 to $578,356. Equity growth for the planning period averaged 11.1% with CRC-75%. The minimum equity growth simulated for the period was -84.4%, while maximum equity growth was 108.4% (Table 18). The standard deviation of equity growth was 40%, slightly less than with all of the other insurance alternatives. Mean income and mean equity growth were lower with CRC-75% than with any alternative insurance policy.

The CV ratios of farm income for insurance alternatives in the high financial stress scenario were much higher due to lower mean income, but patterns were similar to those in the low financial stress scenario (Table 17). The purchase of crop insurance resulted in less risk efficient alternatives. Furthermore, the higher the coverage level the higher the CV ratio. Since crop insurance increased relative variability with respect to farm income, it did not decrease the relative variability of equity growth. Thus, CV ratios of equity growth also increase with the purchase of insurance coverage (Table 18). The failure of crop insurance to limit downside risk is illustrated in figure 11. The equity growth rate associated with no insurance was higher than that associated with CRC-75% at all probability levels.

Figure 11. Equity growth CDFs for High Debt Wheat Scenario



Wheat and Grain Sorghum

The wheat and grain sorghum crop mix yielded a mean farm income of \$79,696, significantly less than in the base case (P <.001). Farm income ranged from -\$128,387 to \$397,404 with a standard deviation of \$76,926 (Table 19). In the low debt scenario adding grain sorghum to the crop mix reduced mean farm income \$3,303, while in the high debt scenario mean farm income was reduced by \$13,277. Thus, in the presence of financial stress the costs associated with reducing income risk through diversification increase considerably. Equity growth for the planning period averaged 17.5% ranging from -59% to 94.3% with a standard deviation of 30.1% (Table 20). In the presence of financial stress the standard deviation of equity growth with the diversified crop mix was 75% of the standard deviation of equity growth in the base case, while in the low debt scenario diversification resulted in a standard deviation of equity growth that was 70% of the base case.

Table 19. Summary Statistics of Farm Income High Debt Wheat and Grain Sorghum Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	$92,973	($151,449)	$621,331	$106,526	1.146
WW-GS	$79,696	($128,387)	$397,404	$76,926	0.965
CAT	$80,177	($127,511)	$397,257	$77,006	0.960
MPCI-55	$69,772	($137,787)	$384,978	$76,434	1.095
MPCI-75	$54,951	($158,881)	$389,858	$75,840	1.380
CRC-55	$68,363	($140,290)	$389,390	$76,555	1.120
CRC-75	$56,638	($129,029)	$402,838	$75,900	1.340

Table 20. Summary Statistics of Equity Growth High Debt Wheat and Grain Sorghum Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	26.6%	-75.7%	119.8%	40.4%	1.519
WW-GS	17.5%	-59.0%	94.3%	30.1%	1.720
CAT	17.8%	-59.2%	95.4%	30.2%	1.697
MPCI-55	10.6%	-65.8%	91.0%	30.3%	2.858
MPCI-75	0.3%	-76.0%	84.8%	31.5%	105.000
CRC-55	9.7%	-68.8%	92.3%	30.6%	3.155
CRC-75	1.5%	-81.5%	84.7%	31.8%	21.200

CAT insurance. Purchasing CAT coverage increased income and equity growth relative to the uninsured scenario. With CAT mean farm income was $80,177 and farm income had a standard deviation of $77,006 (Table 19). Farm income ranged from -$127.511 to $397,257, a slightly narrower range than without insurance. Mean equity growth increased more in the high debt scenario than in the low debt scenario with CAT relative to no insurance. Mean equity growth for the period simulated was 17.8%, .3% greater than in the uninsured scenario. Equity growth ranged from -59.2% to 95.4% with a standard deviation of 30.2% (Table 20).

MPCI 55%. Purchasing MPCI-55% resulted in mean farm income of $69,772 with a standard deviation of $76,434 (Table 19). Farm income ranged from -$137,787 to $384,978. The minimum income received was about $10,000 less than with CAT and the maximum was about $12,000 less than with CAT. Equity growth for the period averaged 10.6% ranging from -65.8% to 91% with a standard deviation of 30.3% (Table 20). Equity growth averaged about 1% per year, thus the average financial situation remains nearly constant across the simulated period.

