FARMER RISK MANAGEMENT BEHAVIOR AND WELFARE UNDER ALTERNATIVE PORTFOLIOS OF RISK INSTRUMENTS

By

Hong Wang

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1996

ABSTRACT

FARMER RISK MANAGEMENT BEHAVIOR AND WELFARE UNDER ALTERNATIVE PORTFOLIOS OF RISK INSTRUMENTS

By

Hong Wang

Agricultural returns are risky because production is highly sensitive to weather, disease, and pests. Production risk contributes to price variability because of biological time lags, inelastic demand, and asset fixity. Farmer income risk comes from the joint effect of price and yield risks. Futures, options, crop insurance, and government programs can be used to manage the overall income risk.

Existing research tends to study particular risk management instruments in isolation from others. This dissertation studies farmers' optimal use of alternative instruments in a portfolio setting and the resulting welfare. Current political debates are concerned with the budgetary cost of supporting crop insurance and government programs. Potential policy changes in the crop insurance and government program may significantly impact a farmer's risk management behavior and welfare. Some of these effects are analyzed in this dissertation.

A bivariate ARCH model with seasonality is used to capture the time-varying volatilities and excess kurtosis properties of commodity cash and futures prices. A deterministic trend model with nonnormal errors from a hyperbolic sine transformation is used to characterize yields based on the limited sample size and asymmetric distribution. Because the distributions and income structure are complicated, numerical

multivariate distributions for prices and yields are simulated, and numerical results are analyzed in an expected utility framework.

The results suggest crop insurance is usually more valuable than the futures and options because yield is generally more volatile than price. Futures and options may be used to "cross hedge" yield risk if price and yield are correlated.

With futures and options, the value of the government program is derived primarily from the implicit subsidy, so it decreases as the subsidy is reduced and its risk reducing effect is not important when futures and options are available.

There is a tradeoff between the yield basis risk using area yield crop insurance (AYCI) and the individual yield crop insurance (IYCI) premium. AYCI may provide higher welfare gain than IYCI while significantly reducing the government cost, if the IYCI premium is above the actuarially fair level, yield basis risk is low, or AYCI trigger yield restrictions are above IYCI levels.

To my husband Hao Zhang,

and my parents Dongxiong & Fengsheng Wang

ACKNOWLEDGMENTS

I'm very grateful to many faculty, staff, and my fellow graduate students in the Department of Agricultural Economics, from whom I have received constant support and encouragement which made my graduate study at Michigan State University pleasant and fruitful.

I'm greatly in debt to my dissertation supervisor, Dr. Steve Hanson, who has continually encouraged me through his kindness and patience. His guidance has made the completion of this dissertation a smooth and enjoyable process, and his advice has helped me develop professionally in the discipline. Furthermore, his personal care and deep concern for his students has kept me in high spirit, without which this dissertation may never have been accomplished. It is impossible to fully express in words my respect and gratitude toward him.

I extend gratitude to my major professor, Dr. Roy Black, for his insightful guidance to my academic program, comments on my dissertation, scholarly challenge to my professional progress, and years of financial support. I also thank Dr. Robert Myers for his active service in my dissertation committee, and the valuable inputs he has contributed to my dissertation. He has not only helped me to widen the scope of my academic vision, but also inspired me with the power of economic theory. I'm also benefited from Dr. Jack Meyer, another committee member, through his excellent teaching in economic theory and consultation on risk analysis.

My gratitude also goes to Dr. Lindon Robison who taught me important concepts in risk analysis; to Dr. Scott Swinton who has helped me develop teaching skills; to Elizabeth Bartilson who helped me format this dissertation; and to Rose Greenman, Nicole Alderman, and Sherry Rich who also provided a lot of help that might go beyond their responsibilities.

I give great thanks to my parents and my sister who would sacrifice everything for my education and have encouraged me since my early childhood to try my best on everything I start and to develop perseverance. My deepest thanks go to my husband, Hao Zhang, to whom I owe the most. His unconditional love, constant encouragement, academic inspiration, and sacrifice are the indispensable factors contributing to my Ph.D degree and this dissertation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

Farm incomes are characterized by instability and risk that stem from several sources. First, agricultural production is biological in nature so yields depend on natural conditions, such as weather (temperature, moisture and sunshine), disease, insects and other catastrophes (flood, drought, wind and fire). Second, many agricultural products are perishable and difficult to store, such as dairy products, eggs, poultry, and livestock products. Production processes also tend to be longer than most manufacturing production processes, and investment is often characterized by asset fixity, causing agricultural production to be inflexible in adjusting to market signals. In addition, the market demand for agricultural products is price inelastic, so small fluctuations in supply can cause large fluctuations in price. To help manage these risks, a variety of risk management instruments are available to farmers.

Yield and price are the two main sources of risk in agriculture. These risks can be managed through both market mechanisms and government programs. Commodity futures markets have been available since the 1800s as a means of price risk management. Options on futures, available since 1984, provide an additional way to manage price risk for some agricultural commodities. Government commodity price support and deficiency payment programs also protect some producers from unfavorable prices. In addition, government sponsored crop insurance provides a tool to help manage yield risk. Available since the late 1930s, crop insurance now exists for most major crops and in most regions throughout the U.S.

However, the crop insurance program imposes a heavy budgetary burden on the government. To encourage participation, the government has subsidized up to 30 percent of estimated premium costs and provided indirect subsidies in the form of free delivery and administrative costs. The aggregate program loss ratio (indemnities paid / premiums earned) during the 1981-1990 period was 1.42[1]. Between 1980 and 1988, government outlays for the federal crop insurance program exceeded 4.2 billion dollars, accounting for over 80 percent of the total indemnities paid to farmers. In fact, indemnities exceeded premiums in every year during the ten year period.

The deficiency payment program reduces price risk and provides an implicit government subsidy to farmers by guaranteeing a minimum target price. The average annual cost to the government has been about $6 billion in the past five years.

Recent political debates have focused on reducing and/or eliminating many farm programs, including deficiency payments and crop insurance programs, because their effectiveness has been questioned and they tend to impose a large cost on the government budget. Current federal budget difficulties have increased this pressure.

Altering or eliminating these farm programs will influence the risk position of farms, and farm risk management strategies and welfare may change correspondingly.

---

[1] This computation of the loss ratio uses total premiums in the denominator. Total premiums are the sum of producer premiums and premium subsidy, Thus, if only the producer premiums are included the loss ratio would be even higher.

The farmer's use of risk management instruments depends not only on the properties of the individual instrument, but also on the properties of other instruments available in the portfolio. Therefore, it is important to study the impacts of change in farm programs on risk management in a portfolio setting.

Considerable research has been done on the behavior of competitive firms using futures and options markets. Danthine (1978); Holthausen (1979); and Feder, Just and Schmitz (1980) investigated production and hedging behavior when producers face only output price risk, and hedge using futures markets. Lapan, Moschini and Hanson (1991) extended this approach to model production and hedging decisions when both futures and options markets are available simultaneously.

Many studies on the optimal use of futures and options to manage income risk assume yields are deterministic. However, as discussed earlier, agricultural commodity yields tend to be stochastic. Sakong, Hayes and Hallam study futures and options under both price and yield risks without crop insurance. A number of studies have examined income risk management in the presence of stochastic yields using crop insurance. Ahsan, Ali and Kurian (1982) showed that, in the absence of price uncertainty, actuarially fair crop insurance can completely eliminate income risk. Chambers (1989) studied crop insurance in the presence of moral hazard. Coble, Knight, Pope and Williams (1993) tested for the existence and level of moral hazard and adverse selection in the use of individual yield crop insurance. Miranda (1991) showed that area yield insurance provides better risk protection for most producers than individual yield insurance and significantly improves the actuarial performance of the insurance program.

Despite the rich set of research in the risk management area, most studies focus on a particular risk management instrument studied in isolation, without acknowledging that the instrument may be part of an overall portfolio of risk management instruments. This dissertation explores the optimal behavior and welfare of agricultural producers, when futures markets, options markets, government deficiency payment programs and crop insurance are simultaneously available to manage price and yield risks. This is one of the first comprehensive studies of farm risk management behavior which allows for such an extensive portfolio of risk management instruments. More specifically, the objectives of this research are:

1. Develop a simulation model which can be used to evaluate farmer risk management behavior and welfare in alternative policy and risk settings.

2. Evaluate the behavior of risk averse farmers when futures, options, crop insurance and a government deficiency payment program are included in the risk management portfolio.

3. Compare and evaluate alternative crop insurance designs and examine the relative performance and tradeoffs between individual yield crop insurance (IYCI) and area yield crop insurance (AYCI).

4. Investigate the impact of alternative designs for the government deficiency payment program on farmer behavior and welfare.

It is necessary to have a model flexible enough so that the impacts of changes in the availability and design of these instruments can be studied. In particular, crop insurance and other government programs are subject to change, and so it is important to be able to evaluate the impact of potential changes on a farmer's risk management behavior and welfare.

The dissertation is organized into nine chapters. Chapter II provides background information on risk and risk management instruments, decision making models under risk, and previous studies on risk management in agriculture. The general model is then developed in Chapter III and the function of each risk management instrument is explained. Because of the portfolio nature of the model it can not be solved analytically except under very restrictive conditions. As a result, numerical optimization and simulation methods are used to solve the model.

Chapter IV explains the simulation model parameterization for stochastic prices and yields. A bivariate ARCH model with seasonal components is used to simulate the cash and futures price distribution, and a deterministic trend model with nonnormal random errors is used to simulate the yield distribution. The correlation between prices and yields is imposed using a technique which constructs a multivariate distribution from univariate distributions.

Chapter V analyzes a representative farmer's optimal behavior and welfare for different combinations of risk management instruments. The optimal combination of risk instruments used by the representative farmer is explored, and the substitute or complement relationships among the instruments is also investigated.

Chapter VI studies the impacts of changes in yield risk and risk preferences on the optimal use of the risk management instruments and welfare. The price-yield correlation, individual farm yield risk, yield basis risk and risk aversion level may vary by individual farm and the geographical location. The results for the representative farm with specific values of these parameters are generalized by examining the changes in farmer behavior and welfare as these parameters change.

Chapter VII compares IYCI with AYCI in an attempt to evaluate the relative performance of the alternative yield indices. Performance under alternative contract designs are evaluated in order to explore the potential use and benefit of each type of indices. The results of this chapter will provide insights into the effectiveness of AYCI as a risk management alternative to IYCI, and the conditions that allow AYCI to outperform IYCI.

Chapter VIII studies the impacts of changes in the government deficiency payment program on participation and farmer welfare. The current policy discussions related to reducing the government subsidy in an attempt to phase out the program in the future may impact farmers' income levels and risk exposure. The use of other risk management instruments in the portfolio may also be affected by changes in the design of the government program.

Chapter IX concludes the dissertation by summarizing the major results of the study and discussing policy implications. The strengths and weakness of the study are also discussed, along with suggestions for future research.

Chapter II

DECISION MAKING UNDER RISK IN THE AGRICULTURAL SECTOR

In agricultural production, risk may have an important impact on decision making, and the existence of risk management instruments and strategies enriches the decision set. The concepts of risk, risk management, and important risk management instruments are introduced in this chapter.

There is a vast literature on risk management strategies for individuals who operate in the agricultural sector. In this chapter, important studies on decision making under risk and the use of risk management instruments are reviewed. These studies are used to develop the theoretical framework used in this research effort.

The expected utility model has been widely used to model decision making under risk. Its advantages and disadvantages in the current research application are explored in this chapter. In this study, utility is a function of net income which is composed of cash income from production and income from risk management instruments. Existing studies of a farmer's decision making under risk using alternative risk management instruments such as futures, options, government programs and crop insurance, are also reviewed in this chapter. Examination of the existing literature suggests a need for additional emphasis of risk analysis in a portfolio setting.

2.1 Risk and Risk Management

When an event has more than one possible outcome, it is uncertain. Robison and Barry define risk as a subset of uncertainty where the outcome of an event can alter the decision maker's well being. Risk faced by a firm can be broken into business risk and financial risk. Business risk is the variability in net returns to total assets as a result of such things as production and price risks. Financial risk is the variability added to the firm's net returns to equity holders that results from fixed financial claims against the firm. Thus, business risk is the risk associated with profit independent of the financial structure of the firm. Table 2.1 lists the general types of business and financial risks faced by a farm business. In this study we focus primarily on business risk.

Table 2.1 Classification of Risk in Agriculture

Type of Risks	Example
Business risk	
production risk	yield variability
market risk	input and output price variability
technological risk	technological change
legal and social risk	policy change
human risk	labor or ownership change
Financial risk	high leverage

A firm's response to risk generally focuses on reducing the likelihood that it is exposed to unfavorable outcomes, e.g., selecting crops that are more disease resistant; transferring risk to other agents, e.g., buying insurance; and increasing its risk bearing ability, e.g., setting up irrigation systems. Risk management strategies can be classified into production, marketing and financial strategies, as outlined in Table 2.2.

Table 2.2 Classification of Risk Management Strategies and Representation

Risk Management Strategies	Example
Production	selection of stable enterprises; diversification; and operating flexibility
Marketing	inventory management; hedging, forward contracting; sequential marketing; participating in public programs, vertical integration; and crop insurance
Finance	self-liquidating loans; liquid assets; liquid credit reserves; purchase of life, disability, and property insurance; and credit reserves

This study focuses on a firm's marketing responses to price and yield risks when a portfolio of risk management instruments is available to the farmer. Evaluating the farmer's behavior and welfare by focusing on each risk instrument individually can provide misleading results so it is important to examine the problem in a portfolio setting. For example, when options are the only instruments, the optimal position may be different than when the government program is added into the portfolio, because the two instruments are substitutes. The risk management portfolio studied here includes futures, options, crop insurance, and a government deficiency payment program.

2.2 Cash, Futures, Options, Government Program, and Crop Insurance

There are three basic types of pricing contracts available to the firm: cash, futures and options. Using these contracts, a firm not only realizes the value of its production but may capture more profit opportunities and/or avoid price risk by shifting it to others willing to accept the risk.

In addition to the market driven pricing instruments, the U.S. Government has provided pricing programs and sponsored crop insurance. The pricing programs are intended to help farmers manage their price risk while the crop insurance program helps farmers manage their yield risk. Both programs are subsidized and result in an income transfer to farmers who participate.

Cash Contracts

A cash contract is an agreement negotiated individually between a buyer and a seller that may be outside the rules and guarantees of an organized exchange. Cash contracts allow buyers and sellers the maximum flexibility in specifying contract terms. Commodity price, quality, quantity, delivery period and delivery location etc. can all be negotiated and specified in the contract. Because of their flexibility, cash contracts are not normally traded on an exchange but are settled by delivery.

Delivery of the commodity may be immediate or at some specified date in the future. Cash contracts for immediate delivery of the physical commodity are referred to as spot transactions and are said to take place on the spot market. The price specified in the spot market is referred to as spot price, or cash price. Cash contracts for future delivery of the physical commodity are known as forward contracts and are said to take place on the forward market.

Futures Contracts

A futures contract is a standardized legal contract to make or take delivery of a commodity during a specified future period for an agreed upon price. However, unlike forward contracts, futures contracts are normally traded on an exchange. To make trading possible, the exchange specifies certain standardized features in the contracts. Sellers and buyers trade through brokers, and all contracts for a specific commodity and delivery period are identical except for the trading price on a given exchange. One party to the contracts agrees to buy the physical commodity in the future and is said to hold a long position; the party who agrees to sell the commodity holds a short position. The contractor who is long (short) futures can either take (make) delivery at the specified time or sell (buy) back the futures contract at the current trading price before delivery is due. The futures price is the price that results in an equal number of short and long holders, and is regularly reported in the financial press.

A futures contract is different from a forward contract in that an exact delivery date is not usually specified, but can be at any time during a pre-specified period, say, the last month of the contract. The holder of the short position has the right to choose the delivery date during that period.

Another difference is that futures contracts are marked to market or settled each day. Both buyers and sellers are required to maintain a margin account with their brokers. At the end of each day when that day's futures price is revealed, adjustment is made to the margin accounts by subtracting (adding) the loss (gain). The initial margin is usually a small portion of the total value of the commodity but is set large enough to cover the maximum daily price movement allowed by the exchange. If the margin drops to a level lower than the "maintenance" margin, which is somewhere below the initial margin, a margin call will require the trader to restore his margin account to its original level. The cost to the trader to maintain the margin account is small because Treasury Bills can be used to satisfy the account requirement.

The performance of each party to honor the futures contract terms is guaranteed by the exchange clearinghouse. Brokers are required to settle accounts daily and maintain margin accounts with the clearinghouse just as their clients are required to do so with them.

Options Contracts

Options contracts give the buyer of the option the right but not the obligation to buy or sell the commodity during some period at a specified price. The primary difference between futures and options contracts is that the owner of a futures contract is legally obligated to make or take the delivery, or an equivalent cash settlement, while the owner of an option only agrees to make or take the delivery when it is favorable to do so, otherwise the contract just expires. While there is no cost to obtain a futures contract, buyers of an option must pay a premium to the sellers for the right to only "exercise" the option when it is profitable. The price specified in the options contract at which delivery is made is known as the exercise price or striking price.

There are two types of options. A call option gives the owner the right to buy the underlying commodity, and a put option gives the owner the right to sell the commodity. The date on which the option can no longer be exercised is known as the expiration or maturity date. American options can be exercised at any time up to the expiration date, while European options can only be exercised on the expiration date.

Options can be thought of as price insurance. If the price level is lower (higher) than the exercise price, the owner of the put (call) option will exercise it at maturity; if the price is higher (lower), the owner chooses not to exercise the option. Similar to insurance, the premium is related to the expected value of the option.

Risk Management Using Futures and Options

There are three basic behavior motives associated with the use of different contracts: arbitrage, hedging, and speculating. *Arbitrage* involves locking in a riskless profit by simultaneously entering into transactions in two or more different markets. *Speculating* is a risky investment made in an effort to achieve a financial profit. *Hedging* is a technique of establishing an approximate price for a cash commodity, or in some cases, ensuring that adequate supplies of some asset are available. The hedging motive is most closely associated with risk management behavior.

A hedger can be a producer, processor, marketing intermediary or a financial intermediary. He takes a position in the futures and/or options market which is opposite his actual or expected cash position. Because cash prices and futures prices are positively correlated, the gain or loss in one market will be offset by the loss or gain in the other. A "perfect hedge" refers to the perfect offset of a gain in one market by a loss in the other markets and rarely occurs because of basis risk. *Basis* is the difference between futures and cash prices. The basis level is the result of transportation cost, storage cost, variable quality and product characteristics, and the change in supply and demand conditions over time. The basis level changes over time and reduces the ability to hedge price risk.

Cross hedging is a concept used to denote the use of futures and/or options to hedge a risk associated with an asset other than the commodity underlying the futures and options contracts. Cross hedging typically occurs when there is no futures contract on a commodity/product, but its price is correlated with another commodity/product that does have an associated futures contracts (e.g., hedge slaughtered cows with beef futures). It is also possible to use futures and/or options to cross hedge yield risk when the commodity yield is correlated with futures price.

Government Deficiency Payments

In many countries, governments provide deficiency payments to farmers to protect them from income risks, to help increase farm income, and/or to help maintain a stable food supply. Farmers who wish to participate in the program for specified commodities enter into contracts with the government that often include a cost. However, the cost is not always a direct payment; for example, a particular program may require a percentage of total acreage to be set aside in order to receive the benefits the program offers. This allows the government to use the program to help control supply of particular commodities. The Commodity Credit Corporation, established in 1933 has administered deficiency payment programs in the U.S.

The specific benefits and obligations of the program vary by year, but the basic format is the same. For the Wheat and Feed Grain Programs provided by the United States Department of Agriculture (USDA), a target price is set, such that when the market price level (or some index related to the market price) falls below the target price, the difference will be paid to the farmer by the government. The amount of deficiency payment is limited to the difference between the target price and a critical price, known as the loan rate. If the price falls below the loan rate, the farmer is eligible to receive a nonrecourse loan up to an amount equal to the difference between the loan rate and the market price. This essentially provides a participating farmer a minimum cash price equal to the target price.

The program payment for each acre is the product of the price difference and a pre-specified yield level. In recent years, the farm's 1981-1985 five-year-average farm program payment yields have been used to establish the base yield levels upon which the payments are based. A participant's obligation is to set a specified percentage of their acreage aside; no crop is allowed to be produced and no benefits are paid on this acreage. Besides the set aside acreage, another portion of acreage may be excluded from the benefits and is classified as flexible acres. Unlike the set aside land, flexible acres may be used to produce any crop, although no program benefits will be received for that portion of production. The total program payment for each crop, called the deficiency payment, is the product of the per acre payment and the covered acreage. The base acreage in each year is the previous five year average of planted acreage plus diverted conservation acreage for that crop.

Crop Insurance

Insurance is a risk instrument which protects property, life, one's person, etc,. against loss or harm, in consideration for a payment proportionate to the risk involved. Buying insurance enables an individual or firm to transfer part of its risk to an insuring party. Insurance companies can lower the cost of risk bearing by diversifying over a large number of clients, assuming the risky outcomes facing the clients do not exhibit a high level of positive correlation. The insurance company accepts the risk in return for a premium which exceeds the certainty equivalent of the loss.[2] In turn, the insurance buyer improves his or her welfare by paying a premium that is less than the loss of certainty equivalent income created by the risk. In this way both the insurance seller and buyer gain from the exchange. So, by pooling individual risk, insurance leads to Pareto-preferred states. Insurance enables individuals to engage in risky activities which they would not otherwise undertake.

There are two main types of insurance, discrete-disaster insurance and insurance with continuous outcomes. Discrete-disaster insurance covers the case in which there

---

[2] Certainty equivalent is a certain value that makes an agent as well off, if he accepts this certain return, as if he faces the risky return.

exist only two possible outcomes: 1) the disaster occurs or 2) it doesn't occur. Fire insurance is a good example. If the disaster (fire) occurs, the insurance company will pay the coverage according to contract, otherwise nothing is paid. The insurance premium is calculated based on both the coverage and the probability of disaster occurrence.

Insurance with continuous outcomes provide payoffs scaled to the realization of continuous outcome risky event. Crop insurance is an example of insurance with a continuous set of outcomes. In the crop insurance contract, a level of output is specified as the trigger point at which loss starts to occur (e.g. corn yield at 80 bu/acre), and the loss level is the difference between realized output and this level. The insurance payment is based on the loss level, and could be anywhere from 0 to 100% loss. For example, if the trigger yield is 80 bu/acre and the realized corn yield is 70 bu/acre, a 10 bu/acre loss occurs and the insurance holder would receive compensation equivalent to the value of 10 bu/acre.

Moral hazard is an important insurance concept. Without insurance, a firm realizes costs in an effort to reduce the likelihood of undesirable outcomes. However, after purchasing insurance, the firm loses part of the incentive to reduce the probability of adverse outcomes and may alter its behavior accordingly. This altered behavior is called moral hazard, and can lead to a breakdown in an insurance market if the insurance company can't observe and price the moral hazard of its clients. When moral hazard occurs, the ex ante probability function used by the insurance company to calculate premiums is different than the ex post one after the insurance is purchased. This results in a premium below the level required by the insurance company to bear the actual level of risk. In the presence of moral hazard, insurance companies may experience excess losses and become economically inviable.

There are measures that can be undertaken by insurance companies to avoid or reduce moral hazard, such as charging deductible payments, coinsurance and/or adjusting the premium rate. A deductible payment is a fixed amount that the insured has to pay first in order to get the insurance company to pay the rest of the loss. Examples of deductibles can be found in auto insurance. Coinsurance requires the insurance holder and the insurance company each to pay a percentage of the total loss. Health insurance often uses coinsurance. Premium rate adjustment is an adjustment by the insurance company for a particular insured agent based on a periodically documented standard. Once a claim is paid, the insurance company may view the insured as a higher risk and raise his premium. Auto insurance providers frequently use this technique. The idea underlying each of these methods is to make the insured bear some of the losses so that they have an incentive to avoid loss, which will hopefully reduce or eliminate moral hazard. Unfortunately, it has been found that sometimes none of these techniques adequately corrects for the problems associated with moral hazard.

Adverse selection is another difficulty that faces insurance providers. Adverse selection arises when insured individuals have better information about the insured risk than the insurance company setting the premium rate. When the insurance purchaser and provider possess asymmetric information, only those whose certainty equivalent loss is larger than the insurance premium would agree to buy the insurance. Thus, the premium calculated based on the information of all potential clients tends to be too low to cover the insurance company's cost of indemnity payments. As a result, insurance companies have to conduct intensive investigations to get accurate information on the likelihood of alternative outcomes, increasing cost and raising premiums, in order to avoid adverse selection problems.

Individual Yield Crop Insurance (IYCI)---MPCI

Crop growers face high yield risk due to uncertain natural conditions. Crop insurance can be used to help manage the risk associated with yield fluctuations. Unlike most types of insurance, agricultural crop insurance is seldom provided by the private sector because providers of crop insurance face a number of special difficulties. One difficulty is the yield risk of crop growers across large geographic areas tends to be positively correlated because of similar weather and soil types. Most small companies have difficulty in pooling these risks in an economical way.

The Federal Crop Insurance Corporation (FCIC), founded in 1938, has provided crop insurance to U.S. crop growers. During the late 1930's and 1940's, the program was criticized for its high costs and low participation. Legislation, passed in 1947, limited the scope of the program, and from 1948 to 1980 the federal crop insurance program was run on an experimental basis. Major revisions were embodied in the Federal Crop Insurance Act of 1980, which set up Multiple Peril Crop Insurance (MPCI).

MPCI provides indemnity payments based on a farmer's individual yield realizations, so it is a special form of IYCI. Under the current MPCI program, corn producers may select one of three yield levels up to a maximum of 75% of their insurable yield[3], and one of the three price levels determined from FCIC forecasts of expected prices with the top price election level set close to the expected market price. If the producer's real yield falls below the elected trigger yield, he/she receives an indemnity payment equal to the product of the elected price and the yield shortfall. This yield shortfall is determined by the amount that actual yield falls below the elected trigger yield. The crop insurance premium varies depending on the elected price and trigger yield levels.

The government has historically subsidized this program in an effort to encourage participation. However, the FCIC has realized billions of dollars in losses over and above the subsidy. Symptomatic of the problem is the fact that the recent indemnity payout is 40% higher than the premium collected. Also troublesome is that in spite of the favorable indemnities-received/premiums-paid ratio for participants, producer participation in the MPCI program fell short of expectations. Not until 1989 did the participation rate exceed 25 percent of insurable acres (Coble, et al, 1993).

---

[3] Insurable yield is determined by FCIC. Prior to 1985, the insurable yield for a particular farm was determined as the average yield in the farm's geographic area. But this exacerbated the problem of adverse selection as farmers with above average loss risks comprised an ever-increasing proportion of the insured pool (Skees and Reed, 1986). After 1985, actual production history (APH), the average of ten years of the farm's actual production, is used as the insurable yield.

In principle, the insurer will break even if they charge an actuarially fair premium to everyone. Approximately, an actuarially fair premium level equals the expected indemnity paid to all the participants, plus a small amount to cover transaction costs. This requires that 1) the insurance agency has reasonably objective knowledge about the risks involved, 2) a large number of similarly exposed individuals are present, 3) the incidence of risk is independently distributed over individuals, 4) individuals cannot influence the nature and occurrence of the risky incident, and 5) nor can they influence the indemnity receivable once they buy a policy. However, it is possible that none of the above criteria is satisfied for crop yield insurance. The failure of MPCI can be at least partially explained by adverse selection and moral hazard.

Moral hazard occurs when behavior changes as the result of holding insurance. Because crop insurance contracts are specified in terms of "result states" (yield realizations) rather than the "state of nature" (weather), even though individuals have no control over the state of nature, they are able to influence the indemnities received through influencing their yields. The insured will have less incentives to take care of the crop when participating in the insurance program and may take steps to reduce production cost (Chambers 1989). As a result, yields tend to be reduced and indemnity payments increase.

Adverse selection occurs when asymmetric information exists between the insurer and the insured. Farmers often have superior information about their own farm yields relative to the insurance company, so those whose yield loss occurs more than the insurance company expects tend to participate at the predetermined premium rate.

The level of transaction cost associated with supplying insurance also impacts its attractiveness to users and the financial competence of insurers. The administrative cost is high for MPCI because the information related to yield shortfall has to be obtained and maintained for each individual farm.

Area Yield Crop Insurance (AYCI)---GRP

Many of the difficulties experienced with MPCI are related to the individual farm yield index used to calculate indemnity payments. Currently, testing is being undertaken on an alternative form of crop insurance which uses an area yield index to calculate indemnity payments. The idea is that both indemnities and premiums would be based not on a producer's individual yield but on the aggregate yield of a surrounding geographical area, usually the county.