MPCI 75%. When the coverage level of MPCI is increased to 75% mean farm income decreased to $54,951 and the standard deviation of farm income decreased to $75,840 (Table 19). Farm income ranged from -$158,881 to $389,858. The minimum income was lower and the maximum income was higher than at the 55% coverage level. Thus, in the maximum income year an indemnity was paid. Equity growth during the period averaged .3% ranging from -76% to 84.8% with a standard deviation of 31.5% (Table 20). Again increasing coverage level reduced expected equity growth.

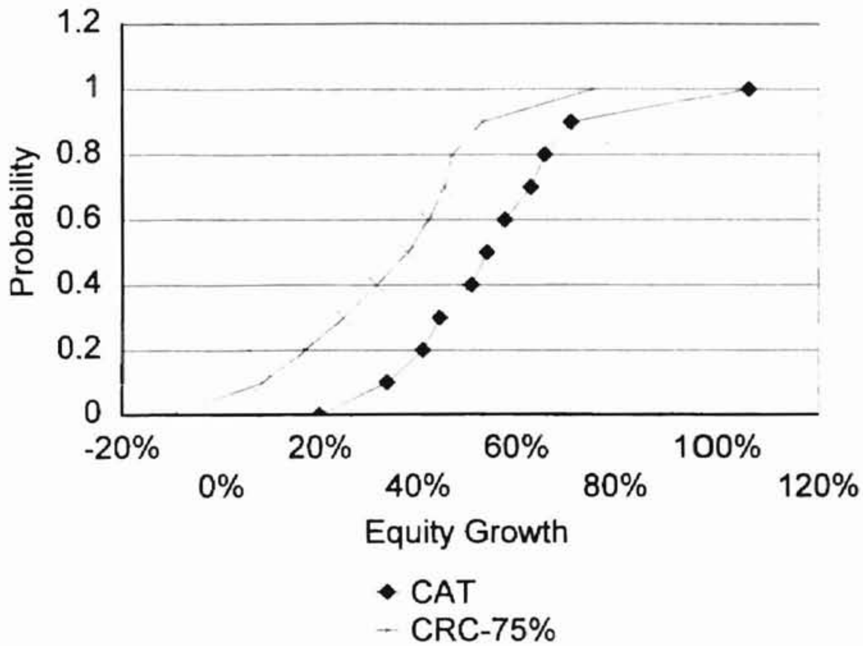
CRC 55%. Purchasing CRC-55% yielded a mean farm income of $68,363 with a standard deviation of $76,555 (Table 19). Mean farm income was about $1,400 less with CRC-55% than with MPCI-55%. Farm income ranged from -$140,290 to $389,390. The minimum farm income received was less than with MCPI-55%, while the maximum farm income was higher with CRC-55%. Equity growth of the farm during the planning period averaged 9.7% ranging from -68.8% to 92.3% with a standard deviation of 30.6%

(Table 20). Average equity growth is slightly lower with CRC than with MPCI at the 55% coverage level.

CRC 75%. Increasing the coverage level of CRC reduced mean farm income to $56,638 with a standard deviation of $75,900 (Table 19). Farm income ranged from -$129,029 to $402,838. Increasing the coverage level of CRC increased minimum income. Equity growth of the farm averaged 1.5% for the ten year period. Equity growth ranged from -81.5% to 84.7% and had a standard deviation of 31.8% (Table 18). Increasing the coverage level of CRC increased the standard deviation of equity growth, while reducing mean equity growth compared to CRC-55%.

The relative variability of farm income resulting with MPCI and CRC, indicated by the CV of farm income, for the high debt wheat and grain sorghum crop mix was greater than that in the CAT and uninsured cases. CAT resulted in the lowest CV of farm income, while MCPI-75% resulted in the highest. The purchase of crop insurance resulted in decreasing mean farm income relatively more than standard deviation. Furthermore, since MPCI and CRC coverage resulted in relatively more variable alternatives with respect to farm income, the same was true of equity growth. Only if an alternative is less variable with respect to farm income can it be less variable with respect to equity growth. However, a less variable alternative with respect to farm income will not necessarily be less variable with respect to equity growth. The impact of CRC-75% on farm equity growth is illustrated in figure 12. CRC-75% reduces equity growth of the farm at all probabilities.

Figure 12. Equity Growth CDFs High Debt Wheat and Grain Sorghum Scenario



Wheat, Grain Sorghum, and Cotton

Including cotton in the crop mix in the high debt scenario significantly reduced farm income relative to either alternative crop mix (P < .001), unlike in the low debt scenario. Mean farm income in the three crop scenario was $74,048 and had a standard deviation of $118,299 (Table 21). Farm income ranged from -$219,733 to $477,723. The minimum farm income experienced was significantly lower than with either of the other crop mix alternatives. Under high levels of financial stress the additional capital requirements necessary to produce cotton are extremely burdensome on the farm's financial position. Equity growth for the period averaged 3.7% well below average equity growth of the traditional crop mixes. Equity growth ranged from -62.2% to 101.8% with a standard deviation of 34.1% (Table 22).

Table 21. Summary Statistics of Farm Income for the High Debt Wheat, Grain Sorghum, and Cotton Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	$92,973	($151,449)	$621,331	$106,526	1.146
WW-GS-CT	$74,048	($219,733)	$477,723	$118,299	1.598
CAT	$77,867	($214,464)	$479,364	$114,992	1.477
MPCI-55	$59,640	($224,761)	$440,402	$109,300	1.833
MPCI-75	$20,253	($223,148)	$384,574	$97,655	4.822
CRC-55	$57,338	($216,688)	$432,055	$107,059	1.867
CRC-75	$17,737	($218,234)	$373,369	$94,432	5.324
MPCI-55CT	$66,160	($222,058)	$446,982	$109,774	1.659
MPCI-75CT	$35,977	($214,304)	$404,434	$99,021	2.752
CRC-55CT	$64,972	($212,877)	$444,203	$107,625	1.656
CRC-75CT	$33,146	($202,756)	$399,125	$95,972	2.895

Table 22. Summary Statistics of Equity Growth for the High Debt Wheat, Grain Sorghum, and Cotton Scenario

Insurance	Mean	Minimum	Maximum	Std.Dev.	CV
Base Case	26.6%	-75.7%	119.8%	40.4%	1.519
WW-GS-CT	3.7%	-62.2%	101.8%	49.6%	13.298
CAT	6.3%	-61.3%	102.3%	49.4%	7.879
MPCI-55	-5.5%	-73.7%	87.7%	48.4%	-8.800
MPCI-75	-31.7%	-99.7%	48.2%	46.7%	-1.473
CRC-55	-7.1%	-76.6%	83.7%	48.3%	-6.803
CRC-75	-33.8%	-110.5%	44.2%	47.2%	-1.396
MPCI-55CT	-1.4%	-69.2%	90.4%	48.3%	-34.500
MPCI-75CT	-21.5%	-89.5%	56.9%	46.1%	-2.144
CRC-55CT	-2.2%	-70.3%	87.1%	48.2%	-21.909
CRC-75CT	-23.5%	-95.5%	56.4%	46.5%	-1.979

CAT Insurance. Purchasing CAT insurance increased mean farm income and mean equity growth of the farm. Farm income was increased to $77,867 and had a standard deviation of $114.992 (Table 21). CAT increased both minimum and maximum farm income and decreased the standard deviation of farm income compared to the uninsured case. Equity growth increased as a result of increased farm income. Equity growth for the simulation period averaged 6.3% ranging from -61.3% to 102.3% with a standard deviation of 33.8% (Table 22). Thus, CAT dominated no insurance in a mean variance analysis of equity growth.

MPCI 55%. Purchasing MPCI-55% yielded a mean farm income of $59,640 with a standard deviation of $109,300 (Table 21). Farm income ranged from -$224,761 to $440,402. The minimum and maximum farm incomes received were about $10,000 and $39,000 less than with CAT, respectively. The simulated farm incomes resulted in mean equity growth of -5.5% for the planning period. Equity growth ranged from -73.7% to 87.7% with a standard deviation of 32.9% (Table 22). MPCI-55% reduced mean, minimum, and maximum equity growth compared to no insurance or CAT.