This idea was first put forth as a Group Risk Plan (GRP) by Halcrow in 1949. Under GRP, a special form of AYCI, a participating producer would receive an indemnity equal to the difference, if positive, between the trigger yield level chosen by farmers and the realized area yield. All participating farmers in a given area would receive the same indemnity per insured acre if they purchase the same policy, regardless of each one's own farm yield. Each farmer therefore would pay the same premium rate for the same contract. GRP is based on the premise that when a county's average yield is low, then most farmers in that county will have a low yield. Therefore, GRP pays only when the yield of the entire county drops below the trigger yield. This may serve the risk management needs of farmers if the major sources of yield risk are common within a small enough area. In addition, because individual farmers will generally have little impact on area yields and are unlikely to have superior information about the area yield distribution, GRP has the potential to avoid adverse selection and moral hazard problems associated with MPCI.

GRP is a new program the Federal Crop Insurance Program established in the United States during 1994 (Baquet and Skees, 1994). The GRP indemnity payment is based on the county yield shortfall below the trigger yield and the coverage level the individual farmer purchases. Both trigger yield and coverage level can be chosen by the farmer within FCIC specified ranges. The price index used to calculate the indemnity payment is specified by FCIC. The insurance payment per insured acre is the product of the price index, coverage level, and the area yield shortfall.

GRP offers a number of advantages over individual yield crop insurance. Because information regarding the distribution of the area yields is generally more available and reliable than that of individual yields, insurers could more accurately assess the actuarial fairness of premiums under GRP, thereby significantly reducing adverse selection problems. Moreover, because the indemnities would be based on the area yield rather than the farmer's individual yield, a farmer could not significantly increase his indemnity by unilaterally altering his production practices. Thus, under the GRP program, moral hazard essentially would be eliminated. Administrative costs would also be substantially reduced under the GRP program because claims would not have to be adjusted individually. GRP has been implemented on an experimental basis in selected areas by the Commission for the Improvement of the Federal Crop Insurance Program.

The use of GRP to manage yield risk has one glaring weakness, it does not fully cover the yield risk faced by farmers because individual yield is not perfectly correlated with area yield. The difference between area yield and individual yield is called yield basis risk. When an individual realizes higher loss than the area average, i.e., basis is positive, he won't be completely reimbursed under GRP. The relative performance and tradeoff between IYCI and AYCI schemes are important policy issues and will receive significant attention in this study.

2.3 Decision Making Under Risk

The idea that the expected value of an outcome cannot fully describe a risky event was raised by researchers some two hundred years ago. Bernoulli used a logarithmic function to convert dollar values to "moral expectation values", later called utilities, in the 1700s. However, it wasn't until the 1940s that the expected utility model was carefully deduced and became the cornerstone of risk analysis (Von Neumann and Morgenstern, 1944). In this framework the characteristics of the decision maker's utility function reflect risk preferences, and the decision maker maximizes expected utility when facing a risky situation.

Expected utility (EU) is not the only technique which can be used to order risky choices. The stochastic dominance (SD) model first introduced by Hadar and Russell (1971), and the mean variance (MV) model originated by Markowitz (1952) and extended by Tobin (1958), are also widely used in risk analysis. The EU, SD and MV models are introduced in the next two subsections.

Expected Utility Model

The expected utility theory of decision making under uncertainty is based on the decision maker's (DM) personal beliefs about the likelihood of uncertain outcomes and his personal valuation of the possible outcomes. The axioms that guarantee the existence of a utility function are now well known (Anderson, Dillon and Hardaker, 1977; Robison and Barry, 1987), and are listed in the following:

1. Preference Ordering: For any two action choices, the DM either prefers one action choice to the other or is indifferent between the two action choices. For choices A and B, either $A \prec B$, $A \succ B$, or $A \sim B$. This says that the DM must be able to make a choice between any two distributions of outcomes or else be indifferent between them.

2. Transitivity: If the DM prefers action choice A to action choice B and action choice B to action choice C, then A must be preferred to C. If the DM is indifferent between A and B and indifferent between B and C, then A and C must be indifferent. For $A \succ B$, $B \succ C$, then $A \succ C$; and for $A \sim B$, $B \sim C$, then $A \sim C$.

3. Continuity: If the DM prefers A to B and B to C, then there exists some probability p between 0 and 1, for which, the DM is indifferent between B and a lottery $pA+(1-p)C$ where $0<p<1$. This indicates that a DM facing a risky situation involving a favorable and an unfavorable outcome will take the risk, if the probability of the unfavorable outcome is small enough. If $A \succ B \succ C$, then $\exists$ $0<p<1$, st $B \sim pA+(1-p)C$.

4. Independence of Irrelevant Alternatives: If A is preferred to B, and C is some other action choice, then a lottery involving A and C must be preferred to a lottery involving B and C if the probability of receiving A and B is the same in each lottery. If $A \succ B$, for $\forall\ 0<p<1$, $pA+(1-p)C \succ pB+(1-p)C$.

The expected utility theorem, also known as Bernoulli's principle, says if a DM's preferences do not violate the preference axioms of ordering, transitivity, continuity, and independence of irrelevant alternatives, then there exists a utility function that: 1) can transform each possible outcome to a real number, so that the ranking of the real number represents the preference ranking of the corresponding outcome; and 2) in the case of uncertainty, can generate an expected utility value under the subjective probability for each action choice, such that the ranking of the value represents the preference ranking of the corresponding choice. Positive linear transformation of a utility function does not change its ranking property.

Application of the EU Model

The expected utility model allows either the choice variable or the stochastic factors to be discrete or continuous. If the stochastic factor in the model, Y, is discrete with n possible outcomes, and the probability, p_i, associated with each outcome, y_i, is known, the expected utility for each action, x, is defined as: $EU(x) = \sum_{i=1}^{n} p_i U(x, y_i)$. On the other hand, if the stochastic factor, Y, is continuous, and the probability density function associated with it, $f(y)$, is known, the expected utility for any action, x, is defined as: $EU(x) = \int U(x,y)f(y)dy$.[4]

The continuity of the expected utility depends on the choice set. When the choice set is discrete, e.g., the decision on whether to participate in the government program or not, the expected utility function is also discrete. The decision can then be made by ranking all the possible expected utility levels, and selecting the one that provides the maximum expected utility. For any action set $\{x_i\}_{i=1}^{m}$, choose x_j, so that $EU(x_j) = max\{EU(x_1), EU(x_2),\ldots, EU(x_m)\}$.

When the choice set is continuous, the expected utility function is also usually continuous, and the optimal decision is made by maximizing the expected utility function. There are convenient ways to maximize a continuous function either analytically or numerically.

One advantage of the EU model is that it provides a functional form associated with the probability density function, so that precise optimal solutions can be obtained either analytically or numerically. Another important advantage is that the EU model can be used to measure the relative welfare levels of any two choices. Two measures of welfare change, *equivalent variation* (EV) and *compensating variation* (CV) are commonly used.

---

[4] There may be more than one stochastic factors and/or choice variables, in which case x and/or Y are vectors. When Y is a vector, the summation in the discrete case or the integral in the continuous case is multiple, and there is a probability p associated with each possible outcome combination of the stochastic factors and the density function f is a joint density function.

Equivalent variation is the certain income adjustment to the current income distribution which provides the DM with the same expected utility level as would be derived from an alternative income distribution: $EU(M+EV) = EU(M_a)$, where M and M_a represent the stochastic current and alternative income, respectively. EV represents the DM's willingness-to-pay in certain dollars to obtain the alternative income distribution.

Compensating variation is the income adjustment to compensate the agents under the alternative income distribution, so that they will be as well off as under the current income distribution: $EU(M) = EU(M_a - CV)$. CV represents the DM's willingness-to-pay in certain dollars to keep the alternative income distribution from moving back to the base income distribution.

EV is used in this study because it measures DM's willingness-to-pay based on the current income distribution which is invariant with the change of risk instruments in alternative portfolios. Thus, the current income distribution provides a constant base from which to evaluate alternative income distributions.

A major disadvantage of the EU model is that the form of the utility function is sometimes hard to obtain. However, various methods for inferring information about farmer risk attitudes have been developed (Saha, et al, 1994). This makes the EU framework a viable option to evaluate the farm decision making and welfare.

Risk Preference Measures

Decision makers' risk preferences can be classified into three general categories: ***risk averse***, ***risk neutral*** and ***risk preferring***. Within each category, there still exists differences in the degree of risk preference. The curvature of a utility function reflects the risk attitude of the DM. The more risk averse the DM, the more concave the utility function.

A measure of the curvature of a utility function, or risk attitudes, was introduced by Pratt and Arrow independently and is called absolute risk aversion:

$$AR(Y) = \frac{-U''(Y)}{U'(Y)} \tag{2.1}$$

AR(Y) is always positive for risk averse individuals; zero for risk neutral individuals; and negative for risk preferring individuals. Preferences are said to exhibit decreasing absolute risk averse (DARA) if $\frac{\partial AR}{\partial Y} < 0$; constant absolute risk averse (CARA) if $\frac{\partial AR}{\partial Y} = 0$; and increasing absolute risk averse (IARA) if $\frac{\partial AR}{\partial Y} > 0$.

Another measure of the curvature of a utility function is relative risk aversion, defined as:

$$RR(Y) = \frac{-U''(Y)Y}{U'(Y)} = AR(Y)\,Y \tag{2.2}$$

Preferences are said to exhibit decreasing relative risk averse (DRRA) (constant relative risk averse (CRRA)) (increasing relative risk averse (IRRA)), when $\frac{\partial RR}{\partial Y}$ is < (=) (>)

0. A commonly used CRRA function takes the form $\frac{Y^{1-a}}{1-a}$, for $RR = a > 1$; or $ln(Y)$, for $RR = 1$. Utility functions with DRRA and CRRA also exhibit DARA.

Saha, Shumway and Talpaz (1994) have reviewed existing empirical research on risk preferences. They claim CARA is generally rejected in favor of DARA, while the nature of relative risk aversion remains ambiguous. Chavas and Holt (1990) also provide the evidence that the risk preference of corn and soybean growers is DARA rather than CARA. Pope and Just (1991) conducted econometric tests for risk preferences of Idaho potato growers, and found CARA was not supported by the data, and that the CRRA hypothesis could not be rejected.

Specific functional forms for utility have also been investigated in some studies which allow the coefficients of absolute and relative risk aversion to be estimated. Using aggregate data, Hansen and Singleton (1982) studied CRRA model with a utility function $U(W) = W^{\alpha}/\alpha$, and estimated a relative risk aversion coefficient between 0 and 2 for consumers. Szpiro (1986) showed that U.S. 1951-1975 insurance data support the CRRA hypothesis and that the relative risk aversion coefficient is between 1.2 and 1.8. Love and Buccola's (1991) results for data from Iowa corn show the coefficient of relative risk aversion is between 2.4 and 19.

Alternative Models for Decision Making Under Risk

In addition to the EU model, stochastic dominance (SD) and mean variance (MV) models are also commonly used in the studies of risk and uncertainty. They both have advantages and disadvantages compared to the EU model, which are discussed in the following.

SD Model

The SD model provides a general way to study the DM's choice of risky events (Hadar and Russell). It compares the cumulated density functions associated with each choice, and tells which choice is preferred by certain types of DMs when the underlying cumulated density functions exhibit specific relationships. For example, first degree stochastic dominance (FSD) says choice A is always preferred to choice B by DMs who prefer more to less if the cumulated density function associated with B is not less than that with A for any outcome level and is greater than A for at least one outcome level. Second degree stochastic dominance (SSD) reveals decision making principles for DMs who prefer more to less and are risk averse. Higher degree stochastic dominance rules can be defined for more specific types of DM preferences.

The advantage of the SD model is that it does not require a specific form for the DM's utility function. Instead, it only places constraints on the DM's risk preferences. However, there are several difficulties with SD rules: 1) they only apply to finite discrete choice sets, because each possible choice generates one outcome distribution to which all other possible distributions must be compared to find the optimal decision; 2) the optimal solution may contain a set of choices so that it may not be possible to identify a single optimum choice; and 3) SD model does not provide a way of measuring the welfare level associated with each choice.

MV Model

The MV model[5], originated by Markowitz, is also widely used in risk analysis. The model selects the action that can maximize the certainty equivalent, Y_{CE}, of the stochastic outcome, which makes the DM as well off as if he faces the random returns, Y, ie. $U(Y_{CE}) = EU(Y)$. The expression of certainty equivalent as a function of its mean and variance is generally derived from the expected utility model using Taylor series, so the MV model can be viewed as an approximation of the EU model.

The major advantage of the MV model is that it is often more tractable than EU, and analytical solutions are sometimes obtainable in a MV model in cases where the EU model provides no closed form solutions. However, the MV model is only consistent with the EU model when probability distribution and/or the DM's risk preferences are restricted. Sufficient restrictions are either 1) the DM's utility function is quadratic (Tobin, 1958); 2) the random attribute is normally distributed and the DM has a concave utility function (Samuelson, 1970); or 3) the random attribute is a monotonic linear transformation of a single random variable (Meyer, 1987).

Choosing a Decision Model

Among the three major decision making models under risk, the expected utility model is chosen as the framework for the analysis conducted in this study for several reasons. In the farm decision model which includes alternative risk instruments in the portfolio, we hope to obtain solutions of the optimal position for each instrument and

---

[5] It is also referred as mean standard deviation model (MS).

measure the welfare changes associated with alternative portfolios and design changes for the various instruments. Thus, the SD model is immediately eliminated because it generally will not provide unique optimal solutions nor allow welfare measurement.

While the MV model can provide unique solutions as well as welfare measures, the sufficient conditions for consistency with the EU model are generally not satisfied under the complete multivariate distribution faced by the farmer. Furthermore, the income distribution is so complex that it is generally not possible to derive analytical results even in a MV setting.

Based on existing studies of risk preferences, the CRRA function is selected as the utility function for this research, and the relative risk aversion coefficient is set at 2 for the base model. Comparative static analysis is done to explore the impacts of alternative levels for the relative risk aversion coefficient.

2.4 Risk Management with Price and Yield Instruments

Under the expected utility model, the farmer maximizes the expected utility of the farm return which is composed of stochastic returns from the cash market as well as alternative risk management instruments. Sandmo (1971) studied the competitive firms' production decision under price uncertainty without any risk management instruments. In his EU model, the deterministic output level was chosen to maximize the expected utility of net income. In the absence of any risk management instruments, the output level depends on the distribution of price and the farmer's risk attitude; and risk averse farmers produce less when facing stochastic prices than in the case of a certain price set at the mean of the random price.

A number of risk management instruments are now available to help farmers manage the risk they face from price changes. Numerous studies have focused on the use of futures contracts, forward contracts, options contracts and the government deficiency payment program (Danthine, 1978; Lapan et al, 1991; and Turvey et al, 1990). Yield risk also contributes to farm income risk, and may alter the optimal use of risk instruments designed to manage price risk. If prices and yields are correlated, the pricing instruments may be able to help manage the risk associated with yields. Even so, the pricing instruments are not likely to be efficient at managing yield risk. Crop insurance is available for many agricultural commodities and can be used to directly manage yield risk. A number of studies have addressed farmers' use of crop insurance (Ahsan, et. al., 1982; and Chambers, 1989).

Several studies allow for both price and yield risks where several risk management instruments are included simultaneously in the portfolio (Myers, 1988; and Poitras, 1993). Before developing the model used in this research, relevant studies in which farmer portfolios include futures, options, government program, and/or crop insurance are reviewed. Most of these existing studies investigate pricing instruments or crop insurance in isolation. Studies on futures and options tend to either assume yields are deterministic or fail to include crop insurance in the portfolio. Likewise, most studies on crop insurance assume prices are deterministic or fail to include futures and options in the portfolio. With a few notable exceptions, most studies on futures and options and/or crop insurance do not allow for a government deficiency payment program in the portfolio.

Futures and Options as Risk Management Instruments

Research on the use of futures contracts started to appear two decades ago. Danthine (1978) developed an EU model where the production decision and hedging position on the futures market are made simultaneously in a setting where output is nonstochastic, and the cash price is the only source of risk. He found that when the possibility of trading futures contracts exists, farmers' output depends on the deterministic futures price and the input price only, not on the risk associated with cash price or farmers' risk attitudes.

Holthausen (1979) examined the competitive firm's behavior under cash price uncertainty while allowing the firm to select output and hedge to maximize expected utility of farm income. He drew similar results to Danthine: 1) production decisions are based on the forward price but not on the price the firm expects to prevail or the degree of risk aversion; 2) the optimal hedge depends on the forward price and the expected cash price. If the forward price is higher (equal) (lower) than the expected cash price, the farmer will hedge more (the same) (less) than he produces; and 3) risk aversion and the level of price risk affect the firm's optimal hedge if the forward price differs from the expected cash price.

Feder, Just, and Schmitz (1980) modified the model to account for opportunity cost across time by assuming the return from the futures contract occurs at planting and the return from spot market occurs at harvest. In addition to the Danthine and Holthausen's results, they found the volume the farmer hedges (or speculates) in the futures market is affected by the discounted expected cash price, the futures price, and the risk of cash price if the discounted expected cash price differs from the futures price.

In these early studies, the "futures contact" was actually a cash forward contract, because the "futures" price at harvest was assumed at harvest cash price level, implying the contract would be settled by delivery. This specification ignores basis which is generally present when futures contracts are used. Recent studies introduce basis and basis risk in the decision problem and find some of the above results are invalid, such as the three studies reviewed in the following.

More recently, a number of studies have addressed the use of commodity options as a risk instrument. Lapan, Moschini and Hanson (1991) examined the use of both options and futures in a farmer's portfolio allowing for both cash price and basis risk. Based on expected utility maximization, they drew several analytical results: 1) when futures and options prices are unbiased and cash price is a linear transformation of futures price plus a white noise, then a fraction of production is hedged in the futures market, options are not used as hedging instruments, and the portion of non-diversifiable basis risk affects the nonstochastic production level; 2) under CARA, a marginal change in the futures price leads to a change in futures and options sold in the same direction; 3) under risk aversion and a symmetric distribution of prices, the qualitative optimal speculative futures position depends only upon the bias in the futures price; and 4) under non-increasing absolute risk aversion (DARA or CARA), an unbiased straddle price and a symmetric distribution of the cash price, the optimal straddle position will always be long when there is an open speculative futures position; also, the straddle position will always be smaller than the open futures position.

A recent study by Vercammen (1995) uses the model of Lapan, Moschini, and Hanson, and allows the stochastic price to be nonsymmetric. He shows that with a biased futures price, options are relatively more valuable for reducing the skewness of a nonsymmetric price distribution than in the symmetric price distribution case. If the market price distribution is skewed to the right, hedgers who perceive a downward bias in the futures price take a long position in the futures market and write put options. Again, deterministic production is implicitly assumed in the model.

Sakong, Hayes and Hallam (1993) extended the model by Lapan, Moschini, and Hanson to include yield risk. In Lapan, Moschini and Hanson's paper, cash price risk can be diversified into a component attributable to changes in the futures price and an orthogonal component reflecting undiversifiable basis risk. Because the diversifiable risk is linear in futures price, futures contracts dominate options contracts, so that when both prices are unbiased options are not used. When yield risk is introduced, it is almost always optimal for the producer to purchase put options and to hedge less on the futures market than expected production. These results are strengthened if the producer expects local production to influence national prices (price and yield are negatively correlated) and if he is DARA.

<u>Government Deficiency Payment Program</u>

Robison and Barry (1987) use the MV model to study the use of a government deficiency payment program to manage price risk. They find that even though the production per acre increases in the presence of the government program, total output may or may not increase, because a portion of acreage has to be set aside to participate in the program.

Turvey and Baker (1990) use an EU model to study farmers' use of futures, options, and farm programs in the presence of price risk, financial risk, and liquidity constraints. Their results suggest the farmer's use of futures and options decreases in the presence of loan rates and target prices. These results indicate that the government program may act as a substitute for futures and options.

These studies lend many insights into a competitive firms' behavior under uncertainty and the use of instruments designed to manage price risk. However, with the exception of Sakong, Hayes and Hallam, each study assumes output to be deterministic and controllable. Allowing yield risk and yield risk management instruments into the analysis may alter the implications of these studies.

<u>Crop Insurance</u>

Ahsan, Ali and Kurian (1982) developed a model of crop insurance and examined the implications of adverse selection. Their work, one of the earliest studies in this area, used a discrete EU model (disaster occurs or does not occur), where producers allocate resources between risky and riskless assets, and select the level of output (yield) to insure. The intent was to find analytical evidence to support the observation that even though there are clear advantages for crop insurance over alternative institutional arrangements, the market generally has failed to provide such a mechanism.

Their results suggest risk-averse farmers choose full insurance coverage if insurance is offered at actuarially fair odds and the optimal allocation of risky resources is chosen by setting the expected marginal product of the resource equal to its opportunity cost, the return on a riskless investment. They also find that it is difficult for the insurance agency to separate the high risk farmers from the low risk farmers so that, in equilibrium, each kind of farmer will buy different contracts. In addition, they find farmers invest less on risky farming in the absence of crop insurance. In the presence of crop insurance, farmers' risky investment will decrease when 1) the premium increases; 2) the endowment decreases; 3) the random yield mean decreases without changing the risk; and 4) the yield risk is increased by a mean-preserving spread. This work provides a theoretical foundation for studying adverse selection.

Nelson and Loehman (1987) studied crop insurance with symmetric information between farmers and insurers. They derived a Pareto optimal result which requires full information, an actuarially fair premium, full coverage, and a different contract for each individual, so that every individual acts risk neutral and there is no moral hazard or adverse selection problems. They also developed a model with moral hazard and adverse selection, in which the insurer chooses the production input after the insurance choice is made other than choosing them simultaneously. They conclude that a Pareto optimal agricultural insurance program would provide full coverage individualized insurance.

Such an insurance program would eliminate income variability and cause farmers to behave as if they were risk neutral. However, they suggest the problems caused by lack of information and incompatible incentives prevent this theoretical optimum from being attained.

Chambers (1989) extended the Nelson and Loehman model to allow asymmetric information in order to consider moral hazard and positive costs of providing insurance. He finds full insurance contracts are dominated by contracts involving coinsurance and deductibles for risk averse insurers. Chambers also considered other alternatives to deal with moral hazard. For example, insurance agencies may collect more information to detect "poor farming practices" and refuse to indemnify avoidable losses, or write multi-year insurance contracts to detect consistent cheating. However, neither alternative is efficient because the former induces high transaction cost and the later can't prevent cheating as long as insurance contracts are finite lived.

Coble, Knight, Pope and Williams (1993) conducted an empirical test for moral hazard and adverse selection in Multiple Peril Crop Insurance (MPCI). First, they separated adverse selection and moral hazard theoretically by "hidden knowledge" or "hidden action". They then set up an econometric model to compare the yield distributions of those who have participated in MPCI to those who have not participated; as well as the yield distributions of farmers before and after participating in MPCI. They concluded that for the crops and districts they studied, moral hazard is always present, but there is less evidence of adverse selection.

Vercammen and van Kooten (1994) study a dynamic model for a risk neutral farmer using individual yield crop insurance with premium surcharges and discounts, depending on the historical ratio of indemnities to premiums. They find even when the insurance contract punishes moral hazard in previous periods through higher premium in the current and future periods, the farmer still has incentive to practice moral hazard.

Concerned with the fact that, even with a 25% deductible, the FCIC still loses money providing MPCI, Miranda (1991) examines the area yield insurance plan. Modelling an individual producer's total yield risk as a systematic component that is explained by factors affecting all producers in his area and a nonsystematic residual component, he concludes that 1) for a given critical yield level, the risk reduction from area yield insurance is determined by the correlation between the farmer's individual yield and the average area yield; 2) the higher the correlation is, the greater the risk reduction he gets from the area-yield insurance; and 3) the more risky one's yield is, the greater the risk reduction he can obtain from area yield insurance.

Using farm-level data from 102 western Kentucky soybean farms, Miranda concludes that for most producers, area yield insurance would provide better overall risk protection than individual yield insurance due to lower deductibles and higher coverage; the reduction of adverse selection and the virtual elimination of moral hazard would significantly improve the actuarial performance of the federal crop insurance program; and area-yield insurance would be less expensive to administer because verification of individual production histories and adjustment of individual yield-loss claims would not be necessary.

Price and Yield Instrument Portfolios

Myers (1988) studied a model with a futures market for trading in contracts to deliver or take delivery of farm output at a future date and a crop insurance market allowing farmers to insure against low yield realizations at the cost of an actuarially fair insurance premium. The futures market can eliminate price risk and the crop insurance market provides insurance against unfavorable yield realizations. By assuming risk averse farmers maximize their expected utilities of net farm income, Myers finds: 1) in the absence of production uncertainty, an unbiased futures market induces complete hedging and expected profit maximizing behavior by risk averse farmers --- the result of Holthausen; 2) in the absence of price uncertainty, actuarially fair crop insurance induces the farmer to completely insure yields and maximize expected profit --- the result of Ahsan, Ali, and Kurian; and 3) if both price and production uncertainty are present, both futures and crop insurance markets are required to complete the market structure and can induce expected profit maximizing behavior. Again, this research does not differentiate futures from forward contracts in that there is no basis risk involved. Also, the stylistic crop insurance design restrains the flexibility in modelling actuarially unfair premium and/or trigger yield restrictions.

Poitras (1993) modeled both price and yield uncertainty with futures and "crop insurance" in the portfolio. "Crop insurance", as defined by Poitras, includes three types of instruments: quantity insurance (yield insurance), price insurance (put options), and revenue insurance. He used mean, variance and skewness to approximate the expected utility model and finds that when yield insurance is included in the portfolio, hedging in futures is increased. However, when put options are included in the portfolio, the use of futures is decreased. Studying futures plus one form of "crop insurance" at a time, the portfolio including futures and options in the presence of yield insurance is left uninvestigated.

These studies provide many insights into farmer behavior under risk. However, the price and yield distributions and/or the portfolio of assets available to the farmer have typically been restricted. In the model used in this study, cash price, futures price and yield are stochastic and their joint distribution is consistent with historical data. The farmer is allowed to participate in the spot market, futures, options, crop insurance, and a government deficiency payment program. Decisions will be made on the level of participation in futures, options, crop insurance and the government program in an effort to maximize expected utility.

This portfolio model will allow us to investigate the optimal risk management behavior given the currently available risk management instruments and a realistic representation of the joint price and yield distribution faced by the farmer. The model provides the flexibility to add (remove) any existing or potential risk management instrument into (from) the portfolio to study the marginal effects of each instrument. The model can also be used to study alternative contract designs, compare welfare levels, and do sensitivity analysis, so that potential changes in crop insurance and government program policy can be evaluated.

Chapter III

THE FARMER DECISION MAKING MODEL

This chapter develops an expected utility model for a risk averse farmer who makes decisions on the use of risk management instruments in a portfolio setting. The farmer maximizes the expected utility of income which is derived from selecting positions in the futures market, options market, government deficiency payment program and crop insurance. The model assumptions, specification and calibration are introduced in this chapter.

3.1 Model

A two-period model is developed for a representative farmer who produces a single crop. In the first period (planting) the farmer makes hedging decisions subject to price and yield *distributions* conditional on information known at planting. In the second period (harvest) prices and yields are realized. Profits are specified on a dollar per acre basis, because the farm production is assumed to exhibit constant return to scale such that the number of acres in production does not impact the farmer's optimal decisions. The farmer exhibits CRRA which, together with the constant return to scale assumption, allows maximizing the expected utility of per acre income to generate the same position in risk management instruments in proportion to output as the expected utility of the whole farm income, when the planted acreage is constant. This is determined by the properties of CRRA functions.

Production cost is assumed constant because the production decision is assumed to be made prior to the risk management decisions. In other words, the price and yield distributions faced by the farmer are known and fixed at the time the risk instruments are selected. The production decision could be modeled explicitly but this is not necessary here because our interest lies in investigating risk management behavior conditional on given input choices. This allows us to focus directly on the use of the risk management instruments.

No discount factor for time is included in the model because, again, the emphasis is on risk management. Actually, most of the cash transactions occur in the harvest period. Option and crop insurance premiums are paid in the initial period, but futures transactions involve no up-front cost other than a margin account which can be satisfied with interest bearing securities. Options are the European type which means no early exercise is allowed, and only one exercise price is investigated.

The farmer's objective function is defined as:

$$\underset{x,z,\xi,\eta}{MAX} \quad EU[\tilde{\pi}]$$

$$where \ \tilde{\pi} = \tilde{CR} + \tilde{FI} + \tilde{OI} + \tilde{GS} + \tilde{CI} - F$$

$$\begin{aligned} \tilde{CR} &= \tilde{p}\tilde{Y}^{l} \\ \tilde{FI} &= x(\tilde{f}-f_0) \\ \tilde{OI} &= z[\max(0,s-\tilde{f})-h] \\ \tilde{GS} &= \xi[\max(0,p_T-\tilde{p})\,Y_b(1-q-r)-r(\tilde{CR}+\tilde{CI})] \\ \tilde{CI} &= \tilde{IP} - \lambda E(\tilde{IP}) \\ \tilde{IP} &= \zeta p_l \ \max[0,\eta E(\tilde{Y})-\tilde{Y}], \end{aligned} \tag{3.1}$$

where E is the expectation operator; $U()$ is the CRRA utility function; π denotes the farmer's net income per acre; and the tilde above a variable denotes it is stochastic. The component CR is the cash income from the spot market, where cash price is denoted by p and the farm-level yield by Y^f. F is the fixed production cost.

FI is the income from the futures market, where f_0 is the future price at planting; f is realized future price at harvest; and x is the hedging amount purchased (sold if negative). OI is the cash income from the options market, where s the strike price; h is option premium required to own the option; and z is the quantity of put options purchased (sold if negative).

GS is the income from the government program. The binary indicator, ξ, signals government program participation, with $\xi = 1$ (0) indicating that the farmer participates (does not participate) in the program. Y_b is base yield and p_T is target price used to calculate the deficiency payment. The proportion of acreage reduction under the program is denoted by r, and the proportion of flexible acres is denoted by q.

CI is the income from crop insurance, where IP is the insurance indemnification payment; ζ is the proportion of acreage to be covered by the insurance; Y is the yield index used by insurance agents (farm yield Y^f for IYCI and county yield Y^C for AYCI); p_I is the price index used to calculate the crop insurance indemnity payment; η is the trigger yield level specified as a proportion of the expected yield index; and λ denotes the crop insurance premium relative to actuarially fair premium level.

3.2 Characteristics of Risk Management Instruments

The farmer produces corn and makes his marketing decision at the planting time based on the information available then. The realized cash return is the cash price, p, times the farm-level yield, Y^f. Besides the cash market, the farmer is allowed to participate in the futures market, options market, government deficiency payment program and crop insurance. The remainder of this section provides a more detailed discussion of the model specification of each instrument included in the portfolio, where the emphasis is on the base model. Modifications to the base model will be made in later chapters when alternative contract designs are studied.

Futures

If the quantity hedged on the futures market, x, is negative (positive), the farmer is short (long) futures. The farmer with a short (long) futures position enters a contract at planting time to sell (buy) the commodity for the current futures price f_0, and buys (sells) the contract back at the time of harvest for the realized futures price f which is unknown when the hedging decision is made. If the futures price at harvest is above the futures price when the contract was established at planting, the holder of a short (long) position experiences a loss (gain) of $(f-f_0)$. On the other hand, if the futures price at harvest is below the price at planting, the holder of a short (long) position experiences a gain (loss) of (f_0-f). The farmer is assumed to face no transaction costs from using the futures market. Thus any brokerage cost or opportunity costs from margin accounts are assumed to be negligible in order to focus on the risk management functions of the

instrument. The net income from the futures market in the model is accordingly denoted $x(f-f_0)$.

Options

Only put options are included in the model, because puts are traded more frequently in the agricultural commodity markets than calls, and the role of calls can be represented by combining futures and puts. So adding futures, puts and calls into the model would result in a redundant instrument. Producers usually hold long cash positions and hedge it with short futures positions. Likewise, put options can be used directly to hedge the long cash position.

If z is positive the farmer buys put options. The cost to buy a put option at planting is the premium, h. The buyer of a put option exercises the contract at the maturity if the strike price s is higher than the futures price f in order to capture the gain of $(s-f)$. If the strike price is lower than futures price the holder of the option lets the contract expire by simply declining to sell at the exercise price and thus avoids the loss $(f-s)$. If the options contract is fair, the premium, h, equals the expected options value which is $E[max(0,s-f)]$.

If z is negative, the farmer sells the put option to collect premium h. If the option is exercised, the farmer must pay to the owner of the option s while the current price is f resulting in a payout at maturity of $(s-f)$. Again, the transaction cost in the options market is assumed zero. The farmer's net income from the use of the option contract is therefore defined in the model as $z[max(0,s-f)-h]$.

Government Deficiency Payment Program

The deficiency payment program specified in the model is a stylized version of the 1994 USDA Wheat and Feed Grain Programs. Total deficiency payment is the product of eligible acreage, base yield and price shortfall. The same crop is also assumed to be planted on the flexible acreage, q (on which any crop can be planted but is not eligible for deficiency payments). Acreage, r, must be removed from production completely for the farmer to be eligible for the deficiency payments. The farm's historical yield moving average from 1981-1985 is used as the base yield in the program. In this stylized model, the expected farm yield for the current year is assumed to be the yield base, Y_b. In the program, price shortfall is defined as the difference between target price, p_T, and the greater of the harvest cash price, p, and the loan rate, if the difference is positive. For simplicity, the realized cash price is assumed to be at or above the loan rate. Thus, the deficiency payment is $(1\text{-}q\text{-}r)Y_b max(0,p_T\text{-}p)$ per base acre.

The cost to the farmer to participate in the program is the loss on the acreage removed from production. The loss comes from the lost income both from lower production and crop insurance (the farmer cannot buy crop insurance for the land set aside). Therefore, the net income from participating in the deficiency program is $(1\text{-}q\text{-}r)Y_b max(0,p_T\text{-}p)\text{-}r(CR+CI)$ per base acre.

Crop Insurance

Currently, two versions of crop insurance are offered to growers on a range of crops. Multiple Peril Crop Insurance (MPCI) is the major individual yield crop insurance program provided by FCIC. The indemnity payment per insured acre is the product of the price index, p_l, and yield shortfall, where the price index can be chosen by the insured farmer. For example, for corn in 1990, farmers could choose a price of \$1.45/bu, \$1.65/bu, or \$2.30/bu. The yield shortfall is the amount the farmer's individual yield realization falls below a pre-specified yield level chosen by the farmer. Because this pre-specified yield level triggers the indemnity, it is called the trigger yield. In the current MPCI program, farmers can select 50%, 65%, or 75% of an FCIC determined insurable yield, Y^*, which is the farmer's historical yield moving average from the preceding ten years. Thus, the indemnity payment can be specified as:

$$IP = p_l \max(0, \eta Y^* - Y^i) \tag{3.2}$$

where the trigger yield factor, η, is chosen by the farmer from *{0.50, 0.65, 0.75}*. Restricting trigger yield to below 75% of the insurable yield implies that the contract features a deductible.

Because of moral hazard, adverse selection, and transaction costs, insurance companies charge a premium which is greater than the expected indemnification, *E(IP)*, even when the insurance companies are subsidized by the federal government. In our stylized IYCI model, we allow η to be selected by the farmer continuously in the range [0, 0.75], and the predetermined insurable yield, Y^*, is set at expected yield index *E(Y)*. The yield index is the farmer's individual realized yield, price is fixed at the expected cash price at harvest, *E(p)*, and the premium is the expected indemnification payment multiplied by a coefficient λ. If λ is 1, the premium is actuarially fair; if it is larger than 1, the insurance company charges a premium loading to the farmer; and if it is smaller than 1, the insurance contains a subsidy. The value of λ is set at 1.35 in the base model.[6] The level of insured acreage, ζ, denotes the number of acres the farmer elects to cover under crop insurance, which is set at 1 in the base model because it is restricted to 100% of the base acreage under MPCI.

Recently, the Group Risk Plan (GRP), an alternative to MPCI, has been offered to farmers by the FCIC. GRP reduces moral hazard, adverse selection, and transaction costs by basing indemnity payments on an area yield index. Its indemnification payment is based on a coverage level parameter, φ, selected by the farmer from 0 to 1.5; the FCIC determined price index, p_l; and a yield shortfall which is specified in a more complicated fashion than in MPCI. The yield shortfall in GRP is specified as the product of the expected county yield and the percentage of county yield realization falling below the trigger yield. The trigger yield can also be selected by the farmer at 65%, 70%, 75%, 80%, 85%, or 90% of the expected county yield. The indemnity payment per acre can be represented by:

$$IP = p_l \max[0,\ \varphi E(Y^c) \frac{\eta E(Y^c) - Y^c}{\eta E(Y^c)}] \tag{3.3}$$

where Y^c is the county yield; η is the indemnification trigger yield factor. Restricting trigger yield to lie below 90% of the expected county yield also implies a deductible.

[6] The break-even level of crop insurance premium is difficult to determine from existing research, however, it is estimated that the reimbursement cost the FCIC pays insurance companies to deliver MPCI is currently between 30% to 50% of the total premiums paid by farmers and the subsidy. Here, the transaction cost of 35% of the actuarially fair premium is used as the premium loading.

Because the indemnification payment in equation (3.3) can be rewritten as $IP = (\varphi/\eta)p_t\max[0, \eta E(Y^C) - Y^C]$, it is obvious that if the coverage level, φ, is smaller than η, a co-insurance is implied in the contract; and if it is greater than η, the loss is inflated. Compared with model (3.1), φ/η plays the same role as ζ.

In our stylized AYCI model, the predetermined price level is set at the expected cash price at harvest, *E(p)*, and η is allowed to be selected within the range of [0, 0.9]. Because of the lower transaction costs and reduced moral hazard and adverse selection problems, the premium is set at the actuarially fair level, *E(IP)*. Notice that φ/η plays the same role as the insured acreage parameter, ζ, so restricting ζ to 100% of the base acreage in the base model implies $\varphi/\eta = 1$. These restrictions assure the indemnification payment equation (3.3) can be expressed by the same equation as in (3.2) in the base model except now Y^C is used as the yield index.

3.3 Methodology

Farm income is derived from the spot market, futures market, options market, government deficiency payment program, and crop insurance, each of which is stochastic. Thus, income depends on the joint distribution of the cash price, futures price, farm-level yield, and county-level yield (when AYCI is included in the portfolio). The farmer maximizes the expected utility of income which can be written as:

$$EU(\pi) = \int_0^\infty\int_0^\infty\int_0^\infty\int_0^\infty U(\pi)g(f,p,Y^I,Y^C|\Omega)\,df\,dp\,dY^I\,dY^C \qquad (3.4)$$

where $g(\cdot|\Omega)$ is a joint density function for futures prices, cash prices, individual farm yield and county-level yield conditional on Ω, a set of information available when the decision is made. When AYCI is replaced by IYCI, the area yield variable does not enter the model explicitly.

The analytical form of the joint distribution of yields and prices is not available. Furthermore, options, government deficiency payment program and crop insurance truncate the distribution of farm income, making it difficult to find an analytical form of the solution to maximize expected utility. However, using market data, the joint distribution of price and yield can be estimated by econometric and simulation techniques. Numerical optimization can then be used to solve the farmer's optimization problem.

The procedure begins by using historical and current market data to estimate the joint price and yield generating process. Simulation techniques are then used to generate a discrete joint distribution of prices and yields. This price-yield distribution is used to obtain a discrete distribution of net income for a given set of possible choice variables. The corresponding level of expected utility is then calculated by substituting the income values into the utility function and taking the expectation. Finally, the maximum value can be found using standard optimization algorithms. The values of choice variables corresponding to the maximum expected utility is the optimal solution. All estimation, simulation, and optimization is done using GAUSS.

In order to compare the effects of that these risk management instruments on farmer welfare, the Equivalent Variation (EV) measure of the decision maker's willingness-to-pay for the instruments is used. The base income distribution is the spot market income distribution pY^I. The alternative income distribution may be impacted by the inclusion of futures, options, government program, and/or crop insurance in the portfolio. Letting π^* represent the income from the alternative portfolio with the risk instruments, the EV is calculated such that:

$$EU(pY^I + EV) = EU(\pi^*). \tag{3.5}$$

When there is no analytical form of expected utility, numerical techniques can be used to find the EV by minimizing the squared difference between the two sides of equation (3.5) as:

$$\underset{EV}{MIN}\ [\frac{1}{N}\sum_{i=1}^{N} U(p_i Y_i^I + EV) - \frac{1}{N}\sum_{i=1}^{N} U(\pi_i^*)]^2, \tag{3.6}$$

where N is the sample size and i indexes the realizations of random variables.

3.4 Model Validation

Because both the multivariate distribution for prices and yields and the income structure are very complicated, a numerical model is used to solve the representative farmer's portfolio problem. In order to validate the numerical model, analytical results from previous studies can be used by replicating the results with the numerical model and the appropriate restrictions.

In the study of Lapan, Moschini, and Hanson, where yield is deterministic, analytical results are drawn from expected utility model. When cash price is assumed to be a linear transformation of the stochastic futures price plus an independent white noise, $p = a + bf + \tau$, and when unbiased futures and options are included in the portfolio, a fraction b of production is hedged in the futures market and no options are used. Same results are obtained from the numerical model when the yield is restricted to be deterministic and the linear relationship between cash and futures price is imposed.

In the portfolio study of Myers, he derives analytical results under the assumptions that the farmer has constant relative risk averse preferences and there is no basis risk. When an unbiased futures market and an actuarially fair crop insurance are available, a full level of crop insurance is purchased and the insured output is fully hedged on the futures market. The numerical analysis in this study provides the same result that, without basis risk the farmer selects full level of IYCI trigger yield as the premium is reduced to the actuarially fair level, and the maximum yield is hedged at the same time on the unbiased futures market. Thus, the model faithfully reproduces the analytical results supporting the model's validity.

Chapter IV

THE JOINT PRICE AND YIELD DISTRIBUTION

In this chapter, the price and yield generating process for the representative farm is outlined. The stochastic returns to the farm depend on jointly distributed prices and yields. When a farmer uses futures or options contracts, participates in crop insurance programs, or utilizes government deficiency payment programs, his returns may depend on the futures price and/or "area" yield as well as the cash price and his own farm-level yield. Therefore, a joint distribution of futures price, cash price, farm-level yield and area-level yield is necessary in order to study the farmer's risk management behavior and welfare in a portfolio setting. However, directly estimating and/or generating the joint distribution of commodity prices and yields is difficult because empirical evidence suggests the random variates have complicated distributions that may not have closed-form density functions. As a result, solving the maximum expected utility problem will require numerical techniques and an empirical joint distribution.

The procedure used in this study is to first generate the price and yield distributions independently, and then impose a correlation between them by using the numerical algorithm introduced by Taylor (1990). Section 4.1 explains the development of the joint cash and futures price distributions. Section 4.2 describes the development of the marginal farm-level and county-level yield distributions, and the technique used to derive the bivariate distribution of farm and county yields. Section 4.3 explains the technique used to join the simulated price distributions and yield distributions to obtain a multivariate distribution of prices and yields.

4.1 The Joint Cash and Futures Price Distribution

In this section, the techniques to model the mean and the higher moments of the bivariate cash and futures price distribution are introduced separately. While the mean price levels are fairly straight forward to model using information available at planting, the higher moments are more difficult to characterize. We begin by examining the stochastic properties of historical corn futures and cash prices, and reviewing literature on modelling commodity prices. The price generating process and parameter estimation used in this research are then presented, along with the procedure for simulating the empirical distribution of futures and cash prices at harvest.

The data used to estimate the price distribution in this study are weekly corn futures and cash prices from the first week of May 1989 to the last week of April 1994. The futures prices are Thursday closing prices of each week for the December contract at the Chicago Board of Trade, and the cash prices are Thursday prices for cash markets in the Southwestern Crop Reporting District of Iowa.[7] When the futures contract expires in December the data series switches to next year's December contract. The contract

[7] Thanks go to the Agricultural Extension Service in the Department of Economics at Iowa State University for supplying these data.

switching date is the first trading day in December. December futures are the new crop futures contracts which farmers would most likely use to hedge their harvest.

Mean Price Levels

Cash and futures prices are stochastic and may have a complicated joint distribution. Generally, the futures market is believed efficient in the sense that there is no expected gain from trade in futures contracts. This suggests that the expected futures price at harvest is equal to the futures price at planting for the same contract. Thus, the farmer's best forecast of the futures price at harvest is the futures price at planting.

Similarly, forward contract prices combine information from both historical prices and current market conditions to estimate forward cash price levels and provide market beliefs about mean cash price levels in the future. The forward contract price at planting provides the farmer with the market's forecast of the cash price at harvest. Therefore, the futures and forward prices at planting are used as the farmer's expectation of the mean futures and cash prices at harvest.

Properties of Corn Price Data

Previous studies have found stochastic trends and time-varying volatility in commodity prices (Myers, 1994). These properties are determined by the characteristics of the markets in which prices are generated. For example, arbitrage opportunities in futures markets generally bid the current price up or down until the price in next period only deviates from the current price by some unpredictable random amount, which is consistent with a stochastic trend, or unit root, model. Although the cash price series could be mean-reverting, there is still evidence suggesting some cash price series may contain a unit root (Ardeni, 1989). Seasonal production and supply of agricultural commodities may cause the prices to show seasonal patterns in either their levels, or volatilities. Also, the volatility of commodity price changes often appears to vary over time, moving between high volatility periods where large price changes tend to be followed by other large changes, and tranquil periods where small price changes tend to be followed by other small changes. Here the stochastic properties of cash and futures price movements for corn are examined first, and results are then used to develop the joint cash and futures price distribution faced by the representative farmer.

Analysis of Price Level Data

A stochastic trend increases or decreases from its value in the previous period by some fixed amount on average, but in any given period the trend deviates from the average by a random error with mean zero. The process can be modeled as:

$$P_t = P_{t-1} + \mu + \epsilon_t, \tag{4.1}$$

where P_t is the price at time t; μ is a constant drift; and ϵ_t is a mean-zero random error which is initially assumed identically and independently distributed (i.i.d) (Bachelier, 1900).

It is common practice in studies of commodity prices to work in the logarithm of the price level. The natural logarithm of the prices can eliminate trends in levels and variances, and reduce the impact of outliers; and has been widely used in previous research on commodity pricing models (Baillie and Myers; Yang and Brorsen).

A time series with a stochastic trend, such as in (4.1), is "non-stationary" because the statistical properties of the random variable can change over time and therefore conventional econometric methods are not generally applicable. The econometric difficulties of this particular specification are easily handled by rewriting the model and working in terms of price changes, or first differences, such as:

$$\Delta P_t = \mu + \epsilon_t,$$

where Δ is the difference operator, $\Delta P_t = P_t - P_{t-1}$. When the price level is replaced by the logarithm of price, the first difference of the logarithms becomes the approximate percentage change in prices.

The price series used in this research are examined first to determine if the hypothesis of a stochastic trend can be rejected. Phillips (1987) and Perron (1988) have developed unit root tests which are more robust than the traditional Dickey-Fuller tests to autocorrelation and heterogeneity in the distribution of the residuals, which are common problems exhibited by commodity prices. Here, Phillips-Perron unit root tests are undertaken on the logarithm of futures and cash prices.

Table 4.1 shows the Phillips-Perron unit root tests for the logarithms of the futures and cash price series. The hypothesis of a unit root cannot be rejected for either futures or cash prices. The first difference model with a drift appears to be appropriate for the mean levels of both futures and cash prices, although the errors may not be i.i.d. The Phillips-Perron test is explained in appendix A. Figures 4.1 and 4.2 show the

Table 4.1 Phillips-Perron Unit Root Test for Prices

$$P_t = \hat{\gamma} P_{t-1} + \hat{\epsilon}_t \qquad (a)$$

$$P_t = \mu^* + \gamma^* P_{t-1} + \epsilon_t^* \qquad (b)$$

$$P_t = \tilde{\mu} + \tilde{\beta}(t - \frac{T}{2}) + \tilde{\gamma} P_{t-1} + \tilde{\epsilon}_t \qquad (c)$$

Parameter	Estimate	
	futures	cash
$\hat{\gamma}$	0.9995	0.9996
μ^*	0.0674	0.0235
γ^*	0.9253	0.9705
$\tilde{\mu}$	0.0678	0.0237
$\tilde{\beta}$	1.095e-5	1.99e-5
$\tilde{\gamma}$	0.9249	0.9702

Statistic	Estimate		Critical Value				H_0
			10%	5%	2.5%	1%	
$Z(\gamma^*)$	-19.421	-7.669	-18.3	-21.8	-25.1	-29.5	$\gamma^* = 1$
$Z(t_{\gamma^*})$	-3.200	-1.966	-3.13	-3.43	-3.69	-3.99	$\gamma^* = 1$
$Z(t_{\mu^*})$	3.186	1.953	2.16	2.53	2.84	3.19	$\mu^* = 0$
$Z(\Phi_1)$	5.123	1.933	3.81	4.63	5.45	6.52	$\gamma^* = 1$ $\mu^* = 0$
$Z(\tilde{\gamma})$	-19.519	-7.737	-18.3	-21.8	-25.1	-29.5	$\tilde{\gamma} = 1$
$Z(t_{\tilde{\gamma}})$	-3.217	-1.987	-3.13	-3.43	-3.69	-3.99	$\tilde{\gamma} = 1$
$Z(t_{\tilde{\mu}})$	3.202	1.973	2.72	3.08	3.38	3.72	$\tilde{\mu} = 0$
$Z(t_{\tilde{\beta}})$	0.513	1.018	2.38	2.79	3.12	3.49	$\tilde{\beta} = 0$
$Z(\Phi_2)$	3.507	1.639	4.07	4.75	5.40	6.22	$\tilde{\beta} = 0$ $\tilde{\mu} = 0$ $\tilde{\gamma} = 1$
$Z(\Phi_3)$	5.258	2.459	5.39	6.34	7.28	8.43	$\tilde{\beta} = 0$ $\tilde{\gamma} = 1$

Note: Z, t, and Φ are statistics defined in Perron's (1988) paper and discussed in Appendix A. The critical values are from the tables composed by Dickey and Fuller (1981).

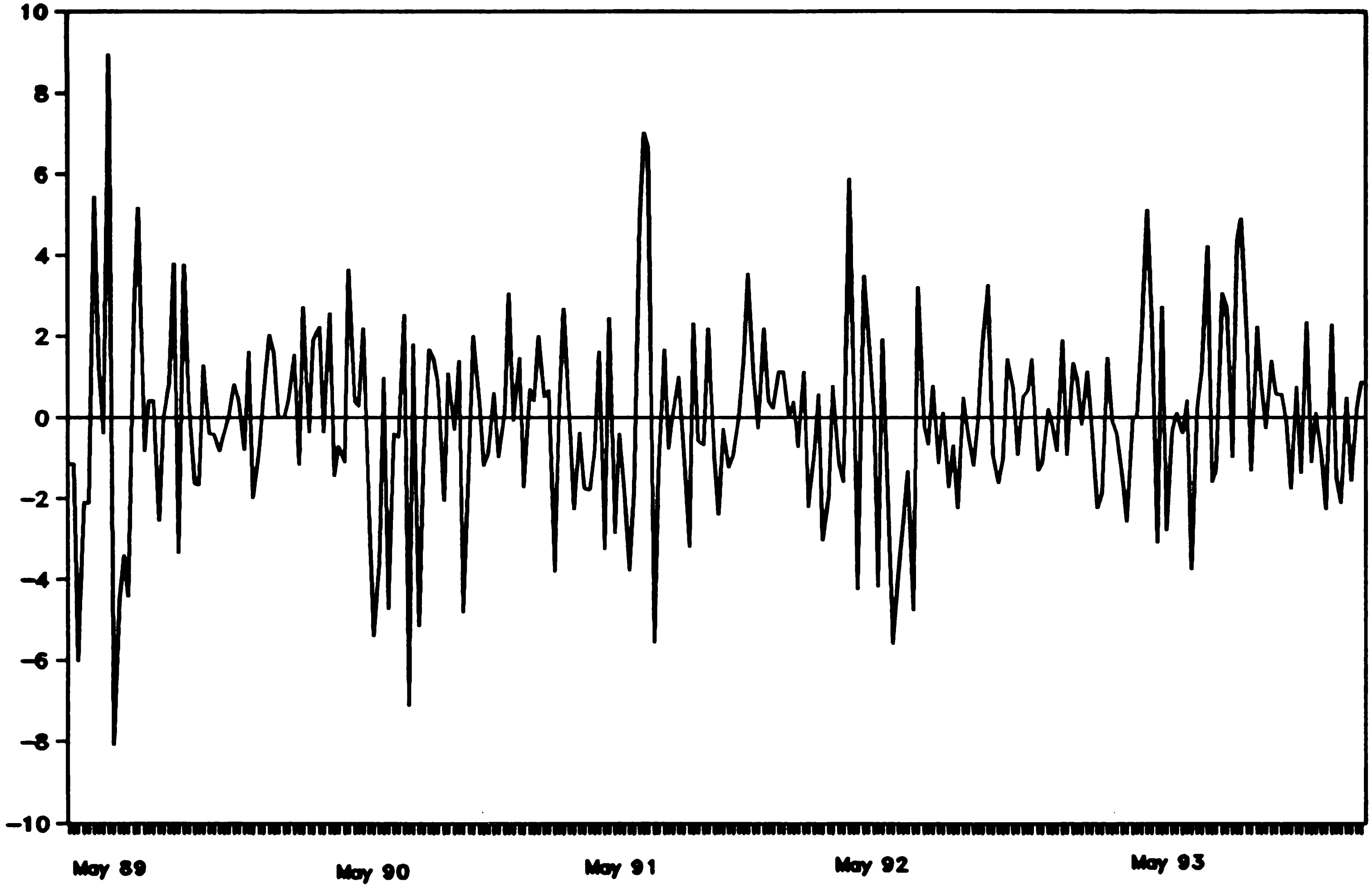

Figure 4.1 Logarithm of December Corn Futures Prices from May 1989 to April 1994

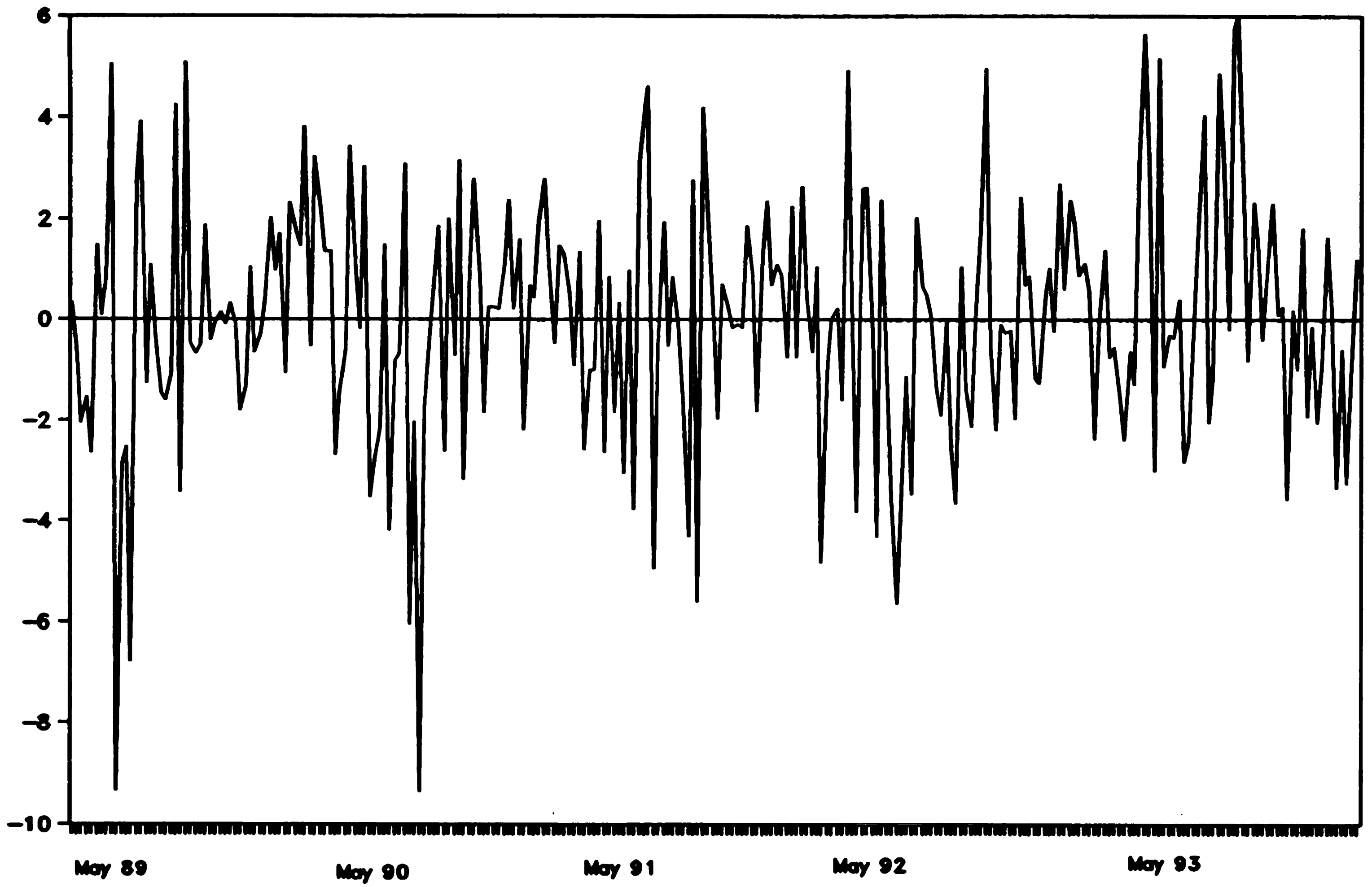

Figure 4.2 Logarithm of Iowa Corn Cash Prices from May 1989 to April 1994

changes in the logarithm of futures and cash prices from the first week of May 1989 to the last week of April 1994.