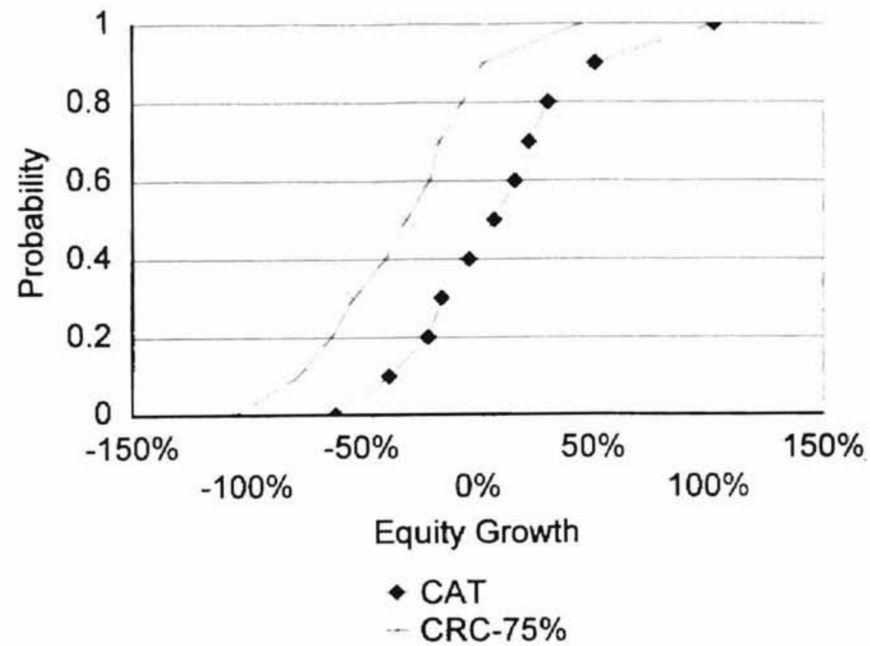
MPCI 75%. Increasing the coverage level of MPCI to 75% further decreased mean farm income to $20,253 (Table 21). Farm income ranged from -$223,148 to $384,574 with a standard deviation of $97,655. The minimum income received is slightly greater than with MPCI-55%. Equity growth of the farm during the planning period averaged -31.8% (Table 22). Thus, the simulated farm lost about 3% of equity per year on average. Equity growth ranged from -99.6% to 48.2% with a standard deviation of 31.2%.

CRC 55%. Purchasing CRC-55% yields a mean farm income of $57,338, slightly less than with MPCI-55% (Table 21). Farm income ranged from -$216,688 to $432,055 with a standard deviation of $107,059. Mean income and standard deviation of farm income are both about $2,300 less than with MPCI-55%. The simulated farm incomes resulted in mean equity growth of -7.1% (Table 22). Equity growth ranged from -76.6%

to 83.7% with a standard deviation of 32.8%. Maximum equity growth was reduced slightly more than minimum equity growth relative to MPCI-55%.

CRC 75%. Increasing the coverage level of CRC to 75% significantly reduced farm income. Farm income averaged only $17,737, about $40,000 less than with CRC-55% (Table 21). Farm income ranged from -$218,234 to $373,369 with a standard deviation of $94,432. Simulated farm incomes resulted in mean equity growth of -33.8% for the planning period. Equity growth ranged from -110.5% to 44.3% with a standard deviation of 31.6% (Table 22). Increasing the coverage level of CRC resulted in a significant reduction in expected equity growth. Figure 13 illustrates the decline in equity growth associated with purchasing CRC-75%. Risk associated with equity growth was not reduced with crop insurance, as the no insurance alternative yielded a higher rate of equity growth for all probabilities.

Figure 13. Equity Growth CDFs for High Debt Wheat, Grain Sorghum, and Cotton Scenario



<u>MPCI 55% CT</u>. Insuring only cotton above the CAT level in the high debt scenario yielded results similar to the low debt scenario. Farm income averaged $66,160, slightly more than when MPCI-55% was purchased for all crops (Table 21). Farm income ranged from -$222,058 to $446,982 with a standard deviation of $109,774. Equity growth of the farm averaged -1.4% for the planning period. Equity growth ranged from -69.2% to 90.4% with a standard deviation of 32.8% (Table 22).

<u>MPCI 75% CT</u>. Increasing the coverage level for cotton resulted in mean farm income of $35,977, significantly lower than with MPCI-55%-CT (Table 21). Farm income ranged from -$214,304 to $404,434 with a standard deviation of $99,021. Simulated farm incomes resulted in mean equity growth of -21.5% for the planning

period (Table 22). Equity growth ranged from -89.5% to 56.9% with a standard deviation of 30.7%. Expected equity growth is well below that of no insurance.