Analysis of Higher Moments

Previous studies suggest high frequency commodity price movements have time-varying volatility and excess kurtosis (Gordon, 1985; Hall, Brorsen and Irwin, 1985). These stochastic time-varying volatility and excess kurtosis properties of commodity price changes have been successfully modeled using the Autoregressive Conditional Heteroskedasticity (ARCH) model, developed first by Engle(1982) and later generalized by Bollerslev(1987) into the Generalized ARCH (GARCH) model. Baillie and Myers (1991) applied univariate GARCH-t models to daily cash and futures prices for corn, soybeans and other agricultural commodities, assuming the conditional error term in the process is distributed as a student-t random variate. Bivariate GARCH-normal models were also used to describe daily cash and futures prices jointly, assuming the conditional error terms are distributed as bivariate normal random variates (Myers, 1991). Though there is some evidence indicating the t-distribution is the appropriate conditional distribution for both cash and futures price errors, modeling a bivariate t-distribution remains technically infeasible because the joint density function is undefined (Yang and Brorsen, 1992; Baillie and Myers, 1991).

Time-varying volatility features can also be modeled with deterministic seasonal variables in the variance equation. A time dependent seasonal function can be useful in capturing volatility changes that occur at regular intervals. Figures 4.3 and 4.4 show

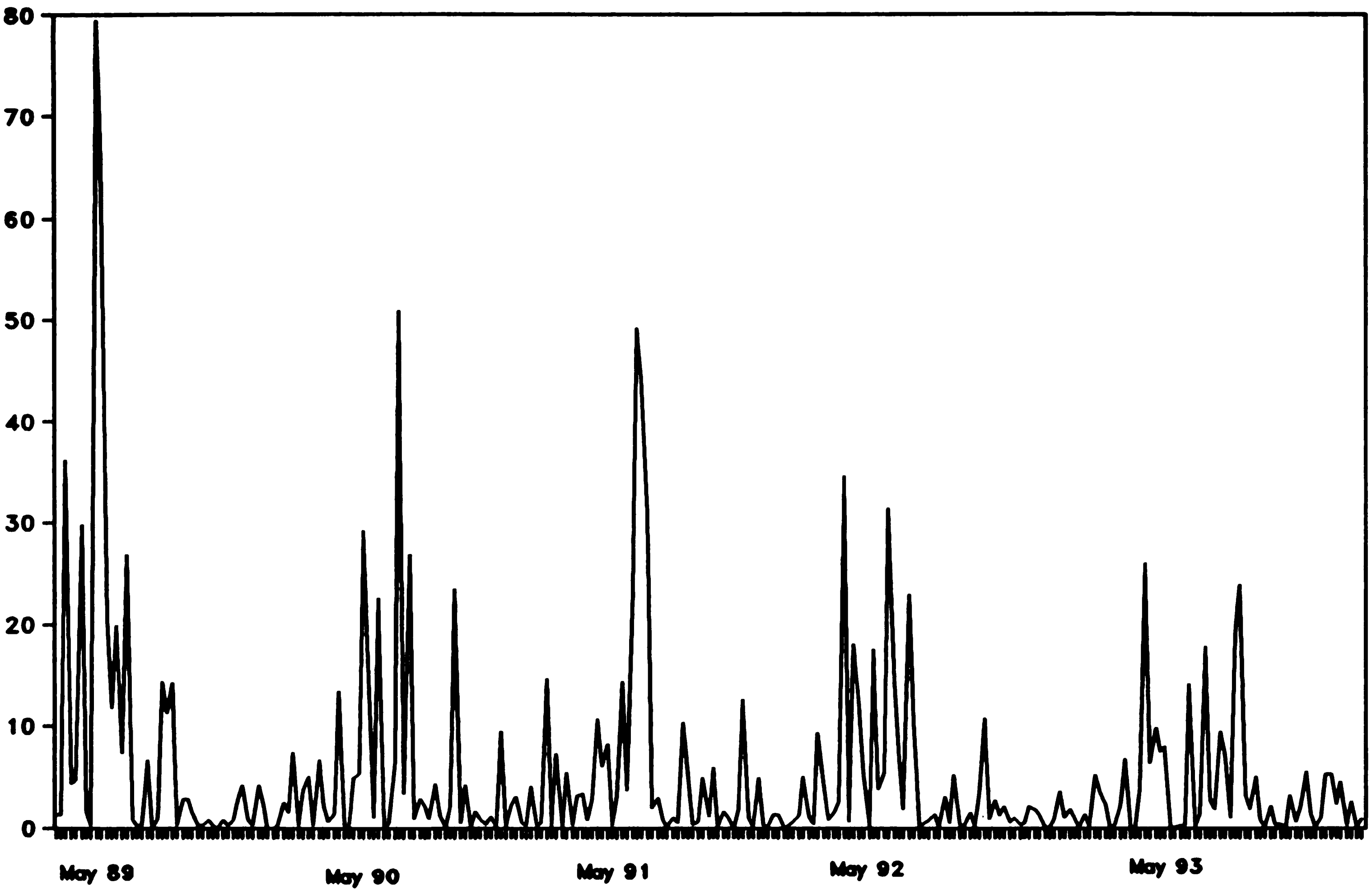

Figure 4.3 Squared Logarithm of December Corn Futures Prices from May 1989 to April 1994

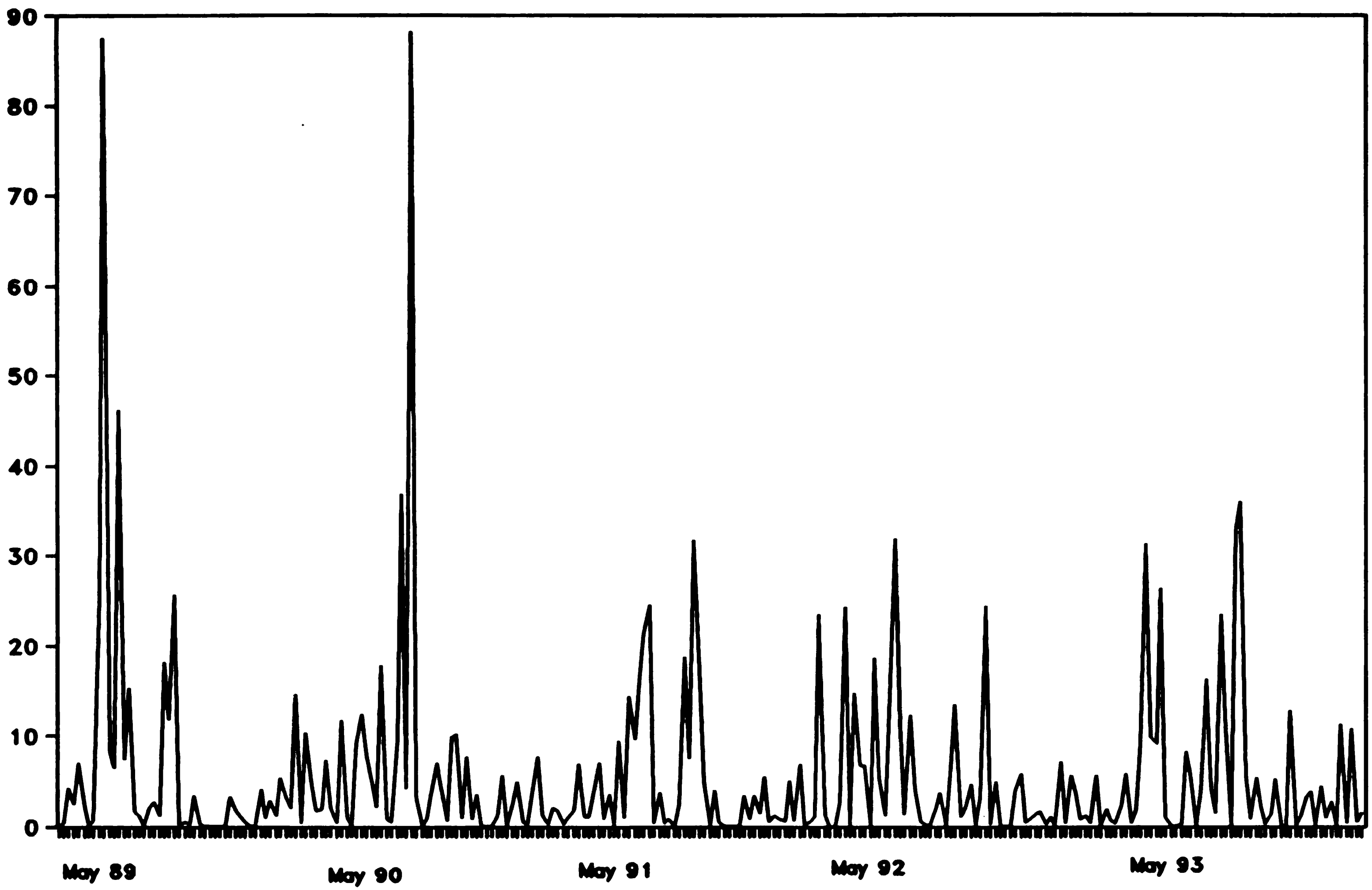

Figure 4.4 Squared Logarithm of Iowa Corn Cash Prices from May 1989 to April 1994

squared changes in the logarithm of futures and cash prices from the first week of May 1989 to the last week of April 1994. A cyclic pattern appears present indicating the existence of a seasonal effect where higher volatility is found during the planting and growing months and lower volatility found in the winter months, which is consistent with Anderson's (1985) observation.

Unfortunately, the seasonal and stochastic components of volatility are often related and difficult to identify separately. Fackler (1986) developed a process represented by both a deterministic seasonal component and a GARCH component, which did a good job of characterizing the variance process for corn prices. The price model used in this study follows that of Fackler, combining GARCH with seasonality.

There are significant and important differences between deterministic seasonality and a GARCH representation of the variance process. First, the time-varying variance of price changes is deterministic in the seasonality model and stochastic in the GARCH model. Second, the volatility prediction of the seasonality model is conditional on the time period for which the forecast is made, while the volatility prediction of the GARCH model converges to a constant unconditional variance that does not depend on the time period. The GARCH specification is best suited to model volatility when volatile and tranquil periods emerge randomly, while the deterministic seasonality model is best suited to model volatility that appears cyclically. Thus, using the GARCH specification by itself can lead to an erroneous long-term variance forecast if the true process contains a strong seasonal component.

Sine and cosine functions are commonly used seasonal functions because they are cyclical and can be combined in different frequencies to provide a flexible representation of many types of cycles (Yang and Brorsen, 1992; Kang and Brorsen, 1993). The frequencies of the seasonal variables and the specification of ARCH/GARCH process interact in characterizing the variance process, and the correct specification is determined by the data. In this study the variance process for cash and futures prices is represented by a bivariate model which includes both a deterministic seasonal component and a stochastic ARCH component. The bivariate models for futures and cash prices in this study assume the conditional errors are bivariate normal. The next section introduces the empirical model of the price process and presents estimates of the process parameters.

Price Model Specification and Estimation

Futures and cash prices are not independent, so a bivariate model is used to characterize the price process. Before presenting the bivariate model, the concepts of the deterministic seasonal component and stochastic ARCH component are first introduced in a univariate model which is used to conduct preliminary analysis of the variance process.

The general univariate price generating process can be modeled as:

$$\Delta P_t = \mu + \epsilon_t, \qquad \epsilon_t \vert \Omega_{t-1} \sim N(0,\sigma_t^2) \tag{4.2}$$

where ΔP_t is the change in logarithm of price at time t; σ^2_t is the time-varying variance at time t for the random error, ϵ_t, conditional on information available at time t-1, Ω_{t-1}; and $N(.,.)$ is a normal distribution with the first argument representing the mean and the second argument signifying the variance.

Examination of Figures 4.3 and 4.4 suggest the presence of a seasonal pattern in the volatility of price changes for both cash and futures prices. A deterministic seasonal variance model can be specified as:

$$\sigma_t^2 = \omega + \sum_{i=1}^{I} [\phi_i \cos(2\pi i d_t/52) + \psi_i \sin(2\pi i d_t/52)] \tag{4.3}$$

where I is the degree of frequency in seasonality variables, and d_t is the current week number. The parameters, ω, ϕ_i and ψ_i, for $i = 1,2,\ldots I$, represent the constant term and the coefficients of the sine and cosine functions respectively. The parameters are restricted so that the variance is positive at each time t.

This model allows the variance to evolve over time periodically moving from high levels to low levels with $52/I$ weeks as a cycle, where the timing of high and low variance levels are determined by the combined values of ϕ_i and ψ_i.

Likelihood ratio tests on the univariate deterministic volatility model suggest seasonality can be well represented by setting $I=1$ (See appendix A). It should be noted that the frequency degree and parameter estimates may change if a stochastic component is introduced and/or the univariate models are specified as a bivariate model. However, these results provide insight regarding the frequency level with which to initialize the bvat

resea

mod

wha

ens

sho

neg

va

Be

le

w

to

sh

eq

bivariate model. The suggested low frequency level is consistent with results in previous research (Fackler, 1986; Yang and Brorsen, 1992; and Kang and Brorsen, 1993).

The stochastic component of the time-varying variance is described by an ARCH model. The variance equation of a univariate ARCH(*J*) model is defined as:

$$\sigma_t^2 = \omega + \sum_{j=1}^{J} \alpha_j \epsilon_{t-j}^2 \qquad \epsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2) \tag{4.4}$$

where all the parameters, ω, α_j, $j = 1,\ldots,J$, are non-negative, and $\sum_{j=1}^{J} \alpha_j < 1$, which ensures the unconditional variance, $\omega/(1-\sum_{j=1}^{J} \alpha_j)$, is positive (Engle, 1982).

The ARCH(*J*) model allows the volatility to evolve over time driven by the shocks from the previous *J* periods; where a previous large shock, either positive or negative, contributes to the current variance level by adding a relatively large positive value to it; and correspondingly, a small shock contributes a relatively small value. Because the shocks exhibit some degree of correlation, a large (small) current variance level means large (small) current shocks, either positive or negative, are likely to occur, which is consistent with the behavior of many commodity prices where large shocks tend to be followed by other large shocks and small shocks are often followed by other small shocks.

A combined univariate ARCH(*J*) with *I* degree seasonality model has a variance equation specified as (4.5):

$$\sigma_t^2 = \omega + \sum_{j=1}^{J} \alpha_j \epsilon_{t-j}^2 + \sum_{i=1}^{I} [\phi_i \cos(2\pi i d_t/52) + \psi_i \sin(2\pi i d_t/52)] \tag{4.5}$$

where the deterministic component should be positive at each time, t, that is, $\omega + \sum_{i=1}^{I} [\phi_i \cos(2\pi i d_t/52) + \psi_i \sin(2\pi i d_t/52)] > 0$, and once again, $\sum_{j=1}^{J} \alpha_j < 1$.

This model allows the volatility to evolve over time driven by both a seasonal cycle and previous shocks. The contribution of each component to the variance level is determined by ARCH parameters α_j, $j = 1,\ldots,J$, and seasonal parameters ϕ_i and ψ_i, $i = 1,\ldots,I$.

The bivariate specification is similar to the univariate specification where the variance process for cash and futures price shocks is characterized by a process with both stochastic and seasonal components. In addition, the error terms are assumed to be bivariate normal, and the covariance term is also characterized by both a stochastic and seasonal component. The bivariate ARCH(J) model with I degree seasonality in the logarithm of futures and cash prices is specified as:

$$\Delta P_t = \mu + \epsilon_t, \qquad \epsilon_t | \Omega_{t-1} \sim N(0, H_t)$$

$$\textit{where} \quad P_t = \begin{bmatrix} \ln f_t \\ \ln p_t \end{bmatrix}, \quad \mu = \begin{bmatrix} \mu_f \\ \mu_p \end{bmatrix}, \quad \epsilon_t = \begin{bmatrix} v_t \\ u_t \end{bmatrix} \tag{4.6}$$

$$Vech(H_t) = W + \sum_{j=1}^{J} A_j Vech(\epsilon_{t-j}\epsilon_{t-j}') + \sum_{i=1}^{I} [\Phi_i \cos(2\pi i d_t/52) + \Psi_i \sin(2\pi i d_t/52)],$$

where P_t is the vector of natural logarithms of futures and cash prices at time t; μ is the mean vector of the differenced log prices; the error vector, ϵ_t, is conditionally distributed as bivariate normal with zero mean, and variance-covariance matrix H_t; *Vech(.)* is an operator which stacks the lower triangle of a symmetric matrix; W, Φ_i, and Ψ_i, are (3x1) parameter vectors for the constant, sine and cosine coefficients respectively; and A_j, are (3x3) parameter matrices for the ARCH coefficients. A diagonal parameterization serves to reduce the number of parameters in this model to make the estimation feasible (Baillie and Myers, 1991). As a result, A_j, for $j = 1,2,\ldots,J$, are specified as diagonal matrices.

Various specifications of model (4.6) were estimated using the maximum likelihood approach and subjected to a number of diagnostic tests. The specification which seemed to do the best job of characterizing the behavior of the price series was a process with a restricted ARCH(9) with first degree seasonality (See appendix A). The parameter estimates for the model and diagnostic statistics are shown in Table 4.2.

As expected, the constant mean for futures price is not significantly different than zero, suggesting there are no constant price changes expected in the futures market which is consistent with weak-form market efficiency. There is a small positive drift in the cash price equation, suggesting an upward trend in cash prices over time. This may be partly attributed to the upward pressure on cash prices during the 1993 flood, which was the last year of the data. The ARCH coefficients at lag 1, except in the futures equation, are statistically significant at the 10% level. Removal of any of the ARCH coefficients in the futures price equation results in invalid diagnostic Q tests which suggest the

Table 4.2 Bivariate Futures and Cash Price Process

$$\Delta P_t = \mu + \epsilon_t, \qquad \epsilon_t|\Omega_{t-1} \sim N(0,H_t)$$

$$where \quad P_t = \begin{pmatrix} \ln f_t \\ \ln p_t \end{pmatrix}, \quad \mu = \begin{pmatrix} \mu_f \\ \mu_p \end{pmatrix}, \quad \epsilon_t = \begin{pmatrix} v_t \\ u_t \end{pmatrix}$$

$$\begin{pmatrix} H_{11,t} \\ H_{21,t} \\ H_{22,t} \end{pmatrix} = \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{pmatrix} + \begin{pmatrix} \alpha_{11} & 0 & 0 \\ 0 & \alpha_{21} & 0 \\ 0 & 0 & \alpha_{31} \end{pmatrix} \begin{pmatrix} v_{t-1}^2 \\ v_{t-1}u_{t-1} \\ u_{t-1}^2 \end{pmatrix} + \begin{pmatrix} \alpha_{13} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} v_{t-3}^2 \\ v_{t-3}u_{t-3} \\ u_{t-3}^2 \end{pmatrix} + \begin{pmatrix} \alpha_{19} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} v_{t-9}^2 \\ v_{t-9}u_{t-9} \\ u_{t-9}^2 \end{pmatrix} + \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \end{pmatrix} \sin(2\pi i d_t/52)$$

Coefficient	Estimate	t-Value	p-Value
μ_f	0.0586	0.526	0.300
μ_p	0.1949	1.583	0.057
ω_1	4.7732	8.639	0.000
ω_2	4.2835	8.727	0.000
ω_3	5.1533	9.208	0.000
α_{11}	0.0499	1.114	0.133
α_{21}	0.0538	1.424	0.078
α_{31}	0.0697	1.412	0.080
α_{13}	0.0179	0.867	0.193
α_{19}	0.0252	1.249	0.106
ψ_1	3.7641	6.481	0.000
ψ_2	3.3444	6.172	0.000
ψ_3	3.4265	5.353	0.000

Futures Residual Statistics		Cash Residual Statistics		Cross Product ResidualStatistics
$M_3 = 0.178$		$M_3 = -0.266$		
$M_4 = 2.934$		$M_4 = 5.626$		
Q(1) = 0.056	$Q^2(1) = 0.808$	Q(1) = 0.368	$Q^2(1) = 0.620$	$Q^3(1) = 0.068$
Q(5) = 5.348	$Q^2(5) = 8.388$	Q(5) = 5.824	$Q^2(5) = 5.286$	$Q^3(5) = 5.071$
Q(10) = 12.68	$Q^2(10) = 16.68$	Q(10) = 11.28	$Q^2(10) = 10.25$	$Q^3(10) = 9.879$
Q(15) = 15.29	$Q^2(15) = 17.50$	Q(15) = 14.44	$Q^2(15) = 15.62$	$Q^3(15) = 11.66$
Q(20) = 18.55	$Q^2(20) = 24.84$	Q(20) = 15.92	$Q^2(20) = 18.33$	$Q^3(20) = 14.55$

Note: M_3 is sample skewness; M_4 is sample kurtosis; Q(*df*) is a Q test for *df* degree autocorrelation in the residuals; Q^2(*df*) is a Q test for *df* degree autocorrelation in the squared standardized residuals; and Q^3(*df*) is a Q test for the standardized cross product of the residuals from the futures price and cash price equations.

presence of unexplained ARCH effects in the squared standardized residuals. All the seasonality coefficients for sine functions are significant and positive, which results in cyclical volatility levels high in the summer time and low in the winter time.[8] All the insignificant coefficients, such as cosine terms and other ARCH terms, are excluded from the model. The Ljung-Box Q statistics for the errors and standard squared errors of all futures, cash and cross errors suggest the model is well specified in the sense that the model does a good job of capturing all the autocorrelations.

Empirical Price Distributions

Unfortunately, the estimated price process does not have a closed form solution and so it is necessary to generate the joint distribution of futures and cash prices numerically in order to solve the farmer's optimization problem. Using the estimators of the joint price process from Table 4.2, we can use simulation techniques to obtain a terminal distribution of the cash and futures prices, conditional on information available at the time of the decision problem.

Let p_0 and f_0 be the initial cash and futures price respectively on the last week of April 1994, t_0, which is assumed to be the planting period. The terminal date, t_1, is the first week of December 1994, which is the assumed harvest period. Starting from $t = t_0$, the simulation steps are:

---

[8] The data series begin from the first week of May and the sine function reaches its peak in August. Similarly, the lowest level of the sine function is at three quarters of a period, which corresponds to February.

1. Simulate $H_{11,t+1}$, $H_{21,t+1}$ and $H_{22,t+1}$ by iterating the variance equation in (4.6) forward one period.

2. Generate two independent standard normal variates, $(e_{v,t+1}, e_{u,t+1})$, so that $(\sqrt{H_{11,t+1}}\, e_{v,t+1}, \sqrt{H_{22,t+1}}\, e_{u,t+1})$ are two independently distributed normal variates with mean zero and variance $H_{11,t+1}$ and $H_{22,t+1}$ respectively.

3. Calculate the errors of joint normal distribution as:

$$\begin{aligned} v_{t+1} &= \sqrt{H_{11,t+1}}\, e_{v,t+1} \\ u_{t+1} &= \rho_{t+1}\sqrt{H_{22,t+1}}\, e_{v,t+1} + \sqrt{(1-\rho_{t+1}^2)H_{22,t+1}}\, e_{u,t+1} \\ \textit{where} \quad \rho_{t+1} &= \frac{H_{21,t+1}}{\sqrt{H_{11,t+1}H_{22,t+1}}} \end{aligned} \tag{4.7}$$

(See appendix B for the deduction of the above equation.)

4. Generate one pair of log prices at $t+1$ by:

$$\begin{aligned} \ln f_{t+1} &= \mu_f + \ln f_t + v_{t+1} \\ \ln p_{t+1} &= \mu_p + \ln p_t + u_{t+1} \end{aligned} \tag{4.8}$$

5. Repeat step 1 - 4 for t_1 - t_0 = 31 weeks until one realization of $(\ln f_{t_1}, \ln p_{t_1})'$ is obtained, and take the exponential of the realized log prices to restore them to price levels. This is used as one random sample of the bivariate price distribution at harvest conditional on information available at planting.

6. Repeat step 1 - 5 m times to generate an m-size sample of the bivariate price distribution at harvest, where m is 1000 in this study.

The above process generates a bivariate distribution of cash and futures prices based on the information available in historical futures and cash prices at planting, which provides important information on higher moments. The mean of each price is then adjusted to the market determined mean levels (current futures and forward prices).

Futures and cash forward prices contain not only the information in historical prices but also other currently available market information. As a result, current futures and forward prices are used as the mean levels of futures and cash prices at harvest. The December cash forward contract price during the last week of April 1994 was \$2.48/bu in the southwest Iowa,[9] and the December futures price during the same week was \$2.56/bu at Chicago Board of Trade. The 8 cents difference between these two prices at planting is the markets' expected basis at harvest, representing the cost to transport the corn from Iowa to Chicago. A linear transformation of the simulated price distribution is used to shift cash and futures means at harvest to 2.48 and 2.56 respectively, in order to eliminate the mean increasing effect caused by the positive mean estimates. This adjustment does not affect the higher moments of the distribution, but ensures the means correspond to the designated levels.

The histograms of the simulated marginal distributions of futures and cash prices for the first week of December 1994 are shown in Figure 4.5. The first four moments of the bivariate distribution are calculated and listed in Table 4.3. As expected from the estimated price process, the joint sample distribution of futures and cash prices at harvest

[9] This is the average of the high and low forward prices for April 28, 1994, obtained from the Agricultural Extension Service in the Department of Economics at Iowa State University.

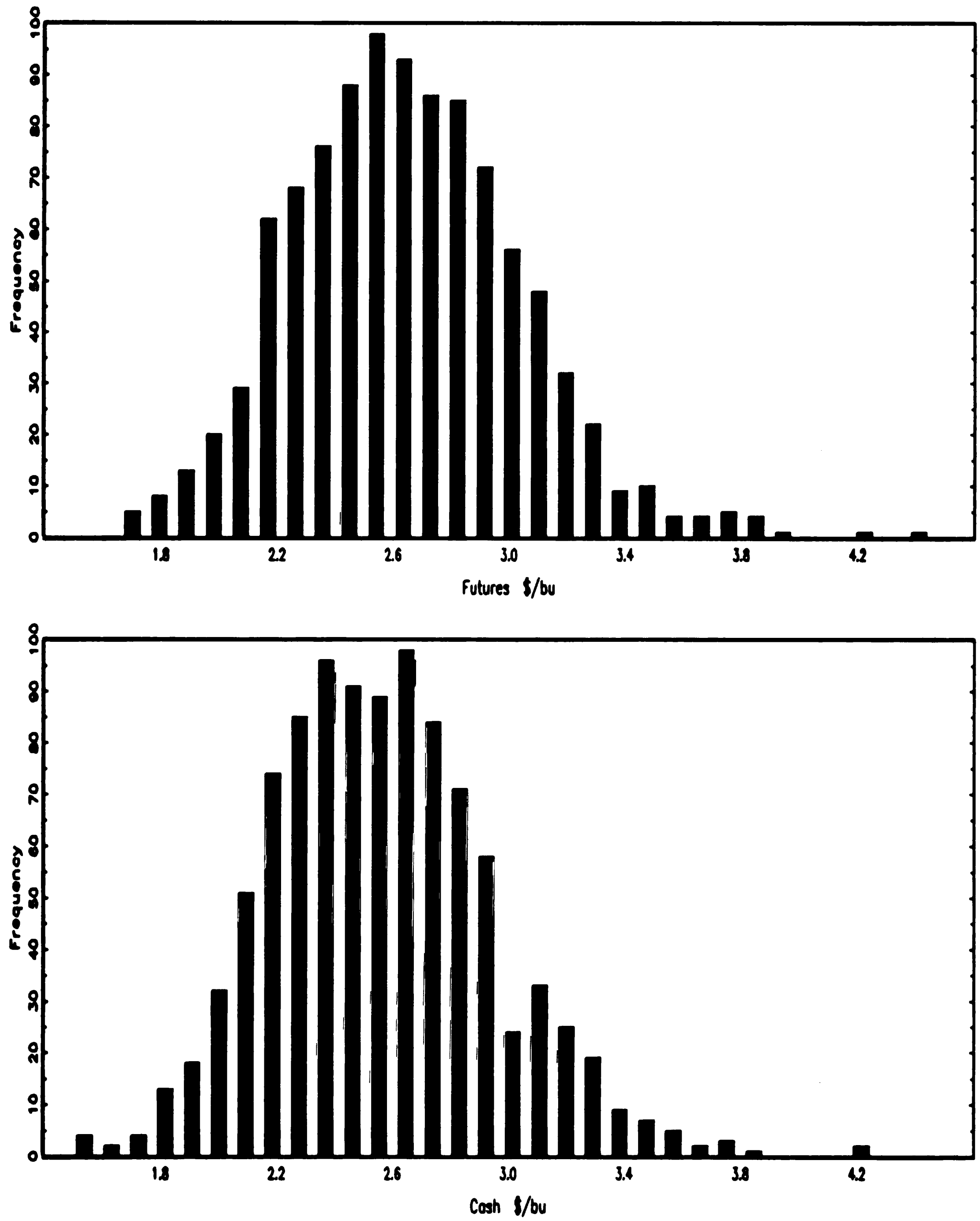

Figure 4.5 Histograms of the Simulated Futures and Cash Price Distributions

Table 4.3 Sample Moments of the Simulated Harvesting Prices

	Mean	Standard Deviation	Skewness	Kurtosis	Correlation
futures	2.5626	0.39237	0.41368	3.5744	0.8433
cash	2.4826	0.38532	0.43658	3.5529	

is not normally distributed. The marginal distributions have slight positive skewness and excess kurtosis, while the normal distribution is symmetric and has a kurtosis level of about 3. This result is consistent with previous observations regarding the distribution of commodity prices (Gordon, 1985). The two prices are highly correlated at harvest, with a conditional correlation of 0.84.

4.2 The Joint Farm and Area Yield Distribution

Although the normal distribution has been used to model yield distributions in past studies of crop insurance, it may not be an appropriate model. It is generally argued from a conceptual standpoint that farm-level yield distributions have a thin long tail on the left side because of the occasional severe catastrophes that can drastically reduce, or totally eliminate, yield; and the distribution's right tail is short because there is a maximum yield limit given current technology.

Day (1965) conducted statistical tests on yields of several major field crops in the Mississippi Delta Region, and found the yields are nonnormal and nonlognormal, and have negative skewness. Recently, Nelson (1990) concluded that beta distribution can better characterize the skewness of yield distributions based on an empirical analysis using data from seven Iowa counties. Nelson and Preckel (1989) studied a conditional beta distribution and drew similar conclusions. The beta distribution is a bounded distribution with the two bounds characterized by two of the distribution's parameters, and it provides the flexibility for fitting skewness by changing two shape parameters.

However, there are a number of difficulties in estimating the parameters of the beta distribution for farm-level yields. In order to estimate the parameters describing the yield generating process for a particular farm, historical yield data from the farm are required. Estimating the central tendency and higher moments of the yield distribution typically places heavy demands on the data and consequently a large set of data is needed to obtain reliable estimates of the yield generating process.[10] Unfortunately, farm-level yield data are usually not well recorded; for example, the Actual Production History (APH) yield data available for individual farms in southwest Iowa contain only ten years of yield observations, which makes it unrealistic to attempt to estimate the beta distribution directly for individual farms.

It is natural to think about using cross sectional data to reduce the difficulties in working with time series and increase the amount of data available for parameter estimation. For example, Nelson (1990) pools the cross sectional data from neighboring farms each of which has several years of time series data on yield levels and estimates the beta distribution. Unfortunately, cross sectional data from the farmer's neighboring

---

[10] The Beta distribution has four parameters. They are the upper bound, lower bound, left skewness and right skewness. As technology improves over time, the upper bound and the two skewness parameters of yield all change, and perhaps the lower bound as well. This increases the number of parameters that must be estimated in order to characterize the yield process.

region are generally highly correlated during the same time period because of local production factors, such as weather, which can lead to biased parameter estimates. On the other hand, cross sectional data from randomly selected remote regions are difficult to use because the variation in factors such as soil fertility, rainfall, and temperature in the different regions must be taken into account. As a result, many studies have resorted to using county-level yield data to estimate representative yield distributions because these data are usually available for longer historical periods, often more than 50 years, and the geographical conditions in a county may be similar for most farms, which would imply that county-level yield distribution may reveal information about the farm-level yield distributions in that county. Hence, in this study county-level time series data are used to estimate the farm-level yield distribution.

Evidence has been found that the historical yield data exhibit time trends due to technological change which needs to be accounted for in yield distribution estimation (Skees and Reed, 1986; Swinton and King, 1991). Recent work by Moss and Shonkwiler (1993) uses an inverse hyperbolic sine function to model yield distributions around a measure of central tendency. The yield process might be thought of as having stochastic shocks, which are due to factors such as weather, insects and disease, around a mean-yield level which increases at a deterministic rate as technology is made available. The residuals around the time-varying mean level are corrected for skewness and kurtosis by using a transformation based on the inverse hyperbolic sine function. This model simultaneously shrinks large residuals toward zero and parameterizes the skewness and kurtosis of the distribution. Equally important, the model characterizes both the deterministic time trend and the stochastic component of yields in a way that easily accommodates the use of time series data. The model used in this study to describe the yield generating process is a variation of the model used by Moss and Shonkwiler.

The remainder of this section introduces the data characteristics and presents the model specification. Next, the simulation procedure for county-level yields and farm-level yields are discussed. Finally, the technique used to generate the bivariate distribution for both county-level and farm-level yields is explained.

Properties of Yield Data

Due to the lack of farm-level yield data, the method used in this study is to estimate parameters describing the county-level yield distribution, which itself is needed in the analysis of the area yield crop insurance program, and then use available data on farm-level yields to make adjustments to the county-level yield generating process that will reflect the characteristics of farm-level yield distributions. Empirical county-level and farm-level yield distributions are then generated using numerical methods. Taylor's (1990) method is used to impose correlation between the farm-level and county-level distributions and obtain a bivariate yield distribution.

Figure 4.6 shows county-level corn yields for Adair, Adams and Case counties in southwest Iowa from 1928 to 1993. Yields in each county increase over time at a nonlinear rate with a slightly upward bending curve, suggesting a nonlinear trend is present in the process. In addition, yield volatility is increasing as the central tendency goes up. Conceptually, this form of heteroskedasticity is expected because the larger the

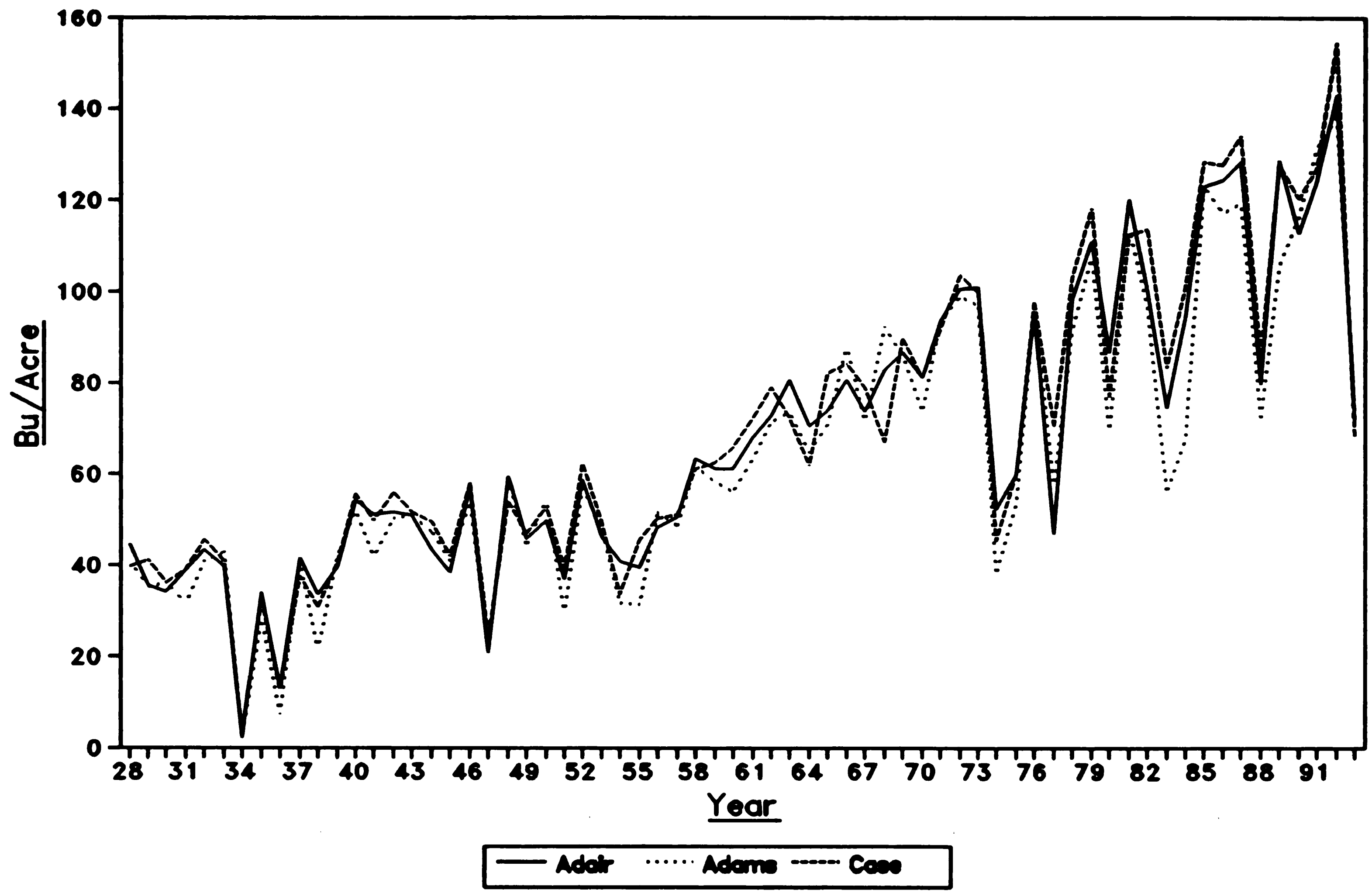

Figure 4.6 Iowa County Average Corn Yield Levels During 1928-1993 for Adair, Adams and Case County Farms

central tendency of the yield, the larger the disturbance can be because there is more room for yields to drop due to negative shocks and there is always the possibility that a major catastrophe cause yields to fall to zero.[11]

It is important to account for the nonlinear time trend and heteroskedastic properties of the yield data. One method would be to incorporate these features directly in the model describing the yield process and estimate parameters using historical data. For example, a quadratic time trend can be used instead of the linear trend to reflect the nonlinear central tendency. The disadvantage of this approach is that the process generating the time trend and heteroskedasticity must be explicitly defined and then estimated, which imposes additional demands on the data set. An alternative approach is to impose a transformation that corrects the data for these general characteristics and then use the transformed data in the estimation.

One common transformation is the logarithm function which adjusts both the convexity of the central tendency and the heteroskedasticity across time. The details of how it accommodates the heteroskedasticity across time will be explained after the model is introduced. Figure 4.7 shows the logarithm of historical yield levels in each county, which appears to have a linear trend and is homoskedastic across time except for one

---

[11] To test for a trend in variance, the errors are obtained as observed deviations from the central tendency. The model used to estimate the central tendency is important to this test, here the inverse hyperbolic sine transformation model, which will be later explained in detail is used. A χ^2 test on the residuals (Harvey, 1990, p158) is undertaken.

The values of the statistic for Adair, Adams, and Case are 54.6, 65.0 and 66.9 respectively, and their probabilities are all less than 0.1%. The null hypothesis of homoskedasticity is rejected essentially at any significance level.

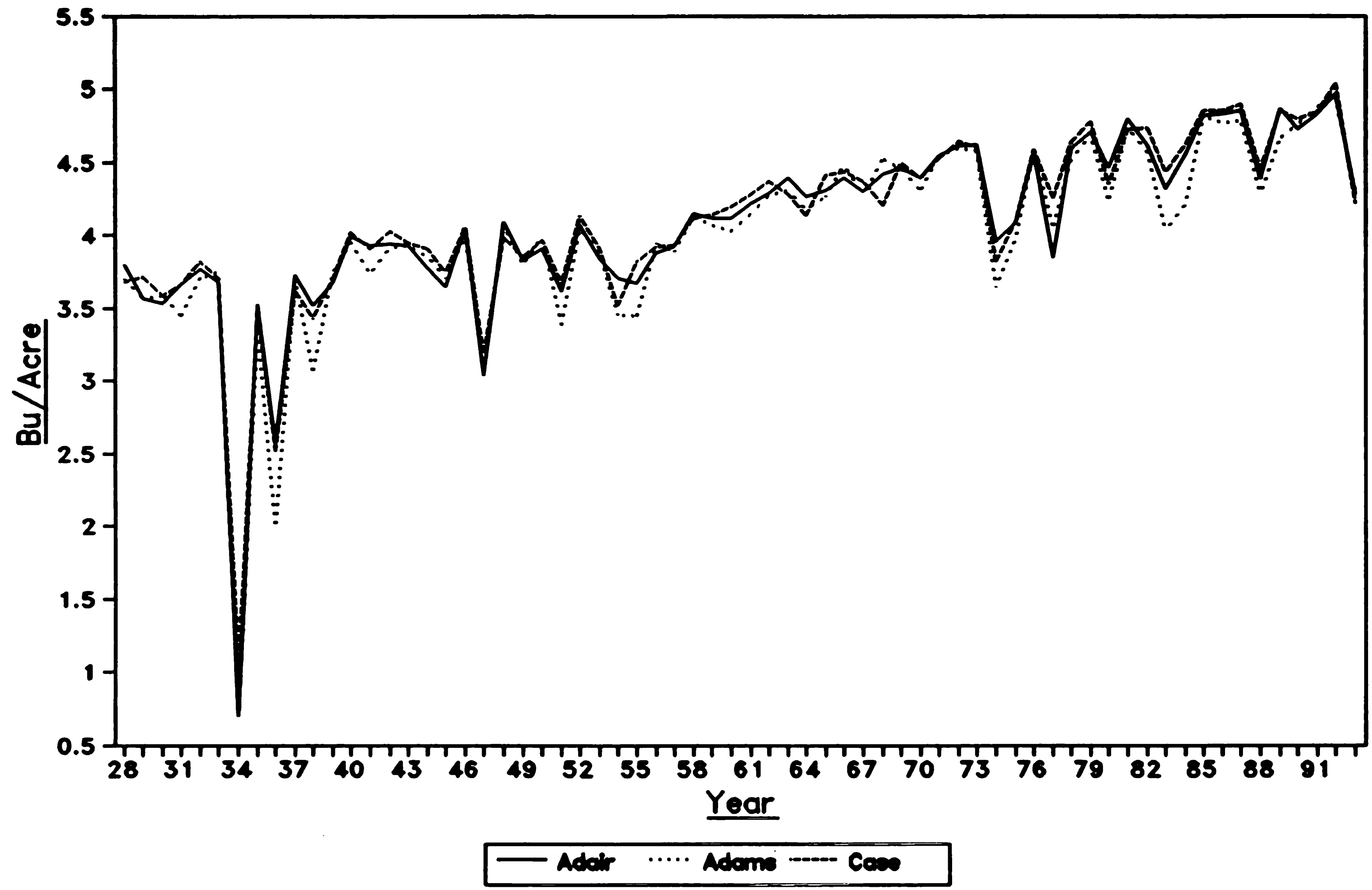

Figure 4.7 Iowa County Average Corn Yields in Logarithms During 1928-1993 for Adair, Adams, and Case County Farms

large negative shock in the beginning of each series. The null hypothesis of homoskedasticity across time cannot be rejected for the log yield data.[12]

In order to determine whether differencing of the yield is necessary to specify the model, the Phillips-Perron unit root tests are undertaken on the logarithm of the yield levels to check if the log yields have a unit root. The results are listed in Table 4.4. Unlike the price series, the hypothesis of unit root in the yield series can be rejected and a linear time trend hypothesis cannot be rejected.[13]

Yield Model Specification and Estimation

Yields are assumed to be governed by the following process:

$$
\begin{aligned}
y_t &= a + b y_{t-1} + ct + e_t \\
e_t &= \frac{\sinh(\theta(\upsilon_t + \delta))}{\theta} \\
\upsilon_t &\sim N(0, \varsigma^2)
\end{aligned}
\qquad (4.9)
$$

where y_t is the logarithm of yield at time t; e_t is the nonnormal disturbance; *sinh(•)* is the hyperbolic sine transformation (HST); υ_t is an i.i.d normal disturbance with mean

---

[12] The same χ^2 test for a trend in variance, as specified in footnote 11, is undertaken on the logged yield data with the same model. The statistics for Adair, Adams and Case are 5.174, 6.463 and 5.571 respectively, and the probabilities are all larger than 99.95%. The null hypothesis of homoskedasticity can't be rejected at the 5% significance level.

[13] Again, following Perron's suggestion, the equation with the linear time trend is tested first. $Z(\Phi_3)$ is large enough to reject the hypothesis that $\tilde{c}=0$ and $\tilde{b} = 1$ at 5% significant level, but it doesn't tell which of the above two equations is violated. However, the small $Z(\tilde{b})$ and $Z(t\tilde{b})$ tell us that $\tilde{b}=1$ can be rejected. Therefore, the unit root hypothesis can be rejected for the yield series. Also, $Z(t\tilde{a})$ is large enough to reject that $\tilde{a}=0$.

Table 4.4 Phillips-Perron Unit Root Test for Yield

$$y_t = a^* + b^* y_{t-1} + e_t^*$$
$$y_t = \tilde{a} + \tilde{b} y_{t-1} + \tilde{c}\left(t - \frac{T}{2}\right) + \tilde{e}_t$$

Parameter	Estimate		
	Adair	Adams	Case
a^*	2.6158	1.7377	1.8462
b^*	0.35597	0.57624	0.54968
$\tilde{a}$	2.7596	1.8927	1.9598
$\tilde{b}$	0.31944	0.53755	0.52141
$\tilde{c}$	0.0071465	0.0036892	0.0032305

Statistic	Estimate			Critical Value			H_0
				10%	5%	1%	
$Z(\tilde{b})$	-44.237	-30.060	-31.108	-18.3	-21.8	-29.5	$\tilde{b}=1$
$Z(t_{\tilde{b}})$	-5.7718	-4.3080	-4.5346	-3.13	-3.43	-3.99	$\tilde{b}=1$
$Z(t_{\tilde{a}})$	5.6984	4.3326	4.5195	2.72	3.08	3.72	$\tilde{a}=0$
$Z(t_{\tilde{c}})$	1.4170	1.3856	1.0138	2.38	2.79	3.49	$\tilde{c}=0$
$Z(\Phi_3)$	16.669	9.3155	10.299	5.39	6.34	8.43	$\tilde{c}=0$ $\tilde{b}=1$

Note: Z, t, and Φ are statistics defined in Perron's (1988) paper. The critical values are from the tables composed by Dickey and Fuller (1981).

zero and variance ς^2; δ and θ are parameters measuring skewness and kurtosis respectively. Generally, when δ is positive e_t is skewed to the right, if it is negative e_t is skewed to the left, and if it is zero e_t is symmetric. When θ is zero, e_t is as kurtotic as the normal distribution (the limit of e_t is $\upsilon_t+\delta$ as θ approaches zero, $\lim_{\theta\to 0} e_t = \upsilon_t + \delta$) and e_t becomes more and more kurtotic as the magnitude of θ increases either positively or negatively. The lagged term y_{t-1} captures autocorrelation, so that e_t is i.i.d. The functional form of the HST is outlined in appendix C.

The first equation in (4.9) is the linear trend equation of log yield, which describes the central tendency of the current yield as being partially determined by time and last period's yield[14]. The transformed stochastic variable, e_t, has a non-zero mean which is determined by the three parameters of the transformation. Although still deterministic, the central tendency of y_t is the sum of the first three terms in that equation and $E(e_t)$. The realized yield is a combination of the deterministic central tendency and a stochastic nonnormal shock. The second equation in (4.9) transforms the normal shocks into nonnormal shocks by the modified HST. Appendix C also discusses some of the properties of the HST. In order to estimate the parameters of model (4.9), the

[14] It is useful at this point to notice that the log yield described in (4.9) implies the errors are multiplicative to the time trend and lagged yield levels rather than additive, $Y_t = Y_{t-1}^b \exp(a+ct+e_t)$, where Y_t is the yield level, and the variance of yield levels equals to the variance of the exponential stochastic shocks multiplied by a trend factor. The conditional mean and conditional variance of yield are: $E_{t-1}[Y_t] = Y_{t-1}^b \exp(a+ct) E[\exp(e_t)]$, and $V_{t-1}[Y_t] = Y_{t-1}^{2b} \exp(2a+2ct) V[\exp(e_t)]$ respectively, and both of them are increasing with time even if the mean and variance of the errors are constant over time, which is consistent with the yield heteroskedasticity observed in Figure 4.6.

maximum log likelihood technique is used. Equation (4.10) gives the maximum log likelihood function (details of this equation are explained in appendix C):

$$\begin{aligned}
\underset{a,b,c,\varsigma^2,\theta,\delta}{MAX}\ L &= -\frac{1}{2}\sum_{t=1}^{T}[\ln\varsigma^2 + \frac{\upsilon_t^2}{\varsigma^2} + \ln(\theta^2 e_t^2 + 1)] \\
\upsilon_t &= \frac{\sinh^{-1}(\theta e_t)}{\theta} - \delta \\
&= \frac{1}{\theta}\ln(\theta e_t + \sqrt{(\theta e_t)^2 + 1}) - \delta \\
e_t &= y_t - a - by_{t-1} - ct
\end{aligned} \tag{4.10}$$

The model is estimated for county-level yield using annual corn yield data from Adair, Adams and Case county from 1928 to 1993 as obtained from the University of Kentucky. The log yield is multiplied by 100 for computational convenience. The estimated parameters and their t-statistics are shown in Table 4.5. The second, third and fourth moments and Ljung-Box Q statistics for the nonnormal errors are listed in the table as well. All the parameters are significantly different than zero at the 5% level except the variance for Case County.

The estimated yield processes for all the three counties show the same pattern. The positive b and c estimates indicate expected yields are increasing over time, and positively related with the yields in the previous period. The negative θ and δ estimates indicate errors are skewed to the left and are more kurtotic than the normal distribution, which is consistent with the calculated third and fourth sample moments listed in Table 4.5. Adair and Adams county have similar estimates for the transformation parameters,

Table 4.5 County-level Yield Model Estimates

	County					
	Adair		Adams		Case	
Coefficient	Estimates	t-Value	Estimates	t-Value	Estimates	t-Value
a	360.5	918.5	355.91	908.3	325.28	44.6
b	0.052	9.8	0.050	6.4	0.142	6.8
c	1.86	35.0	1.93	24.5	1.72	21.0
ς	0.0032	3.5	0.0083	3.5	20.00	1.2
θ	-16.21	-41.3	-11.27	-28.8	-0.2375	-2.3
δ	-0.41	-31.4	-0.55	-25.2	-8.80	-3.8
M_2	1987.47		2319.31		1699.44	
M_3	-4.3532		-3.5274		-3.9091	
M_4	26.9436		19.0132		22.6256	
Q(1)	0.388		0.293		1.341	
Q(5)	4.483		6.775		5.911	
Q(10)	5.384		8.259		7.085	

Note: M_2 is sample variance; M_3 is sample skewness; M_4 is sample kurtosis; and Q(*df*) is a Q test for *df* degree autocorrelation in the residuals.

while Case county clearly has different parameter estimators. However, the transformation parameter estimates combine to produce quite similar distributions for all three counties (see appendix C for further discussion of the relationships among the three parameters). The Ljung-Box Q test suggests there is no remaining autocorrelation in the residuals from this model.

Empirical County-level Yield Distribution

Because the time series data on yields are annual observations, we can predict the yield process for the upcoming year by specifying the current year's yield and iterating the model forward one period. There is no closed form distribution for the yield process, but it is straightforward to simulate the yield distribution empirically. The simulation starts by generating a sample of n normal variates, and then plugging each variate into the recursive equation specified by (4.9), to get n realizations of yield. The detailed simulation procedure for $n = 1{,}000$ is:

1. Generate normally distributed random variates, $v_{i,t+1}$, with mean zero and variance ς^2, for $i = 1,\ldots,1000$.

2. Transform the simulated random variates, $v_{i,t+1}$, into nonnormal disturbance using the HST:

$$e_{i,t+1} = \sinh(\theta(v_{i,t+1}+\delta)) \,/\, \theta, \text{ for } i = 1, \ldots, 1000.$$

3. Simulate log yields using the yield trend equation

$$y_{i,t+1} = a + b\, y_t + c(t+1) + e_{i,t+1}\,, \text{ for } i = 1,\ldots,1000.$$

4. Take exponential of the log yields to obtain yield levels:

$$Y_{i,t+1} = \exp(y_{i,t+1}) \ , \text{ for } i = 1,\ldots,1000.$$

This provides a sample of 1,000 yield observations conditional on information available at planting. To illustrate, a simulation was conducted for each of the three counties using the parameters estimated in Table 4.5. Histograms for each simulated distribution are given in Figure 4.8 and Table 4.6 lists the statistics for these distributions.

Table 4.6 Statistics of the Simulated Yield Distribution

County	Mean	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Adair	117.51	30.40	-1.203	4.072	.6749	156.9
Adams	117.38	32.84	-1.209	3.921	1.562	157.5
Case	124.22	31.00	-1.317	4.567	5.400	164.3

For 1994, each simulated yield distribution for the three counties has a mean yield of approximately 120bu/acre, a maximum possible yield of about 160bu/acre, is skewed to the left, is more kurtotic than the normal distribution, and has a possibility, though low, of a yield realization near zero. Note, again, the similarities in each of the simulated distributions despite the difference in the estimated values of the transformation parameters.

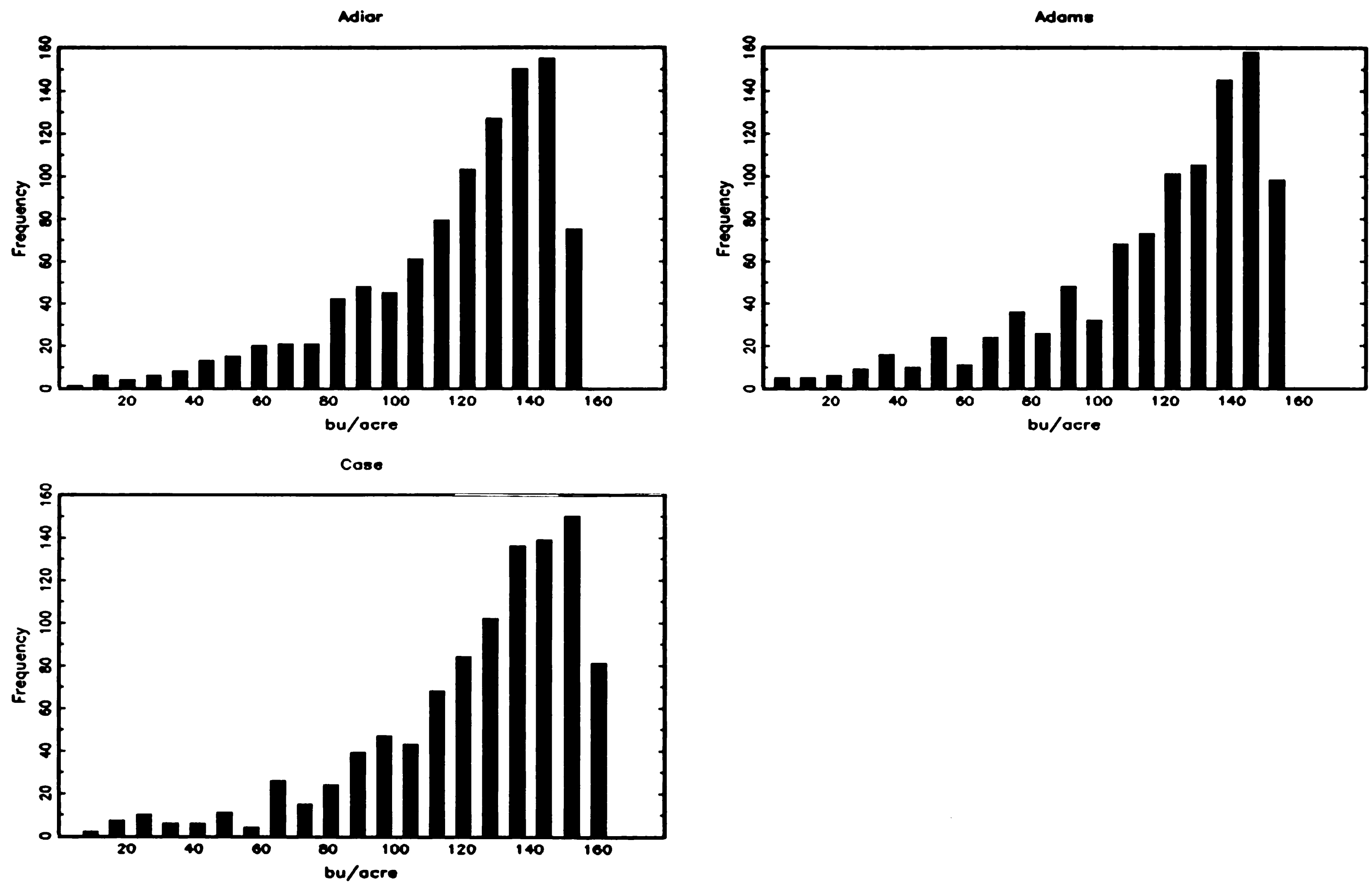

Figure 4.8 Simulated 1994 Corn Yield Distributions for Adair, Adams and Case County

Farm-level Yield Distributions

Because data on farm-level yields are generally available for only relatively short time horizons, for example, less then ten years, it is difficult to directly estimate a farm-level yield generating process using historical farm-level data. Although several years of farm-level yield data are generally not sufficient to estimate the higher moments of the distribution, such as skewness and kurtosis, they may provide useful information regarding the distribution's central tendency and variance. In order to proceed, it is assumed that the farm-level yields in each county have the same central tendency as the county-level yield and that the distributions are similar except for differences in the variances.[15] The reasoning is that farmers in a given county face similar technology, soil, and weather conditions, so that average yield levels will be similar across farms. However, even if farm-level yields are i.i.d., the county average yield distribution will have a smaller variance due to the averaging effect. Hence, the farm-level yield variation would be expected to differ from the county-level yield variation, and in general to be larger.