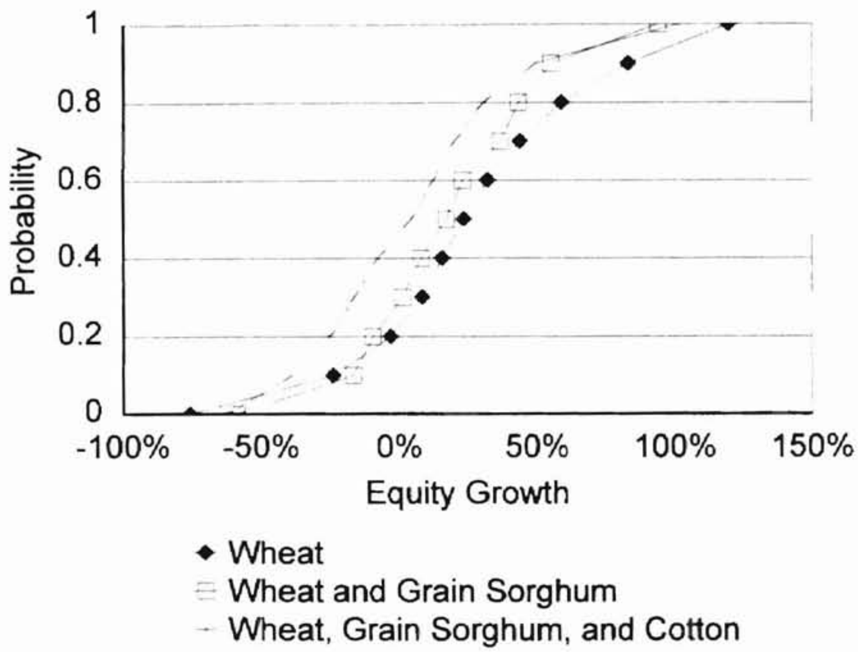
CRC 55% CT. Insuring cotton with CRC-55% yielded a mean farm income of \$64,972, slightly lower than with MPCI-55%-CT (Table 21). Farm income ranged from -\$212,877 to \$444,203 with a standard deviation of \$107,625. Equity growth for the planning period averaged -2.2%, lower than with MPCI-55%-CT. Equity growth ranged from -70.3% to 87.1% with a standard deviation of 32.7% (Table 22). The minimum and maximum equity growth rates were less than with MPCI-55%-CT.

CRC 75% CT. Increasing the coverage level of cotton to 75% resulted in mean farm income of \$33,146 (Table 21). Farm income ranged from -\$202,756 to \$399,125 with a standard deviation of \$95,972. Mean farm income was significantly lower, while minimum income was significantly higher than at the 55% coverage level. Equity growth for the 10 year period averaged -23.5%, much lower than with CRC-55%-CT (Table 22). Equity growth ranged from -95.5% to 56.4% with a standard deviation of 31%.

Results indicated that CAT insurance yielded the lowest CV ratio of farm income of all crop insurance alternatives for the three crop high debt scenario. Purchasing crop insurance increased the relative variability of farm income and equity growth. Purchasing MPCI or CRC for all crops or for cotton only resulted in relatively more variable farm income. Also mean farm income is reduced to the point mean equity growth is negative.

The effectiveness of crop insurance with respect to reducing income variability was not increased in the high debt scenario. The costs of insurance were still too high, not allowing crop insurance to truncate the equity growth distribution. In the high debt scenario crop diversification reduced mean income more than in the low debt scenario, while reducing the standard deviation of farm income about the same amount. Increasing the debt levels by producing cotton was more than the high debt farm could bear. Including cotton in the crop mix reduced equity growth at almost all probabilities (illustrated in figure 14).

Figure 14. Equity Growth CDFs of Crop Mix Alternatives Without Insurance High Debt Scenario



The costs and benefits of the insurance alternatives were calculated and analyzed. The simulated premiums and indemnities were calculated based on the simulated yields and prices. Since, MPCI is the yield component of CRC it follows that the ability of MPCI to manage yield risk will influence the ability of CRC to manage income risk. The impacts of crop insurance on farm income distributions indicated that the cost to benefit ratio of MPCI and CRC were very high. This is confirmed by the premiums and indemnities simulated. Indemnities for insurance policies above the CAT level are about 11% of mean premium for wheat and grain sorghum, but are about 40% for cotton at the 55% coverage level for MPCI. For the same yield coverage level with CRC indemnities for wheat, grain sorghum, and cotton are about 19%, 18%, and 43% of premiums respectively. Increasing the coverage level to 75% causes indemnities as a percentage of average premium to be about 47%, 17%, and 29% for wheat, grain sorghum, and cotton respectively. Buying up to CRC coverage from MPCI coverage at the 75% yield coverage level increases expected indemnities as a percent of premium as it did at the 55% yield coverage level. Simulated premiums and indemnities of the three crop scenario are summarized in table 23.

Table 23. Simulated Per Acre Crop Insurance Premiums and Indemnities

		Indemnity				Premium			
Commodity	Insurance	Mean	Minimum	Maximum	Std. Dev.	Mean	Minimum	Maximum	Std. Dev.
wheat	CAT	0.01	0.00	2.63	0.17	0.04	0.04	0.04	0.00
grain sorghum	CAT	0.13	0.00	19.15	1.81	0.12	0.12	0.12	0.00
cotton	CAT	1.82	0.00	74.03	9.86	0.06	0.06	0.06	0.00
wheat	MPCI-55	0.21	0.00	13.73	1.18	1.91	1.25	2.98	0.31
grain sorghum	MPCI-55	0.45	0.00	48.23	5.35	4.00	2.06	6.80	0.76
cotton	MPCI-55	4.53	0.00	157.24	22.41	11.36	5.76	18.10	2.40
wheat	MPCI-75	3.42	0.00	50.72	8.56	7.28	4.79	11.02	1.18
grain sorghum	MPCI-75	2.62	0.00	101.93	16.17	14.98	7.66	25.56	2.89
cotton	MPCI-75	12.43	0.00	247.85	43.25	42.53	21.63	67.78	8.94
wheat	CRC-55	0.51	0.00	33.69	2.52	2.64	1.94	3.74	0.32
grain sorghum	CRC-55	0.94	0.00	64.13	8.55	5.33	3.13	8.42	0.82
cotton	CRC-55	6.20	0.00	212.17	28.54	14.53	7.83	22.93	2.97
wheat	CRC-75	5.30	0.00	74.76	11.91	9.70	7.05	13.38	1.20
grain sorghum	CRC-75	4.68	0.00	115.25	23.65	18.84	10.76	30.23	3.06
cotton	CRC-75	16.95	0.00	334.43	54.78	51.02	26.94	80.75	10.52

Chapter 5

Summary and Conclusions

Summary

A simulation of the financial transactions of a farm business was performed for 100 iterations of a 10 year planning period. The financial simulation used simulated yields and prices to calculate the costs and returns of the farm enterprise. The case farm consisted of 3000 acres of cropland. The farm was analyzed under two debt scenarios with three crop mix strategies. Crop mixes included wheat only, wheat and grain sorghum, and wheat, grain sorghum, and cotton. Each crop mix was evaluated in the presence of six insurance alternatives. Insurance alternatives were no insurance, catastrophic insurance (CAT), multiple peril crop insurance (MPCI), and crop revenue coverage (CRC). Both MPCI and CRC were evaluated at the 55% and 75% coverage level. Distributions of farm income and equity growth of the planning period were compiled and analyzed. The assumption of normality for the distributions of average farm income could not be rejected. Thus, paired t-tests for means were used to test for significant difference between mean farm incomes resulting with different crop mix and crop insurance alternatives.

For the low debt uninsured wheat only case, farm income averaged $163,570 with a standard deviation of $101,762. Purchasing crop insurance or increasing the level of coverage increased minimum income, while reducing mean income. When CRC-75%

was purchased mean farm income was $150,207 with a standard deviation of $88,343. In the single crop case crop insurance reduced standard deviation and mean income, while increasing minimum income.

For the wheat and grain sorghum crop mix, the uninsured farm yielded a mean farm income of $160,267 with a standard deviation of $71,765. Minimum income in the diversified case was about $34,000 higher than in the single crop case. Insuring both crops with CRC-75% resulted in a mean farm income of $146,329 with a standard deviation of $70,617. In the diversified case minimum income was not increased with the purchase of crop insurance. The reduction of standard deviation of farm income resulting with crop insurance is very small compared to the single crop case. Thus, crop diversification appears to be a substitute for crop insurance.