A linear mean-preserving spread technique is used to generate farm-level yield distributions from the county-level yield distributions.[16] The mean-preserving spread

---

[15] The constant central tendency assumption can be relaxed but the emphasis of this study will be on the dispersion of the distribution around the central tendency.

[16] Suppose X is a random variable with mean, μ, and variance σ^2, then, Y is called a mean-preserving spread from X when $Y = l+kX$, and l and k are chosen so that the mean of Y is also μ, and the variance of Y is $k^2\sigma^2$.

$E(Y) = E(l+kX) = l+kE(X) = l+k\mu$, $V(Y) = k^2V(X) = k^2\sigma^2$, so that $l = (1-k)\mu$.

If $0<k<1$, it is a mean preserving shrink; if $k>1$, it is a real mean-preserving spread; if $k = 1$, $Y = X$. The case $k<0$, or $k = 0$, is beyond our study.

technique provides the flexibility to alter the spread of the distribution, so that alternative yield distributions with different risk levels can be generated. First, we use historical farm-level data to estimate reasonable values for the variance of the representative farm yield, and then the mean-preserving spread is used to transform the simulated county yield distribution to the farm-level yield distribution.

The available farm-level yield data consist of ten years of APH data for Adair, Adams and Case county of Iowa from 1983 to 1992.[17] There are 218 farms in the counties: 113 in Adair, 66 in Adams, and 39 in Case. Each farm may have more than one plot of land. The yield and acreage are recorded each year for each of the plots in the data set. A whole farm average yield is obtained each year by calculating a weighted average of all yields for each farm, weighted by the relative acreage for each plot. Because the simulated county-level yield distribution is for 1994, we estimate the 1994 yield variance of each farm.

Because the APH are time series data and not homoskedastic, the yield for each year has a different variance, and so the sample variance cannot be used to forecast the yield variance. Therefore, a procedure has to be used to transform the time series data into 1994 farm-level yield data so that a variance which is compatible with the 1994 county yield can be calculated.

The farm-level APH data from 1983 to 1992 are detrended using the first equation in model (4.9), where the parameters a, b, and c for farms in a given county are those

---

[17] Thanks go to Jerry Skees in the Agricultural Economics Department at the University of Kentucky for supplying these data.

estimated for county yield in Table 4.5 and $t=1$ is corresponding to the year 1928, to obtain a set of residuals for each farm that are independent of time. The detrended residuals provide a small sample of the time-independent, nonzero-mean, and nonnormal random errors, $e = (e_{57}, e_{58},\ldots, e_{65})'$, which can be imposed on the time trend in 1994 to obtain a sample of farm-level yield realizations for 1994. The time trend for yield in any year depends on the yield of the previous year and, unfortunately, the 1993 farm-level yield is not available. The expected farm-level yield for 1993 to be predicted first as:

$$E(y_{t+1}) = a = by_t + c(t+1) + E(e). \tag{4.11}$$

A small sample of farm-level yield for 1994 can then be generated by iterating the equation forward again with the random error imposed as:

$$y_{t+2} = a + bE(y_{t+1}) + c(t+2) + e. \tag{4.12}$$

Noting that equation (4.12) is still in logarithms, the exponential transformation is taken to restore the log yield sample to yield levels. Then, the sample standard deviation of each farm's 1994 yield sample can be calculated and will be directly comparable with the standard deviation of simulated 1994 county-level yields. The distribution of the farm-level yield standard deviations for each county is graphed in Figure 4.9, and the maximum, average and minimum standard deviations are listed in Table 4.7.

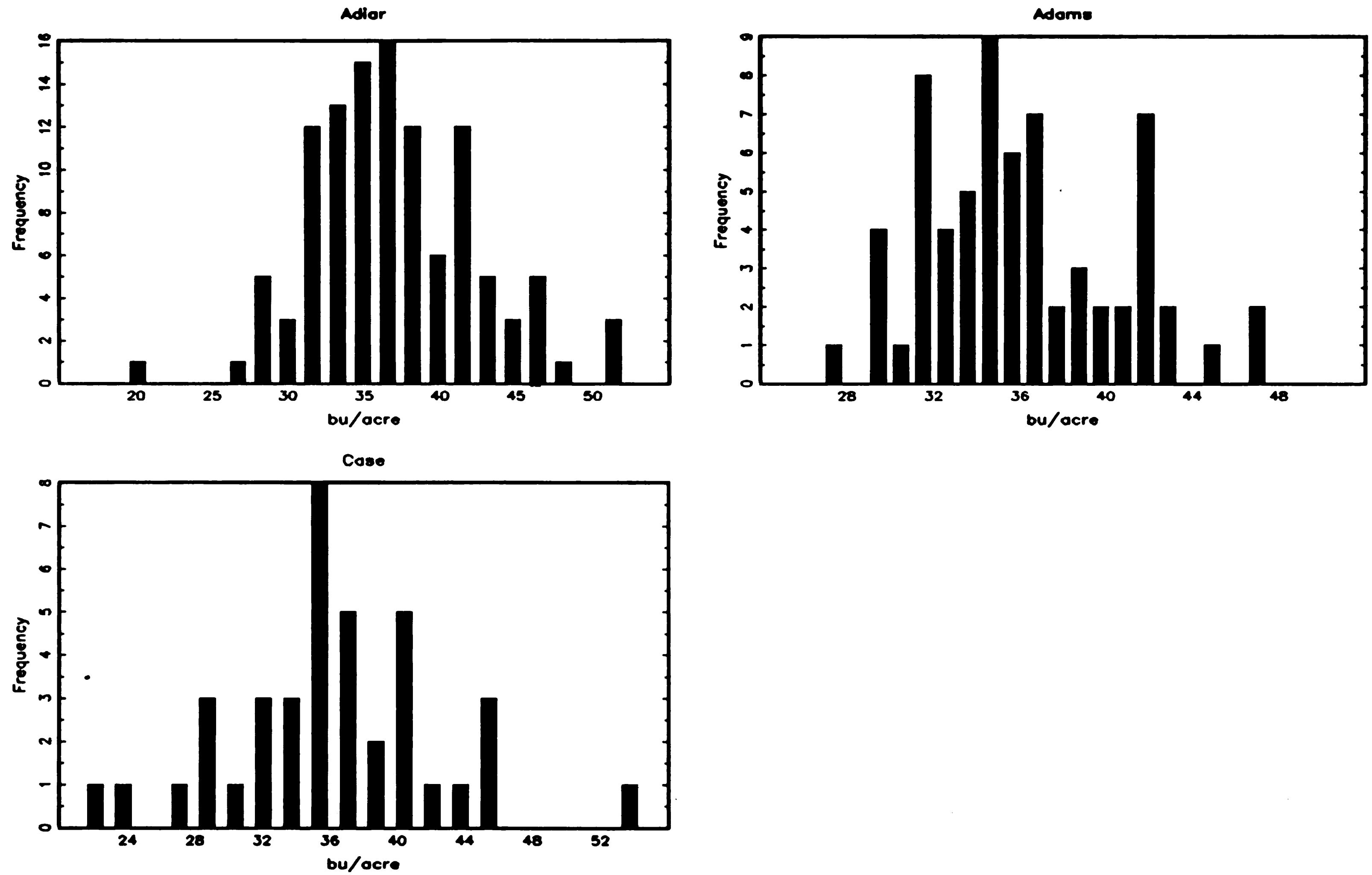

Figure 4.9 Histograms of Farm-level Yield Standard Deviation Distributions for Adair, Adams and Case County

Table 4.7 Maximum,Minimum and Average Standard Deviation of Farm Yield

County	Maximum	Average	Minimum	County Yield
Adair	52.18	37.02	19.30	30.40
	(1.72)	(1.22)	(0.63)	
Adams	47.51	35.96	26.89	32.84
	(1.45)	(1.10)	(0.82)	
Case	54.57	36.11	21.25	31.00
	(1.76)	(1.16)	(0.69)	

Note: The numbers in parentheses are the ratios of the individual yield standard deviations to the county yield standard deviations.

The standard deviations of the farm-level yields range from 63% to 176% of the county-level standard deviation with an average of 122%, 110% and 116% of the county-level standard deviation for Adair, Adams and Case county respectively.

Because all three county-level yield distributions are similar and Adair county has 113 farms (more than half of the farms in all the three counties), Adair is used as the representative county in southwest Iowa. Three representative farm-level yield distributions are then simulated, representing the yield distributions for low risk, medium risk and high risk farms. A linear "mean-preserving" spread on the logarithm of the county-level yield distribution is used to generate these distributions for two reasons: 1) the yield model has a deterministic central tendency on the logarithm of yield; and 2) the mean-preserving spread on yield levels may result in negative yields, an impossible case for crop yields. By performing the transformation on log yield, the models remain consistent and a negative yield will never occur because the exponential function restores all negative log yields to nonnegative yield levels.

The two parameters of the linear transformation are estimated by numerical methods because the linear transformation is taken on the log yields while the mean-preserving spread criteria are specified with respect to yield levels, so there is no apparent way to explicitly find analytical expressions for the two linear transformation parameters. Formally, the transformation parameters were estimated by solving (4.13):

$$\begin{aligned} \min_{l,k}\ OBJ &= [E(Y^C) - E(Y^I)]^2 + w[S_T - S(Y^I)]^2 \\ \text{where}\quad l &= y^I - k y^C \\ y^I &= \ln(Y^I) \\ y^C &= \ln(Y^C) \end{aligned} \tag{4.13}$$

where Y^C and Y^I are the county-level and farm-level yields respectively; y^C and y^I are the logarithm of the two yields; $S(.)$ is the standard deviation operator; S_T is the target standard deviation for the representative farms; and w is a weight parameter set at 10, to normalize the magnitudes of the mean and standard deviation.

The distribution of farm-level yield standard deviation in Figure 4.9 for Adair shows that the majority of the standard deviations fall into the category of 30 to 43 bu/acre, which corresponds to a range of about 100% to 140% of the county-level yield standard deviation, with a mean at about 120%. Actually, only 15% of the standard deviations fall outside this range. Therefore, 100%, 120%, and 140% of the county-level yield standard deviation are used as the target standard deviations in the mean preserving spread process to calculate the parameters for low risk, medium risk and high risk farm-level yield, respectively. Table 4.8 shows the mean preserving spread parameter estimates for the representative farms in each county.

Table 4.8 Transformation Parameters for Mean-preserving Spread Yield

Low Risk		Medium Risk		High Risk	
l	*k*	*l*	*k*	*l*	*k*
0.000	1.000	-0.1113	4.083	-0.2087	19.639

One thousand farm-level yields are simulated for each representative farm using the linear transformation on the logarithm of yields as in equation (4.14), where the transformation parameters *l* and *k* are taken from Table 4.8 for each type of farms:

$$y^{l} = l + ky^{c} \qquad \textbf{(4.14)}$$

The histogram of each simulated distribution is shown in Figure 4.10, and Table 4.9 lists statistics describing the simulated distributions.

Table 4.9 Statistics of the Simulated 1994 Farm-level Yield Distributions

Risk Ranking	Mean	Standard	Skewness Deviation	Kurtosis	Minimum	Maximum
Low	117.51	30.40	-1.203	4.072	0.674	156.9
Medium	117.51	36.48	-0.966	3.280	0.147	168.4
High	117.51	42.56	-0.759	2.744	0.027	181.2

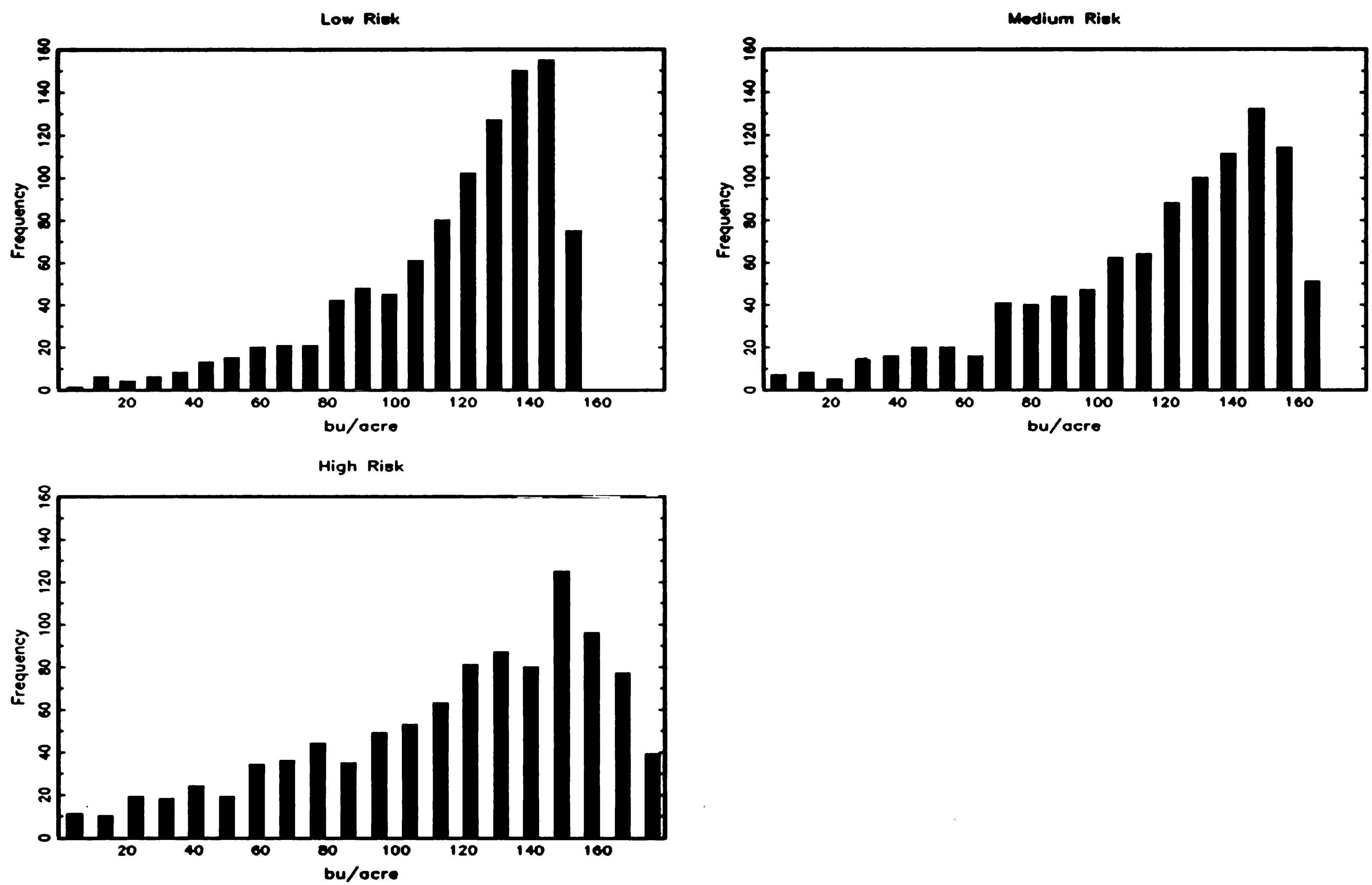

Figure 4.10 Histograms of Simulated 1994 Farm-level Yield Distributions for Low, Medium and High Risk Farms

Bivariate Farm-level and County-level Yield Distributions

Area yield crop insurance uses an average yield measure for an area as the index value from which to determine indemnity payments. In this study, county-level yields are used as the index for area yield crop insurance programs. Thus, the county-level yield distribution developed earlier provides the necessary distribution to calculate farm income for area yield crop insurance participants. However, farm-level and county-level yields are not independent because they are affected by similar factors such as weather. Accordingly, county- and farm-level yields must be generated simultaneously by a joint process which imposes the appropriate level of correlation between the yields. This correlation may impact risk management decisions so it is important to take it into account.

Correlation Between the Farm- and County-level Yields

The correlation between area yield and farm-level yield is very important to farmers participating in an area yield crop insurance program. Miranda finds that the higher the correlation, the more protection a farmer receives from the program. The univariate distributions of 1994 farm-level and county-level yield have already been simulated. It is now necessary to generate the joint distribution between farm- and county-level yields by imposing a correlation between the two yield distributions.

The sample correlation between farm-level yield, Y^f, and county-level yield, Y^C, is defined as:

$$\rho_{IC} = corr(Y^I, Y^C) = \frac{Cov(Y^I, Y^C)}{\sqrt{(Var(Y^I)\, Var(Y^C)}}. \qquad \textbf{(4.15)}$$

Historical data can be used to estimate the correlation. However, as discussed earlier, it is important to detrend the mean and variance, and account for any autocorrelation in the data, in order to obtain an unbiased estimate of the correlation. Using a procedure similar to the one used to estimate the standard deviation of farm-level yields, we can detrend the both farm-level and county-level yields using the log-linear model (4.9). Remember, $e=(e_{57}, e_{58},\ldots, e_{65})'$ are the residuals from farm-level log yield process which are homoskedastic and trend free. By taking the exponential, we have farm-level "residuals" in yield levels, $D_t = exp(e_t)$, for $t = 57,\ldots,65$, that are trend free, uncorrelated, homoskedastic and consistent with yield levels. Using the same procedure on the county-level yields, we can obtain county-level "residuals", D^C_t, for the same period. Now we can use D_t, D^C_t, and equation (4.15) to obtain sample correlations.

The statistics and a histogram of the sample distribution of the correlations are shown in Table 4.10 and Figure 4.11 respectively.

Table 4.10 Statistics of the Estimated Yield Correlations

Mean	Standard Deviation	Maximum	Minimum
0.8549	0.0575	0.9603	0.6489

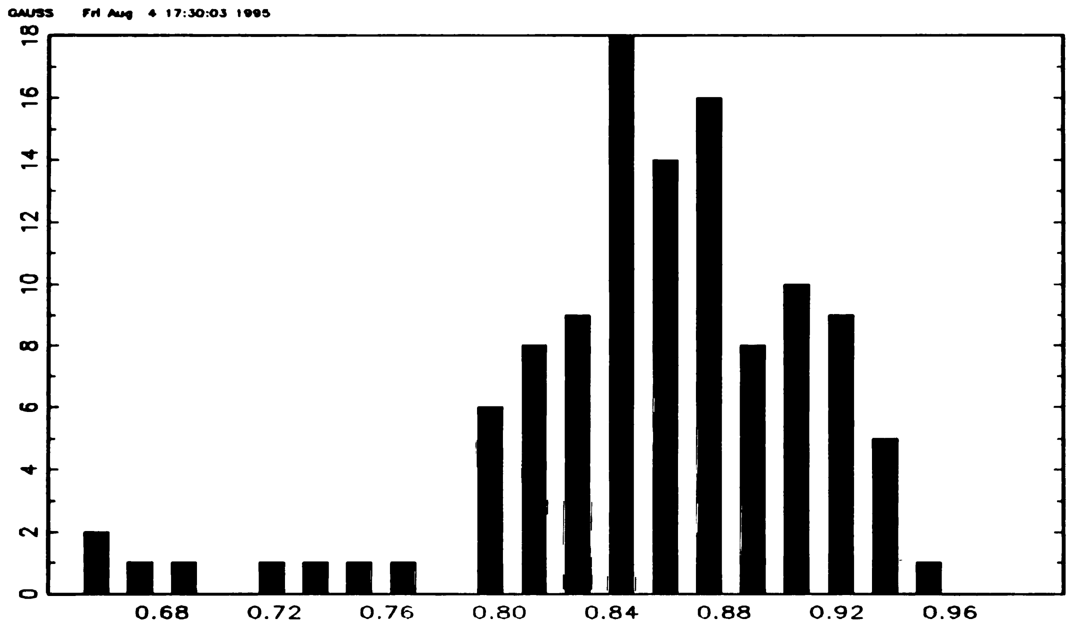

Figure 4.11 Histogram of Farm- and County-level Yield Correlations in Adair County

The sample correlation between the farm-level yields and the county-level yields from 1983 to 1992 ranges from 0.65 to 0.96 for the 113 farms in Adair with an average of about 0.85. These estimates reflect the fact that farms in the same area are affected by the similar conditions, such as weather, so that their yields tend to exhibit strong positive correlations.

In order to study the optimal use of area yield crop insurance by farms, it will be useful to study the farms whose yield distributions exhibit different kinds of correlations with the county-level yield, which is used as the yield index in the area yield crop insurance. In this study, we will consider correlation levels of 0.65, 0.85 and 0.95 to represent low, medium, and high correlation levels, respectively.

Imposing Correlation Between Farm and County Yields

Although a multivariate nonnormal random variable generator is not commonly available in most computer programming languages, most do include an independent or multivariate standard normal random number generator. In any event, correlated normal variables can be easily obtained by algebraic transformation of the uncorrelated standard normal variables, and appendix B has outlined this transformation process. Taylor (1990) developed a method to generate multivariate nonnormal random variables by transforming correlated normal random variables. This can be used to impose correlation between the simulated univariate distributions for the farm-level and county-level yields.

Using Taylor's method, the following steps will convert the simulated farm-level and county-level yield distributions into a joint distribution with a correlation of ρ_{IC}:

1. Generate the empirical cumulated density functions $F(Y^I)$ and $G(Y^C)$ for farm-level and county-level yields respectively, using the 1,000 yields observations simulated from the univariate yield processes.
2. Generate 1,000 jointly distributed bivariate standard normal variates (X^1_i, X^2_i), $i=1,\ldots,1000$ from iid normal variates, with correlation ρ_{IC} using the linear transformation method in equation (B.7) in appendix B, where ρ_{IC} is the estimated correlation between farm-level and county-level yield.
3. Empirically generate the marginal distributions for each of the correlated standard normal variables $fN(X^1)$ and $gN(X^2)$. Empirically generate the two cumulated density functions, $FN(X^1)$ and $GN(X^2)$, corresponding to the standard normal marginal distributions.

4. For each of the normal variates obtained from step 2, (X^1_i, X^2_i), find their cumulated function values $FN(X^1_i)$ and $GN(X^2_i)$. Then, find the closest cumulated function values from the empirical distributions for farm- and county-level yields so that $F(Y^I_i) = FN(X^1_i)$, and $G(Y^C_i) = GN(X^2_i)$. Then, locate the farm- and county-level yields corresponding to these function values, (Y^I_i, Y^C_i). The pair (Y^I_i, Y^C_i) provide one sample observation of jointly distributed farm- and county-level yields which will have a correlation level of ρ_{IC}.

An example using the Taylor transformation to project (X^1_0, X^2_0) on (Y^I_0, Y^C_0) is illustrated in Figure 4.12.

4.3 Multivariate Price and Yield Distribution

Because the spot market is competitive, the cash price acts to clear the market by equating demand and supply. Given the generally inelastic demand for crop commodities, cash prices tend to exhibit negative correlation with aggregate production. Because of the generally fixed nature of land available for production, acreage doesn't change dramatically from year to year, so that the total production is determined mainly by the yield levels of land in production. The level of correlation between prices and yields can have significant impacts on the risk position of a farm and, consequently, on the demand for different types of risk management instruments. As a result, it is important to consider the joint process that generates prices and yields.

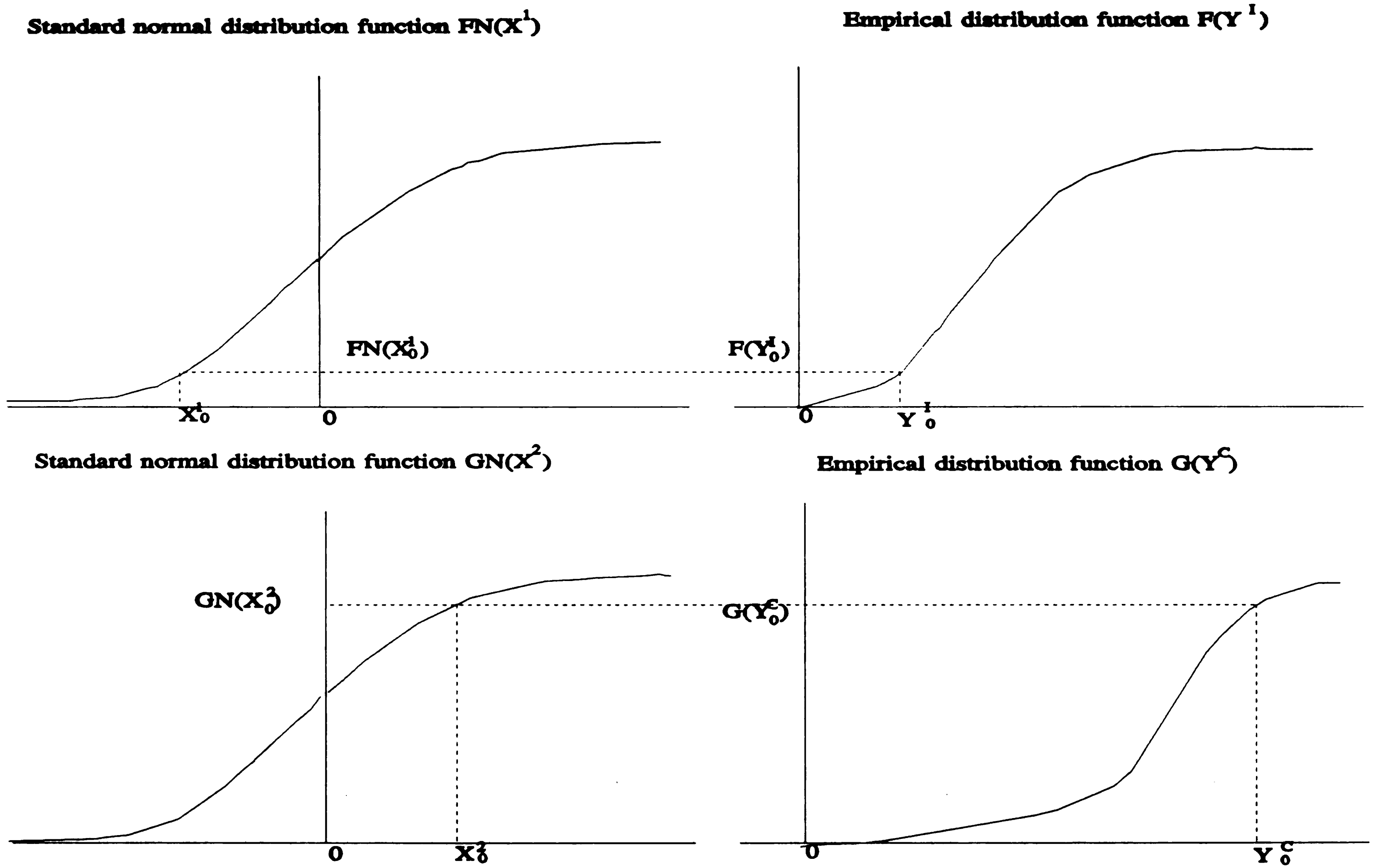

Figure 4.12 Illustration of the Taylor Transformation

The previous sections have developed empirical bivariate distributions for both cash and futures prices and farm- and county-level yields. This section concludes the chapter by using Taylor's method again to impose correlation between prices and yields and generate empirically a multivariate distribution of cash price, futures price, farm-level yield and county-level yield.

Correlation Between Cash Price and Area Yield

The first step is to obtain an estimate of the correlation between the cash price at maturity and county-level yield conditional on information available at planting. Because we are interested in the conditional correlation based on information at planting, the ideal procedure would be to find the correlation between the residuals of forward price and yields that are trend free. Unfortunately, a historical forward contract price series was not available, and so historical futures prices, which are highly correlated with forward contract prices, are used as an approximation. The county-level yield residuals were obtained using the same procedure as was used to estimate the correlation between county- and farm-level yields: detrending the log yields, and taking the exponential. The price changes between harvest and planting are used as price residuals.

The weekly futures price data from April 1975 to December 1995 and the Adair county yield data from 1974 to 1993 are used to estimate the price-yield correlation. Matching price and yield, we have 19 samples from 1975 to 1993. The sample correlation for Adair County are calculated as -0.50. The estimated negative correlation between price and yield is consistent with the market demand/supply mechanism. That is when yield is high, the increased grain supply tends to reduce the price; and when yield is low, the market demand bids the price up due to the lack of supply.