Mean farm income was the highest, $178,834, when cotton was included in the model and CAT was elected. The uninsured case yielded a mean farm income of $175,914 with a standard deviation of $124,983. The mean income is significantly higher than for the single crop case. However, the standard deviation is relatively higher when cotton is included in the crop mix. Insuring the three crop case results in outcomes similar to the two crop case. Purchasing CRC-75% yielded a mean farm income of $134,307 with a standard deviation of $102,122. Insuring the three crop case results in a standard deviation of farm income slightly higher than the uninsured single crop case, but mean farm income is reduced well below that of the uninsured single crop case.

The uninsured wheat case resulted in mean equity growth of 48.1%, the minimum equity growth experienced was 6.2%. The impact of crop diversification on farm income is apparent in the resulting equity growth distribution. The uninsured wheat and grain sorghum case resulted in mean equity growth of 46.6%. However, the minimum equity growth experienced was increased to 15.7% with diversification. Further increasing diversity by adding cotton to the crop mix resulted in more variable income, but resulted in the highest mean and minimum equity growth experienced among crop mix alternatives, 52.5% and 19.2% respectively.

When debt levels are increased, the single crop case yielded a mean farm income of $92,973 with a standard deviation of $106,526. The wheat and grain sorghum scenario yielded a mean farm income of $79,696 with a standard deviation of $76,926. Including cotton in the crop mix resulted in mean farm income of $59,640 with a standard deviation of $118,299. The standard deviation of farm income is slightly larger under high financial stress. Under high financial stress crop diversification and crop insurance reduced mean income more than in the low debt scenario. The magnitude of the reduction of the standard deviation of farm income is consistent across debt levels. Crop diversification yielded a larger reduction in standard deviation of farm income, with a smaller reduction of mean income, than did crop insurance, just as in the low debt scenario.

In the high debt scenario the wheat only case resulted in mean equity growth of 26.6%, while the minimum equity growth experienced was -75.7%. Diversifying in the high debt scenario results in a larger decrease in mean equity growth than in the low debt scenario. The uninsured wheat and grain sorghum case resulted in mean equity growth of 17.5%, while the minimum equity growth experienced was -59%. Further increasing diversity by including cotton in the crop mix resulted in mean equity growth of 3.7%, while the minimum equity growth experienced was -61.3%. While minimum equity growth was still increased with diversification, mean equity growth was reduced substantially with diversification. Including cotton in the crop mix failed to increase minimum equity growth relative to the wheat and grain sorghum scenario, as it did in the low debt scenario.

In the low debt base case the impacts of crop insurance on farm income were not as large as expected. Crop insurance redistributed farm income by truncating the income distribution. However, the high costs of crop insurance relative to its benefit resulted in decreasing maximum and mean income more than minimum income was increased. The reduction of income variability provided by crop insurance was not sufficient to truncate the equity growth distribution as well. Thus, even in the single crop case, where results were consistent with expectations, crop insurance did not truncate the lower end of the equity growth distribution. Interest costs were higher when crop insurance was purchased, as the premium to indemnity ratio was well below 1.

Crop diversification provided valuable risk reduction. Diversifying the crop mix resulted in reducing income variability without significantly reducing mean income ($P<.001$). The benefits of crop diversification, unlike crop insurance, were significant enough to truncate the equity growth distributions. Thus, the probability of experiencing extremely low equity growth, long term, is reduced by crop diversification.

In the presence of crop diversification, crop insurance reduces income variability less per dollar decrease in mean income. Thus, as the level of diversification increases the benefits of crop insurance become increasingly smaller. It appears that crop diversification is a substitute for crop insurance.

Income enhancement through introduction of a new crop may be accomplished with cotton in the North Central Oklahoma area, for farms not already in financial stress. Results indicate including cotton in the crop mix increases income risk relative to wheat and grain sorghum and wheat. This is the result of cotton having greater yield variability than wheat and grain sorghum. However, including cotton in the crop mix limited downside equity growth risk. The increase in income risk may be more than a farm in financial stress can bear. In the high debt case including cotton in the crop mix yielded a lower mean income than either of the other crop mix alternatives. The standard deviation of farm income was still higher with cotton in the crop mix. Growing cotton is not likely to outperform other crop mix alternatives for farms already facing high levels of financial stress. The financial obligations associated with purchasing new machinery increase debt levels to the point the farm has a high probability of losing equity. The simulation indicated that the line of credit was used to make loan payments and equity actually decreased when cotton was included in the high debt case crop mix in numerous iterations.

The results indicate that the farm business scenario analyzed could attain higher levels of equity growth through self insurance than purchasing crop insurance, regardless of financial stress level. Borrowing capital in low income years and saving during high income years is a means of self insurance. It pools risk across time, while crop insurance pools risk spatially. Self insurance requires large cash reserves or a strong relationship with the capital supplier, which is another source of risk not evaluated in this study.

Increasing financial stress did not affect the impacts crop insurance had on farm income distributions.

In terms of risk, crop insurance did not perform as well as crop diversification. The wheat and grain sorghum crop mix resulted in far less income variability than that of the wheat only scenario with crop insurance. However, diversifying with the production of cotton, a relatively risky crop compared to wheat and grain sorghum, increased income variability beyond that of the single crop scenario. The wheat and grain sorghum scenario yielded the lowest CV of farm income in the low debt scenario, while, in the high debt scenario the single crop case yielded the lowest CV of farm income.

Conclusions

In theory insurance is not designed to increase profits. However, premiums have been subsidized and additional discounts offered to entice farmers to purchase crop insurance policies. Previous work has indicated crop insurance may increase mean income and equity growth in other regions (Lemieux, Richardson, and Nixon). The effectiveness of crop insurance as a risk management tool should be analyzed on a case by case basis. Different farms will experience unique benefits from crop insurance. Each farm is unique in size, geographic diversity, and average yield all of which have some impact on yield variability (Zering, McCorkle, and Moore). It is illustrated that for the farm scenario analyzed crop insurance does not perform as well as crop diversification in limiting income risk.

For the base case in this study crop insurance did perform as would be expected, increasing minimum income while decreasing mean income. However, the magnitude of its effects were less than anticipated. This could be the result of forming expectations based on the outcomes of previous studies that analyzed average farm scenarios. Alternatively, the performance of crop insurance may have been less than expected because the costs of insurance are high relative to the benefits it provides. Excessive cost to benefit ratios bring into question the accuracy or the structure of crop insurance actuarial tables.

Current crop insurance actuarial tables set premium rates based on average yield. Thus, average yield is the only variable used to predict yield variability for a given crop. The current structure is such that as average yield increases premium per dollar at risk decreases. There are several reasons this actuarial structure may not set fair rates. First, farm size impacts yield variability (Zering, McCorkle, and Moore). Second, producer behaviors including moral hazard and adverse selection will influence yield variability and actuarial performance (Carriker et al.). Finally, Coble et al. suggest that moral hazard increases during years in which growing conditions are not favorable, an actuarial problem that requires a very long actuarial history to set fair rates. Individual farms should analyze the performance of crop insurance based on their historical performance. Actuarial problems caused by adverse selection and moral hazard and actuarial structural problems, such as average yield being a poor indicator of yield variability, influence the premium structure. Thus, the costs and benefits of crop insurance will vary from farm to farm.

In the case of insuring wheat, actuarial documents fail to penalize producers for early planting. In Oklahoma a significant percentage of wheat acres are planted prior to the first of October to increase forage yield for grazing stocker cattle throughout the winter (Epplin, Hossain, and Krenzer). Agricultural producers change production practices to utilize the benefits of new farm programs (Epplin). Epplin, Hossain, and Krenzer conclude that grazing wheat influences planting date, which in turn impacts wheat yield. This creates adverse selection potential for dual purpose wheat producers. The failure to distinguish between dual purpose wheat and wheat for grain may prevent fair crop insurance premium rates from being set (Epplin, Hossain, and Krenzer). While most other crops are not dual purpose, the existence of adverse selection based on management levels may prevent fair premium rates from being set for all crops.

The results of this study indicate that insurance premiums are too high to cost effectively reduce the income risk faced by the farm scenario considered relative to crop diversification strategies. Actuarial tables need to be tailored to individual farms based on their historical yield records. Until a suitable indicator of a farms yield variance is included in the actuarial structure, opportunities for adverse selection in the crop insurance market will exist. Further research is needed to identify effective actuarial structures for the crop insurance market.

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