Imposing Correlation Between Price and Yield

Once again, Taylor's method is used to impose the correlation between the independently simulated bivariate price and yield distributions. To impose a fixed correlation between cash price and county yield, the same steps are followed as when imposing the correlation between farm- and county-level yields, except the variables (Y^I, Y^C) are replaced by (p, Y^C) and the correlation ρ_{IC} is replaced by ρ_{pY}, which is set at -0.5. Because futures and cash price are jointly simulated through the bivariate ARCH model, they are kept pairwise during this procedure to guarantee the correlation between them is not affected. Likewise, farm- and county-level yields are kept pairwise to maintain their imposed correlation level. After repeating those steps, a set of 1,000 jointly determined realizations, $\{f, p, Y^I, Y^C\}$, are obtained.

There are three sets of farm-level yields representing the low risk, medium risk and high risk farms, and three levels of correlations between county-level yield and farm-level yield, so that the process is repeated nine times. Because of simulation error, the simulated correlations among the variables of the joint distribution are sightly different than the designated values. The correlation matrices of the four variables are listed separately for each distribution in Table 4.11. The marginal distributions are not affected by Taylor's transformation, so that the moments of the marginal price and yield distributions remain unchanged.

Table 4.11 Correlation Matrices of Simulated Prices and Yields

	Low Yield Correlation				Medium Yield Correlation				High Yield Correlation			
	f	p	Y^I	Y^C	f	p	Y^I	Y^C	f	p	Y^I	Y^C
Low Risk												
f	1.00	.843	-.212	-.370	1.00	.843	-.313	-.370	1.00	.843	-.340	-.370
p		1.00	-.277	-.459		1.00	-.378	-.459		1.00	-.434	-.459
Y^I			1.00	.623			1.00	.830			1.00	.941
Y^C				1.00				1.00				1.00
Medium Risk												
f	1.00	.843	-.215	-.370	1.00	.843	-.310	-.370	1.00	.843	-.338	-.370
p		1.00	-.281	-.459		1.00	-.378	-.459		1.00	-.436	-.459
Y^I			1.00	.628			1.00	.831			1.00	.941
Y^C				1.00				1.00				1.00
High Risk												
f	1.00	.843	-.218	-.370	1.00	.843	-.307	-.370	1.00	.843	-.337	-.370
p		1.00	-.284	-.459		1.00	-.378	-.459		1.00	-.436	-.459
Y^I			1.00	.628			1.00	.830			1.00	.937
Y^C				1.00				1.00				1.00

The realized correlation is 0.843 between futures and cash prices, and 0.459 between cash price and county-level yield for all the distributions. The realized correlations between farm-level yield and county-level yield, are about 0.63 for low correlation, 0.83 for medium correlation, and 0.94 for the high correlation.

Because cash price is correlated with county-level yield and county-level yield is correlated with farm-level yield, the correlation between cash price and farm-level yield is implicitly determined by the joint distribution, and depends on the two directly imposed correlations. The same reasoning holds for the correlations between futures price and farm-level yield. When the correlation between county- and farm-level yields is low (0.63), the correlation between cash price and farm-level yield is at about -0.28, and the correlation between futures price and farm-level yield is at about -0.22. When the correlation between county-level and farm-level yields is medium (0.83), the correlations with farm-level yield are -0.38 and -0.31 for cash and futures, respectively. When the correlation between county-level and farm-level yields is high (0.94), the farm-level yield correlations with cash and futures are -0.44, and -0.34 respectively. The correlation between futures price and county-level yield is also implicitly determined by the joint distribution. It depends on the correlation between futures and cash prices and the correlation between cash price and county-level yield, and is at -0.37 for all the distributions.

Chapter V

OPTIMAL RISK MANAGEMENT CHOICES UNDER ALTERNATIVE PORTFOLIOS OF RISK INSTRUMENTS

In this chapter, we study the optimal use of different risk management instruments in an expected utility framework using numerical methods and the multivariate price and yield distributions simulated in the previous chapter. Risk instruments available in the farmer's portfolio include futures contracts, options contracts, crop insurance, and a government deficiency payment program. The objectives are to study the demand for the various risk management instruments by risk averse farmers and to estimate their welfare effects. Additional insights into the impact of various factors on the demand for the alternative risk instruments will be provided in the comparative static analysis of the next chapter.

The demand for a particular risk management instrument may typically change when another instrument is added or dropped from the portfolio. In some cases the instruments may partial substitutes and, in other cases, they may be complements. When instruments are substitutes, they tend to play the same role in reducing the impact of a given type of risk, so adding a substitute instrument will tend to reduce the demand and/or value of the existing instrument in the portfolio. For example, put options and the government deficiency payment program may be substitutes because the mechanics of the two instruments are similar and both act to reduce the same type of price risk. Complementary instruments work together to manage a particular type of risk more efficiently than when used in isolation. Thus, adding a complementary instrument will tend to increase the demand and/or value of the existing instrument(s). For example, price instruments such as futures contracts, and yield instruments, such as crop insurance, may be complements if they can combine to reduce income risk more efficiently than if either was used in isolation. These substitution and complement effects are explored in detail in this chapter.

The two forms of crop insurance, individual yield crop insurance (IYCI) and area yield crop insurance (AYCI), are also compared in this chapter, each of which is studied in alternative portfolios.

For convenience, the expected utility model introduced in Chapter III is presented here again:

$$
\begin{aligned}
&\underset{x,z,\xi,\eta}{MAX}\ \ EU[\tilde{\pi}] \\
&st\ \tilde{\pi} = \tilde{CR} + \tilde{FI} + \tilde{OI} + \tilde{GS} + \tilde{CI} - F \\
&\tilde{CR} = \tilde{p}\tilde{Y}^{I} \\
&\tilde{FI} = x(\tilde{f}-f_0) \\
&\tilde{OI} = z[\max(0,s-\tilde{f})-h] \\
&\tilde{GS} = \xi[\max(0,p_T-\tilde{p})Y_b(1-q-r)-r(\tilde{CR}+\tilde{CI})] \\
&\tilde{CI} = \tilde{IP} - \lambda E(\tilde{IP}) \\
&\tilde{IP} = \zeta p_I \max[0,\eta E(\tilde{Y})-\tilde{Y}],
\end{aligned}
\tag{5.1}
$$

where $\tilde{p}$ is the cash prices at harvest; $\tilde{Y}^{I}$ is the farm-level yield per acre; $\tilde{f}$ is the futures price at harvest; f_0 is the futures price at planting; x is the futures position; z is the option position; h is the option premium; s is the option strike price; ξ is a binary indicator for participation in the government deficiency payment program; Y_b is base yield; r is the percentage of acreage reduction program (ARP); q is the percentage of flexible acres; p_T is target price; ζ is the insured acreage; λ is the crop insurance premium proportion relative to the actuarially fair level; p_I is the price index used to calculate the crop insurance indemnity payment; η is the trigger level of crop insurance; and $\tilde{y}$ is the yield index used to determine crop insurance payouts. $\tilde{y}$ is specified as $\tilde{y}^I$, the farm-level yield for IYCI and $\tilde{y}^C$, the county-level yield, for AYCI.

Initially, the maximization problem in (5.1) is solved for a set of parameters representative of those faced by southwest Iowa corn growers in 1994 as listed in Table 5.1. After analyzing this base solution in detail in the remainder of this chapter, a comparative static analysis is conducted in next chapter to study cases where some of the model parameters deviate from their base values, e.g., the relative risk aversion increases or decreases.

The base model is characterized by a futures market that is perceived unbiased, which implies that the futures price at planting is also the mean of the stochastic futures price at harvest. This ensures hedging with futures is done to manage risk with no speculative profit motive in the base solution. Likewise, the options market is also perceived unbiased in that the premium equals the expected value of the option.[18]

[18] We have not explicitly accounted for the difference in the timing of the cash flow to pay the option and the crop insurance premiums at planting and the other cash flows which occur at harvest. Using standard option pricing arbitrage arguments, the implicit assumption in the model is that all cash flows are discounted at the risk-free interest rate.

Table 5.1 Model Parameters for the Base Solution

Parameter	Notation	Value
Futures price at planting	f_0	\$2.56/bu
Option strike price	s	\$2.60/bu
Option premium	h	$E[\max(0, s-\tilde{f})]$
Target price	p_T	\$2.75/bu
Acreage reduction program	r	0
Flexible acreage	q	15%
Base yield	Y_b	$E(\tilde{Y}^I)$
Insured acreage	ζ	1.00
IYCI premium rate	λ	1.35
AYCI premium rate	λ	1.00
Crop insurance indemnification price	p_I	$E(\tilde{p})$
Ratio of farm-level yield standard deviation to county-level yield standard deviation	R	1.20
Correlation between farm and county yield	ρ_{IC}	0.83
Correlation between cash price and county yield	ρ_{pY}	-0.46
Relative risk aversion	RR	2

The strike price for the option contract in the model is set at the level closest to the current futures price. The government deficiency payment program is specified according to the *1994 USDA Wheat and Feed Grain Programs*, setting target price at \$2.75/bu, requiring no set-aside acreage, and imposing flexible acreage of 15%. The expected farm-level yield is used as the predetermined yield base.

The insured acreage is set at 100% of the base acreage. The IYCI premium is set at a level 35% above the actuarially fair premium to reflect transaction costs and the impacts of moral hazard and adverse selection of farmers being modeled, and the AYCI premium is set at the actuarially fair premium. The farmer can select the indemnification trigger yield up to 75% of his expected yield for IYCI and 90% for AYCI. It is assumed that both IYCI and AYCI pay the indemnification at a price equal to the expected cash price at harvest.

The joint price and yield distributions were developed in Chapter IV. The farm-level yield distribution for the base solution is set at the medium risk farm whose yield standard deviation is 120% of the county yield standard deviation, and is positively correlated with area yield at a medium correlation level, 0.83. The county-level yield is negatively correlated with cash price at a correlation level of -0.46 in the base solution. The utility function used in the base model is a constant relative risk aversion function with the relative risk aversion parameter set at 2.

The remainder of the chapter is divided into four sections. The first section analyzes equation (5.1) when only price instruments are used to manage income risk. The second section studies equation (5.1) when both price instruments and IYCI are used to manage risk. The third section explores equation (5.1) when price instruments and AYCI are used to manage risk. In each case, the optimal levels of participation in the risk instruments, the first four moments of the income distribution, and willingness-to-pay for alternative instruments are examined. Histograms of the income distribution are also provided for some cases, in order to illustrate the effects of various instruments on the income distribution. The fourth and final section summarizes the results and gives conclusions.

5.1 Price Instruments

Six portfolios are studied in this section, which are: 1) no risk management; 2) futures only; 3) futures and options; 4) government program only; 5) futures, and government program; and 6) futures, options, and government program. The optimal participation levels; resulting mean, standard deviation, skewness and kurtosis of income; and willingness-to-pay for the various instruments are listed in Table 5.2 for all six portfolios. Each portfolio is discussed in turn.

No Risk Management Instrument

When no risk management instruments are used, income risk comes from the joint effect of yield and cash price risk. Model (5.1) is restricted by setting futures, options, government program and crop insurance positions to be zero ($x=z=\xi=\eta=0$). The histogram of the resulting income distribution is shown in Figure 5.1(a). The distribution

Table 5.2 Optimal Positions, Income Distribution, and WTP without Crop Insurance

	Portfolio					
	No Risk Instr.	Futures	Futures and Options	Govt.	Futures, and Govt.	Futures, Options, and Govt.
Futures	0	0.219	0.276	0	0.649	0.472
Options	0	0	0.131	0	0	-0.497
Govt.	0	0	0	1	1	1
$E(\pi)$	286.43	286.43	286.43	319.11	319.11	319.11
$Stdv(\pi)$	89.20	90.54	90.25	90.29	89.90	90.93
$Skew(\pi)$	-0.617	-0.437	-0.432	-1.024	-0.532	-0.509
$Kurt(\pi)$	3.324	3.169	3.201	3.696	3.379	3.199
Willingness-to-pay	0	5.87	5.95	0.35	32.11	32.53

Note: The participation levels for futures and options are reported as the percent of the expected yield; the income mean and standard deviation and willingness-to-pay levels are reported in $.

has a mean of $286.43 per acre, a standard deviation of $89.20 per acre, and is skewed to the left.

The coefficient of variation, defined as the ratio of standard deviation to mean, measures the relative standard deviation of a stochastic variable and is sometimes used as a measure of the standardized risk of the stochastic event. The coefficient of variation is 0.311 for income when no risk management instruments are used, and the cash price and farm-level yield coefficients of variation are 0.155 and 0.310 respectively. The relative standard deviation of income is similar to that of yield because the negative

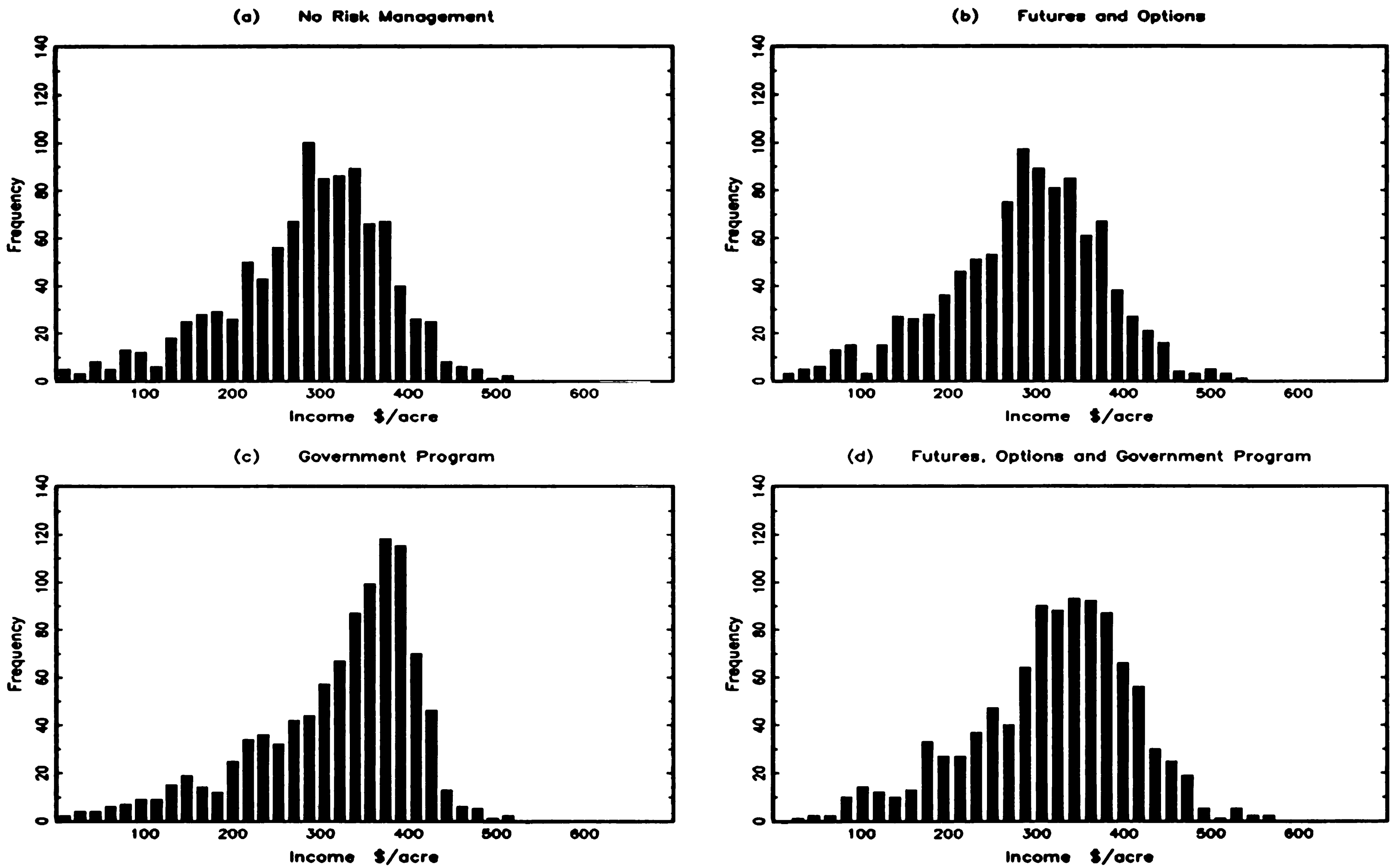

Figure 5.1 Histograms of the Income Distribution without Crop Insurance

correlation between price and yield provides an implicit form of risk protection so that income, the product of price and yield, is not more volatile. Also, the large coefficient of variation for yield relative to price suggests yield is relatively more volatile, and it contributes more to the income variability than does price.

Futures Only

In this case, futures contracts are included as the only risk management instrument in the portfolio. Equation (5.1) is restricted by setting options, government program, and crop insurance positions to be zero ($z=\xi=\eta=0$). A negative (positive) x value means the farmer sells (purchases) futures at planting and buys (sells) the equivalent amount back at harvest, i.e., the farmer takes a short (long) position in the futures market which is offset at harvest.

The optimal futures position in the base case is to go long 22% of the expected yield. This behavior, at first, appears in conflict with traditional notion of hedging in which the position in the futures market is opposite to the cash market position. The traditional notion of hedging is that by taking a short position in the futures market, price changes in the cash market (the producer's long position) tend to be offset by price changes in the futures market. Indeed, most hedging studies have found the optimal position in the futures market is to go short futures.

The optimal long position in the futures market found here is a result of the strong negative correlation between cash price and farm-level yield, combined with the relatively large yield variability. The benefit of offsetting yield variability through the negatively correlated price variability tends to outweigh the benefit of reducing price variability by taking a short position in the futures market. Put another way, taking a long position in the futures market allows the farmer to "cross hedge" a portion of the yield risk using futures.

The mean of income stays the same as when no risk management instruments are available because the futures market is assumed to be unbiased. However, the standard deviation of income increases slightly as a result of futures, though skewness and kurtosis both decrease. It is apparent that the long position in futures helps reduce the negative skewness of the income distribution, making it more symmetric, because of the cross hedging effect between the futures contract and negatively correlated yield. A histogram of the income distribution with futures is shown in Figure 5.1(b).

Although a risk averse decision maker (DM) usually prefers the stochastic return with a small variance to a large one when the mean is the same, higher moments also affect the DM's preference. Tsiang (1972) found that a risk-averse individual would have a preference for positive skewness and an aversion for variance of the distribution. However, a DM often has to evaluate the trade off between skewness and variance. In this case, the DM prefers the income distribution with the smaller negative skewness but slightly larger variance, which gives the farmer a higher expected utility level.

Willingness-to-pay for the opportunity to trade futures is $5.87 per acre. Because the futures market is unbiased, the $5.87 is the amount the farmer is willing to pay for the reduction in the negative skewness and kurtosis of the income distribution that futures provide.

Futures and Options

If both futures and options are allowed in the portfolio, equation (5.1) is restricted by setting the government program and crop insurance positions to zero ($\xi = \eta = 0$). We only allow put options and define z such that a positive (negative) value means the farmer buys (writes) the put option.[19]

The optimal futures and options positions are to go long futures 28% of the expected yield and buy put options equivalent to 13% of expected yield. The put options position reduces some of the price variability, exposing the farmer to additional yield variability because of the negative price-yield correlation. As a result, the long position in the futures market increases slightly to cross hedge the increased yield risk exposure. This result is consistent with the analysis of Sakong, Hayes and Hallam (1993), who find that with yield risk and no crop insurance it is almost always optimal for the producer to purchase put options and to underhedge on the futures market under CARA. They also claimed these results are strengthened further if price and yield are negatively correlated and if the farmer has DARA preference.

The mean of income remains as in the previous two cases because both futures and options are unbiased. The other three moments of the income distribution are similar to the case of futures only. This is not surprising given the relatively small position in the options market and the small change in the optimal futures position.

[19] Synthetic call options can be constructed from combinations of futures and puts, so call options are included implicitly in the analysis.

The farmer's willingness-to-pay is increased slightly to $5.95 over the case where only futures are available. The marginal value to the farmer of adding the put options into the portfolio is only $0.08 per acre, indicating options have little value in this setting.

Government Deficiency Payment Program Only

In this case, the farmer is assumed to participate in the government deficiency payment program, but does not use any other risk management instruments in the portfolio. Equation (5.1) is restricted by setting futures, options and crop insurance positions to be zero, and the government program position to one ($\xi=1$, $x=z=\eta=0$).

The government program is similar to a put option but provided at no cost with zero ARP. Because willingness-to-pay for the government program is positive, the farmer chooses to participate and $\xi = 1$ is the optimal position.

The mean of income when participating in the program increases by about $33 per acre over the no risk instrument case, which is the amount of the expected subsidy implicit in the program in this setting. However, participation also causes the standard deviation of income to increase, and the distribution of income to skew more to the left relative to the no risk management case. This is because the elimination of the downside price variability resulting from participation in the government program reduces the implicit income risk protection provided by the negative correlation between cash price and yield, and therefore the farmer is exposed to more yield variability. The resulting income distribution is illustrated in Figure 5.1(c).

Despite the high level of expected subsidy, the willingness-to-pay measure is only \$0.35 per acre. The cost to the farmer to bear the additional income risk (higher standard deviation and larger leftward skewness) that results from participation is high enough to offset much of the benefit from the higher mean income resulting from the implicit subsidy.

Futures and Government Program

In this case, the farmer participates in the government deficiency payment program and the futures market, but does not use any other risk management instruments in the portfolio. Equation (5.1) is restricted by setting the options and crop insurance positions equal to zero, and the government program position equal to one ($\xi=1$, $z=\eta=0$). Again, expected utility increases from participation in the program, so that the government program is in the farmer's optimal portfolio.

The farmer's optimal futures position is long 65% of expected yield. As in the case when put options were included in the portfolio, the government program eliminates downside price variability so as to reduce the implicit income risk reduction from the negative price-yield correlation. A larger long futures position is then taken to help cross hedge the increased yield risk exposure.

As expected, mean income with futures and the government program is the same as the government program only case, \$33 above the no risk management instrument case. However, the standard deviation, negative skewness and kurtosis are reduced below the levels in the government program only case because the futures position helps to cross hedge the increased yield risk exposure that results from participation in the government program. Nevertheless, the skewness and kurtosis are increased from the futures only case because, again, participating in the government program increases the farmer's yield risk exposure.

The willingness-to-pay increases significantly to $32 per acre, close to the level of the expected subsidy built into the government program. The ability to cross hedge the additional yield risk exposure resulting from participation in the government program by taking a larger long position in the futures market allows the farmer to capture most of the expected subsidy value without bearing the additional risk exposure.

Futures, Options and Government Program

In this case, futures, options and the government program are all allowed in the farmer's portfolio. Equation (5.1) is restricted by specifying participation in government program and zero crop insurance ($\xi=1$, $\eta=0$). Once again, it is optimal for the farmer to participate in the government program, so setting $\xi=1$ is not restrictive.

The farmer again takes a long position in futures, in this case equal to 47% of expected yield. Unlike in earlier cases, the presence of the government program causes the farmer to write put options equal to 50% of expected yield. The reason for this is that the government deficiency payment program eliminates much of the downside price variability faced by the farmer, and the long position in the futures market and the writing of put options combine to help cross hedge the additional yield risk exposure which results from participation in the government program. This result is also consistent with the result from Sakong, Hayes and Hallam (1993), who find that when a government program is used, farmer tend to write put options.

As before, the expected income level is not changed by adding options into the portfolio because the options are fairly priced. However, the standard deviation of income increases relative to the case without options in the portfolio, but the skewness and kurtosis levels decrease slightly. The income distribution histogram is graphed in Figure 5.1(d).

The value of adding options to the portfolio that contains the government program and futures is small, increasing willingness-to-pay only $0.42 per acre above the case with no options in the portfolio. So, despite the significant size of the options position, the gain to the farmer of adding options to the portfolio is again relatively small.

Summary

In the base case where price and yield are negatively correlated and yield variability is relatively higher than price variability, price instruments are used to cross hedge yield risk rather than to hedge price risk. This may lead to market positions which appear contrary to conventional wisdom, in which they actually accomplish more in the reduction of yield risk than they do in the reduction of price risk. In addition, low willingness-to-pay measures suggest that price instruments do not work very effectively to manage income risk in the absence of crop insurance.

In the base case, the government deficiency payment program provides an implicit subsidy but does not reduce income risk, because the reduction in downside price risk resulting from participating in the program reduces the implicit income risk protection of the negatively correlated price and yield. In fact, the program actually increases the farmer's income risk exposure to the point that the costs of bearing the additional risk are almost as great as the benefit of the expected subsidy provided by the program (willingness-to-pay for the government program is very low despite the high value of the implicit subsidy).

The use of futures contracts allows the farmer to capture most of the benefits of the implicit subsidy by cross hedging the additional risk exposure resulting from participation in the program. In the base case, when crop insurance is not allowed in the portfolio, futures contracts and the government program act as compliments to each other.

In the presence of the futures market, options contracts seem to have little additional value to the farmer as indicated by the small increase in willingness-to-pay when options are included in the portfolio. When the government program is also included in the portfolio, a significant number of options are written by the farmer to offset the extra risk exposure caused by the government program. However, the marginal welfare gain to the farmer from including options in the portfolio with futures and the government program is still relatively small.

In several cases, the standard deviation of income actually increases under optimal use of risk management instruments while the mean is kept unchanged. In these cases, welfare gains are attained through changes in higher moments of the income distribution, mainly from reducing leftward skewness. This suggests that a mean-variance modeling approach would provide quite different results to the expected utility maximization approach used here.

The above discussion suggests the combined effect of price risk and yield risk on income have important implications for the farmer's optimal use of price risk management instruments. In the next section, we allow the use of a yield risk management instrument in the portfolio and examine implications for all risk management instruments when both price and yield risk can be directly managed.

5.2 Price Instruments With Individual Yield Crop Insurance

In this section, the risk management role of individual yield crop insurance (IYCI) is studied. The effectiveness of crop insurance in the presence of price instruments is compared with the cases in last section which only included price instruments in the portfolio. Six portfolios are explored in this section: 1) IYCI only; 2) futures and IYCI; 3) futures, options and IYCI; 4) government program and IYCI; 5) futures, government program and IYCI; and 6) futures, options, government program and IYCI. The optimal market participation levels, the first four moments of the income distribution, and willingness-to-pay for the optimal portfolios are each listed in Table 5.3. The major results from each portfolio are discussed in the following subsections.

IYCI Only

In this case, only IYCI is included in the portfolio. Equation (5.1) is restricted by setting the futures, options and government program positions to be zero ($x=z=\xi=0$).

The farmer chooses the trigger yield level to be the maximum of 75% of expected yield, despite the fact that the premium charged is 35% above the actuarially fair level. Participation in IYCI partly eliminates the downside yield variability, which increases price risk exposure due to the negative correlation between price and yield. However, because the variance of price is relatively lower than yield, partly eliminating downside yield variability reduces the income standard deviation.

Mean income is $5.28 per acre less than with no risk management instruments. This represents the cost of the premium being set 35% above the expected indemnity payment. The standard deviation of income is decreased significantly and the income distribution becomes skewed to the right. The histogram of the income distribution is shown in Figure 5.2(a). Comparing this histogram to Figure 5.1, it is obvious that the income distribution is more compressed when using the crop insurance than under any alternative portfolio in the absence of crop insurance.

The farmer's willingness-to-pay for the IYCI is $25.66 per acre, which is much higher than the value of futures, options, or even the government program when they are used in isolation, despite the fact the farmer has to pay an actuarially unfair premium. This again suggests that IYCI is an effective risk management instrument in the base model where yield variability contributes more to income risk than price variability.

Table 5.3 Optimal Positions, Income Distribution, and WTP with IYCI

	Portfolio						
	No Risk Instr.	IYCI	Futures, and IYCI	Futures, Options, and IYCI	Govt. and IYCI	Futures, Govt. and IYCI	Futures, Options, Govt. and IYCI
Futures	0	0	-0.265	-0.023	0	0.214	0.208
Options	0	0	0	0.507	0	0	-0.012
IYCI	0	0.750	0.750	0.750	0.750	0.750	0.750
Govt.	0	0	0	0	1	1	1
$E(\pi)$	286.43	281.15	281.15	281.15	313.83	313.83	313.83
$Stdv(\pi)$	89.20	65.12	63.00	62.66	62.61	62.51	62.50
$Skew(\pi)$	-0.617	0.324	0.195	0.228	-0.077	0.086	0.085
$Kurt(\pi)$	3.324	2.578	2.257	2.342	1.985	2.247	2.242
Willingness-to-pay	0	25.66	26.20	26.38	51.45	51.76	51.76

Note: The participation levels for futures and options, and the selected trigger yield for IYCI are reported as the percent of the expected yield; the income and standard deviation and willingness-to-pay levels are reported in $.

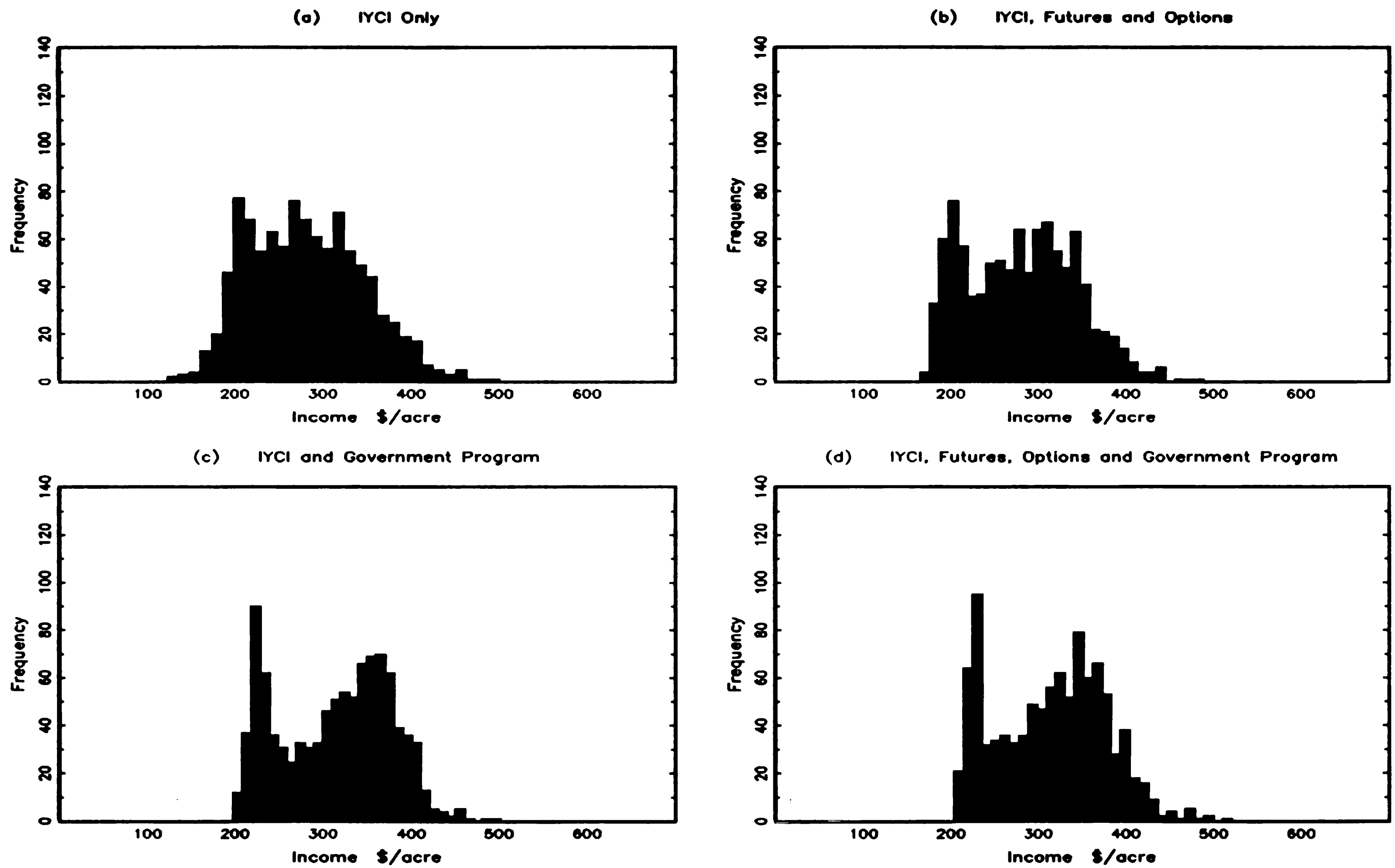

Figure 5.2 Histograms of Income Distribution with IYCI

Futures and IYCI

In this case, IYCI and futures contracts are both included in the portfolio. Equation (5.1) is restricted by setting the options and government program positions to be zero ($z=\xi=0$).

These two instruments allow the farmer to manage both price and yield risks directly. The optimal futures position is to go short 27% of the expected yield, and the selected trigger yield for IYCI is again the maximum 75% of expected yield. Because the yield risk is now managed by the IYCI, futures can be used to mange price risk directly by taking a position opposite of the farmer's cash position. However, because the 75% trigger yield restriction prevents IYCI from fully reducing the yield risk, part of the price variability is still necessary to cross hedge the remaining yield variability through the negative price-yield correlation. This is what prevents the futures position from going beyond short 27% to manage price risk.

Because the futures market is unbiased and the IYCI trigger yield level stays the same as without futures, the mean of income is the same as with IYCI only. The standard deviation of income is reduced relative to the IYCI only case, and the distribution is more symmetric and less kurtotic.

The willingness-to-pay for the two instruments is only about $0.50 per acre more than the IYCI only case, indicating that futures market is not very valuable to the farmer once the yield risk is reduced. The reason for the small short position and the small value associated with futures is, again, that even though the IYCI eliminates the downside yield risk associated with yield shortfalls below 75% of expected yield, there is still a large proportion of yield risk present which is at least partially offset by the negative correlation between price and yield.

Futures, Options and IYCI

In this case, IYCI, futures, and options are all available in the farmer's portfolio. The restriction on equation (5.1) is to set the government program position to be ($\xi = 0$).

The futures market position is close to zero and the farmer takes a relatively large options position by buying put options equivalent to 51% of expected yield. When yield is effectively managed by IYCI, the income distribution depends primarily on the price distribution. As indicated by Vercammen (1995), options are valuable to risk averse farmers because they can increase the skewness of income distribution. The trigger yield is still selected at the maximum possible level, 75% of expected yield.

The income distribution has same mean as the previous two models, and the standard deviation is slightly smaller. Its skewness is larger than the case without options which is consistent with the above analysis. It is also slightly skewed to the left and less kurtotic than a normal distribution, similar to the previous case with futures and IYCI. The income distribution is graphed in Figure 5.2(b), which is similar to the IYCI alone case, but has the left tail truncated.

The farmer's willingness-to-pay for this portfolio is only $0.18 per acre higher than the portfolio without options, suggesting futures and options are substitutes in the presence of IYCI, and that the value of options when IYCI and futures are in the portfolio is also not high. However, the almost zero futures position and the additional

\$0.18 per acre willingness-to-pay show that options can manage price risk more effectively that futures when IYCI is in the portfolio. When either options or futures are included in the portfolio with IYCI, the resulting income distribution is similar.

Government Program and IYCI

In this case, the farmer's portfolio includes IYCI and the government deficiency payment program. Equation (5.1) is restricted by setting the futures and options positions to zero, and the government program position to one ($\xi=1$, $x=z=0$).

The optimal trigger yield selection is still the maximum 75% of expected yield and it is optimal for the farmer to participate in the government program. The IYCI reduces the downside yield risk, and the government program eliminates the downside cash price risk.

The mean of income is nearly \$33 higher than the previous cases because of the subsidy implicit in the government program; the standard deviation of income is further reduced from the cases without the government program; and the distribution is skewed to the right under IYCI but symmetric in this case. The histogram is graphed in Figure 5.2(c). Comparing Figures 5.2(c) to (a), the income distribution is shifted to the right and its left tail is truncated, showing a more preferable shape to the farmer.

Willingness-to-pay increases by about \$26 per acre over the IYCI only case, which is slightly below the amount of the expected government subsidy. The value of adding the government program into the portfolio is relatively low considering its subsidy value. Part of the reason is that even though IYCI reduces downside yield risk, there is still yield risk left unprotected, and participating in the government program eliminates price risk and increases the farmer's exposure to the remaining yield risk due to the negative price-yield correlation.

Notice that the farmer's absolute risk aversion is decreasing as his/her wealth level increases under CRRA preferences, and when the subsidy inherent in the government program increases the mean income, the farmer values the IYCI less than before. As a result, the true value of government program may be more than the additional $26 per acre, which is not separable from the total willingness-to-pay. Therefore, an experiment is conducted by adding an "actuarially fair" government program, obtained by subtracting the expected subsidy, $33 per acre, from the government program, into the portfolio containing IYCI only, and calculating the willingness-to-pay to this portfolio which is $25.83 per acre, $0.17 higher than the value of IYCI. This result suggests the government program slightly reduces the income risk by eliminating part of the downside price variability when IYCI is in the portfolio, but its risk management value is much smaller than IYCI and even smaller than futures and options. The resulting income distribution is the same as the case with a subsidized government program, except the mean is smaller.

Futures, Government Program and IYCI

In this case, the farmer uses the government deficiency payment program, crop insurance, and futures contracts in the portfolio. Restrictions in equation (5.1) set the options position to zero and government program position to one ($z=0$, $\xi=1$).

It is optimal for the farmer to select 75% of expected yield as IYCI trigger yield, participate in the government program, and change the futures position from short 27% to long 21% of expected yield. The elimination of the downside price variability by participating in government program results in additional exposure to the yield risk remained from using IYCI under 75% trigger yield restriction. The long futures position allows the farmer to cross hedge the additional yield risk.

As before, adding futures to the portfolio does not change the mean of income, but the standard deviation decreases slightly. The distribution remains nearly symmetric as in the case without futures, but the skewness measure increases from a small negative value to a small positive value.

The additional willingness-to-pay when adding futures to a portfolio containing both government program and crop insurance is only $0.30 per acre, suggesting that the futures market has a little additional risk management value when IYCI and the government program are in the portfolio.

Futures, Options, Government Program, and IYCI

In this case, the farmer's portfolio includes the government program, crop insurance, futures contracts and options contracts. The restriction on equation (5.1) is to set the government program participation level to be one ($\xi = 1$).

In the presence of the government program and IYCI, the put options position changes from buying 52% to writing 1% of expected yield, supporting the conclusion in the previous section that the government program and options are substitutes. Again, because the government program reduces downside price variability which exposes the farmer to additional yield risk when the maximum IYCI trigger yield is restricted to 75% of expected yield, the long futures position helps to cross hedge this yield risk. The futures position remains nearly the same as in the last case because the options position is close to zero, and the IYCI trigger yield is again selected to be 75% of expected yield.

The income distribution is almost identical to the previous one, and willingness-to-pay stays the same because the options position is very small and the options play almost no role in the portfolio. The histogram of the income distribution is shown in Figure 5.2(d).

Summary

In the base model where yield is relatively more volatile than price, adding crop insurance into the farmer's risk management portfolio provides direct risk protection for yield risk which is more effective than the "cross hedging" through the negatively correlated cash price. Crop insurance frees the price risk management instruments to deal more directly with price risk.

In the base model, the farmer selects the indemnification trigger yield at the maximum permitted level, 75% of his expected yield, despite the fact the crop insurance premium is set 35% above the actuarially fair premium. The willingness-to-pay for IYCI is relatively high, over $25 per acre for the IYCI only case, even with the restriction on trigger yield and the premium loading. The standard deviation of income is greatly reduced whenever IYCI is allowed in the portfolio. These facts suggest crop insurance can manage income risk effectively, and the farmer's potential demand for crop insurance may go beyond the current restriction even in the absence of a moral hazard motivation.

When IYCI is used to manage yield risk, the farmer goes short futures. When the government program is included in the portfolio the farmer goes long futures; however, the magnitude of long futures is decreased from the cases when IYCI was not available. In the base model, the size of the futures position in each case is about 20%, long or short, and the marginal willingness-to-pay is never more than about $0.50 per acre, indicating it is not a very valuable risk management instrument in the presence of IYCI.

The marginal willingness-to-pay for the government deficiency payment program is significant in the presence of IYCI, at around $25 per acre. This suggests that, in the base model, the government program's value to the farmer is a result of the subsidy to income. The program does not contribute much towards the management of income risk, because it eliminates downside price variability which increases the farmer's exposure to yield risk because of the negative price-yield correlation.

The farmer tends to buy more (or write fewer) put options when crop insurance is introduced into the risk management portfolio, even though the trigger yield level is restricted to 75%. This suggests that, in the presence of IYCI, options contracts can be used to manage price risk directly. The value to the farmer of including options in the portfolio is generally small when IYCI and futures are already available, suggesting that the options and futures are substitutes in the presence of IYCI.

5.3 Price Instruments With Area Yield Crop Insurance

In this section, the role of area yield crop insurance (AYCI) as opposed to IYCI is studied as a risk management instrument. In the AYCI scheme, the indemnity index is the county-level yield as opposed to the individual farm-level yield. AYCI is assumed to charge an actuarially fair premium and has a maximum trigger yield of 90% of the expected yield. Correlation between farm- and county-level yields is assumed to be 0.83. Each case in this section is the same as those in section 5.2 except that IYCI is replaced by AYCI. The optimal market participation levels, the first four moments of the income distribution, and the willingness-to-pay levels are all listed in Table 5.4. The results for each portfolio are discussed in the following subsections.

AYCI Only

In this case, only AYCI is included in the farmer's portfolio. Equation (5.1) is restricted by setting futures, options and government program positions to be zero ($x=z=\xi=0$).

The farmer chooses the maximum trigger yield level of 90% of expected yield. Using AYCI to manage yield risk instead of IYCI introduces yield basis risk as a result of the imperfect correlation between farm- and the county-level yield indices used for crop insurance. In the base model, the farm-county yield correlation is 0.83, indicating that county-level yields are highly correlated with farm-level yields. Furthermore, some of the cost of yield basis risk can be offset by the benefit from being allowed to select higher trigger yield levels and only paying an actuarially fair premium.

Table 5.4 Optimal Positions, Income Distribution, and WTP with AYCI

	Portfolio						
	No Risk Instr.	AYCI	Futures and AYCI	Futures, Options and AYCI	Govt. and AYCI	Futures, Govt. and AYCI	Futures, Options, Govt. and AYCI
Futures	0	0	-0.095	0.010	0	0.325	0.192
Options	0	0	0	0.206	0	0	-0.266
AYCI	0	0.900	0.900	0.900	0.900	0.900	0.900
Govt.	0	0	0	0	1	1	1
$E(\pi)$	286.43	286.43	286.43	286.43	319.11	319.11	319.11
$Stdv(\pi)$	89.20	71.44	70.32	70.19	67.35	68.44	68.42
$Skew(\pi)$	-0.617	-0.303	-0.377	-0.359	-0.785	-0.483	-0.507
$Kurt(\pi)$	3.324	3.476	3.534	3.598	3.920	3.840	3.730
Willingness-to-pay	0	22.38	22.47	22.52	49.23	50.07	50.13

Note: The participation levels for futures and options, and the selected trigger yield for AYCI are reported as the percent of the expected yield; the income mean and standard deviation and the willingness-to-pay levels are reported in $.

Optimal mean income is $286.43 per acre which is same as when no risk management instruments are available because AYCI is actuarially fair. The standard deviation of income is smaller than the case of no risk management but larger than the case when IYCI is the only risk management instrument available, even though the trigger yield for IYCI is only 75% as opposed to 90% for AYCI. Unlike the IYCI only case, the income distribution is skewed to the left but more symmetric than the no risk management case. The higher standard deviation and negative skewness under AYCI results from yield basis risk, which is zero in the IYCI only case. The income distribution is graphed in Figure 5.3(a). This distribution is more "spread-out" than the distribution using IYCI only in Figure 5.2(a) but more compressed than the no risk management case in Figure 5.1(a).

The willingness-to-pay for AYCI alone is $22.38 per acre, $3.28 less than for IYCI, which suggests that AYCI works slightly less effectively than IYCI by itself to manage the income risk, despite the fact that trigger yield is higher and the premium is actuarially fair for AYCI. On the other hand, this result also suggests that AYCI actually works quite well in managing the farmer's yield risk, while providing with FCIC an inexpensive way to administer crop insurance at the same time.

Futures Market and AYCI

In this case, AYCI and futures contracts are both in the farmer's portfolio. The restrictions on equation (5.1) are to set the options position and government program participation level to zero ($z=\xi=0$).

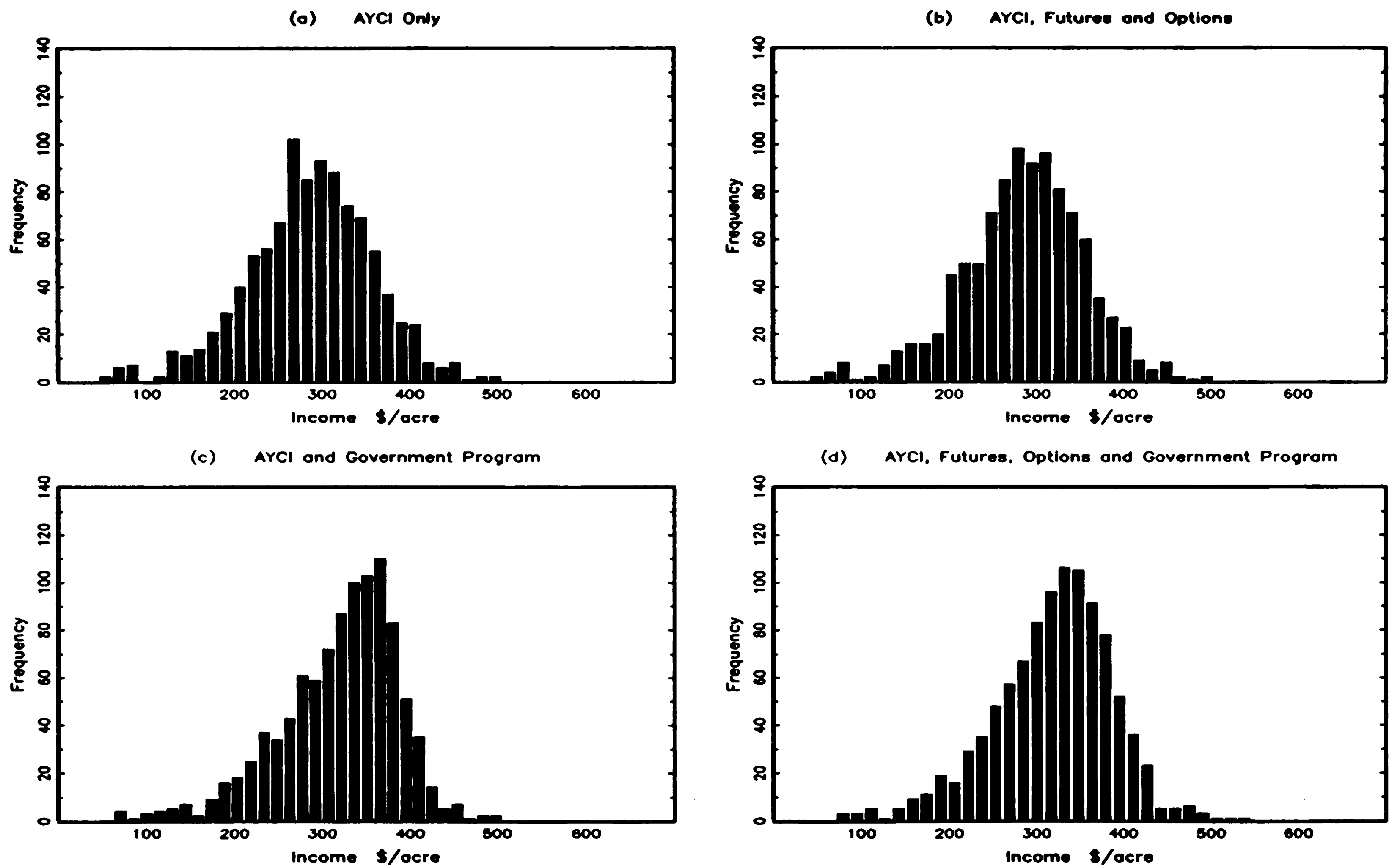

Figure 5.3 Histograms of Income Distribution with AYCI

The farmer selects the maximum trigger yield level of 90% of the expected yield for AYCI and goes short futures 10% of expected yield. Similar to the case with IYCI, the yield risk is partially managed by the AYCI, so futures contracts are then used to manage price risk. However, because of the restricted trigger yield level and yield basis risk, AYCI leaves a certain amount of yield risk unprotected. Despite the higher trigger yield level, the existence of yield basis risk exposes the farmer to additional yield risk which reduces the short futures position below the position in the IYCI only case, in order to reduce the exposure to the remaining yield risk which is negatively correlated with price.

The mean of income does not change because the futures market is unbiased. The standard deviation of income is reduced, and the distribution is skewed more to the left than in the case without futures contracts.

The marginal willingness-to-pay when adding futures to the portfolio is relatively small, $0.09 per acre, which is not surprising because of the small futures position. The small short position and the small marginal willingness-to-pay suggest that the risk management value of futures is limited when the portfolio contains AYCI.

Futures, Options and AYCI

In this case, AYCI, futures contracts and options contracts are included in the farmer's risk management portfolio. The restriction on equation (5.1) is to set government program participation level to zero ($\xi = 0$).

The optimal futures position in this case is essentially zero. The farmer buys put options equivalent to 21% of expected yield and selects the trigger yield to be the maximum 90% of expected yield. As in the IYCI case, the options contract reduces downside price variability and AYCI reduces downside yield variability. The options position is smaller than in the IYCI case, because the AYCI is not as efficient at reducing yield risk, so there is more yield risk left unprotected which requires more price variability to offset it.

The distribution is graphed in Figure 5.3(b). The mean of income stays the same as in the cash only case because all risk instruments are perceived to be priced at a level equal to their expected payoff. The standard deviation of income is smaller than the previous two cases with AYCI, and is more symmetric than the case without options in the portfolio.

The willingness-to-pay for including options in the portfolio is increased by only $0.04 per acre. The relatively large options position combined with the decrease in the use of futures in the portfolio suggesting that options are substitutes for futures in the presence of AYCI. Similar to the IYCI case, the almost zero futures position and the additional $0.04 per acre willingness-to-pay suggest that options can manage price risk at least as effectively as futures in the presence of AYCI.

Government Program and AYCI

In this case, the farmer participates in AYCI and the government deficiency payment program to manage income risk. In equation (5.1), the futures and options positions are restricted to zero, and the government program participation level is restricted to be one ($\xi = 1,\ x = z = 0$).

Participating in the government program is again the farmer's optimal choice and the trigger yield is again chosen at the maximum 90% of expected yield. When yield is the major source of income risk, the farmer uses crop insurance to reduce yield risk. When the trigger yield is restricted and yield basis risk exists, buying the maximum level of AYCI still leaves a certain amount of yield risk unprotected. The government program reduces the downside price variability but exposes the farmer to more yield risk that is left after using AYCI. The government program may increase income risk in this case. However, the implicit subsidy in the government program still makes it attractive to the farmer.

The mean of income is increased by about $33 per acre, which is the expected level of subsidy from participating in the government program. The standard deviation of income is reduced, but the negative skewness is larger in magnitude than without the program. The histogram of the income distribution is shown in Figure 5.3(c).

The willingness-to-pay is increased by $27 per acre when the government program is added to the portfolio, which is below the expected subsidy value, indicating the government program is not very effective at managing risk in the base model but provides benefit to the farmer through the implicit subsidy.

An experiment where the "actuarially fair" government program is replaced by a subsidized government program by subtracting the expected subsidy, $33 per acre. The resulting income distribution is the same except the mean is $33 lower. Willingness-to-pay for this portfolio, unlike the case with IYCI, is only $20.08 per acre which is lower than the value of AYCI alone, suggesting the government program actually increases income risk when AYCI is used.

Futures, Government Program and AYCI

In this case, the farmer's portfolio includes the government deficiency payment program, AYCI, and futures. Restrictions on equation (5.1) are to set the options position to zero and the government program position to one ($z=0$, $\xi=1$).

Participating in the government program is optimal and the maximum trigger yield of 90% of expected yield is chosen. The farmer now chooses to go long futures 33% of expected yield. As in the IYCI case, participation in the government program exposes the farmer to additional yield risk when the price and yield are negatively correlated, yield risk is not fully eliminated by AYCI, and the price variability is reduced. Futures are then used to cross hedge this additional yield risk. The long futures position is larger than in the IYCI case but smaller than the no crop insurance case, implying that AYCI can manage yield risk, but not as effectively as IYCI in the base model.

The mean of income stays the same when futures are added to the portfolio, however, the standard deviation of income is larger and the negative skewness is smaller than that in the previous cases without futures. Compared to IYCI, the income distribution in this case has a larger standard deviation and a larger negative skewness.

The marginal willingness-to-pay to include futures in the portfolio is $0.85 per acre. Though still small, it is larger than the value when including futures without the government program. The role of futures contracts to manage income risk with AYCI is more important when the government program is available. In this case, the value of using futures to cross hedge the additional yield risk exposure caused by the government program is greater than the value of using futures to hedge price risk in the absence of the government program.

Futures, Options, Government Program and AYCI

In this case, the government deficiency payment program, crop insurance, futures contracts and options contracts are all allowed in the farmer's risk management portfolio. The restriction on equation (5.1) is to set the position in the government program to one ($\xi = 1$).

It is again optimal for the farmer to participate in the government program. The optimal portfolio is to go long futures 19% of expected yield, write put options at 27% of expected yield, and select the trigger yield at its maximum level of 90%. Futures and options combine to cross hedge the increased residual yield risk exposure due to the reduced downside price variability resulting from participation in the government program. Compared to the case with IYCI instead of AYCI, the futures position is at a similar level while more put options are written. This suggests that AYCI is not as effective as IYCI at managing yield risk, so that more put options are written to cross hedge the remaining yield risk.

The mean of income stays the same as when futures, government program and AYCI are in the portfolio because the options are priced at their expected payout. Both the standard deviation and skewness of income are slightly decreased. The income distribution histogram is shown in Figure 5.3(d), and is quite similar to the case with government program and AYCI (no futures or options).

The marginal willingness-to-pay to include options in the portfolio is only $0.05 per acre, which, although small, is above the value in the IYCI case. When options are added into the portfolio, the farmer takes a relatively large options position and reduces the futures position, and the resulting willing-to-pay increases very little. This suggests that futures and options are acting as substitutes.

Willingness-to-pay for AYCI is close to the IYCI case, which suggests that when all the price instruments are available, AYCI provides almost as same welfare gain as IYCI at managing income risk given the specific IYCI premium loading and the current trigger yield restrictions.

Summary

The farmer always selects the AYCI trigger yield at the maximum 90% of expected yield. Even though the trigger yield level is higher and the AYCI premium is actuarially fair, willingness-to-pay for AYCI is still lower than the corresponding IYCI cases, suggesting that AYCI is generally not as effective in reducing the farmer's income risk as individual yield crop insurance, given the level of basis risk in the base model.

Mean income is consistently larger than in the corresponding cases with IYCI and equal to mean income without any crop insurance, because the insurance participant pays an actuarially fair premium for AYCI as opposed to a premium set 35% above the actuarially fair level for IYCI. However, the willingness-to-pay for AYCI is smaller than for IYCI, with the magnitude of the difference ranging from \$1.65 to \$3.86 per acre. This suggests that AYCI can be a reasonable substitute for IYCI. When all the price instruments are included in the portfolio, the difference between willingness-to-pay using AYCI and IYCI is only about 3%.

Because of yield basis risk, AYCI leaves more yield risk unprotected than the IYCI, despite the farmer's ability to choose a higher trigger yield level using AYCI. As a result, futures and options are used less to manage price risk directly and more to manage yield risk through cross hedging when AYCI is used in the portfolio rather than IYCI. This also results in smaller willingness-to-pay values for futures and options in cases where they are used to hedge price risk as opposed to cross hedging yield risk. Regardless, the willingness-to-pay value for futures and options are negligible in comparison to the willingness-to-pay values for crop insurance.

Again, the willingness-to-pay for participating in the government deficiency payment program is significant but always smaller than the expected subsidy from participation. This suggests the government program's value to the farmer is the income subsidy and that, with negative price-yield correlation, participation actually exposes the farmer to additional income risk because of the additional exposure to yield risk.

When participating in the government program, the farmer goes long futures, writes put options, and sets the AYCI trigger yield to the maximum level. AYCI provides similar risk protection as IYCI, but IYCI is generally more effective in the base model.

5.4 Conclusions

In the base model, yield risk is a more important component of income risk than price risk. In addition, prices and yields are negatively correlated which provides a built-in form of income risk management.

In the absence of crop insurance, futures and options are generally used to cross hedge yield risk rather than hedge price risk, in contrast to the conventional hedging results. This result rests on a strong negative price-yield correlation. However, the willingness-to-pay for futures and options are relatively low, under $6 per acre, and the resulting income distributions are similar to the no risk management case, implying that futures and options are not effective income risk management instruments in the absence of crop insurance.

When IYCI is included in the portfolio, the income risk is significantly reduced. The farmer always selects the maximum trigger yield level. The willingness-to-pay for IYCI is significant (approximately $26 per acre), despite the fact that the trigger yield is restricted and the premium is 35% above the actuarially fair level. The optimal trigger yield level and willingness-to-pay for IYCI suggest it is an effective instrument for managing income risk. When IYCI is in the portfolio, futures and options are used to manage price risk in the absence of the government program; and they are used to cross hedge the additional yield risk exposure caused by the government program when the program is in the portfolio. However, the additional willingness-to-pay for including futures and options in the portfolio is less than $1 per acre.

When AYCI is included in the portfolio, income risk is reduced in a manner similar to when IYCI is included. The maximum trigger yield level is always chosen by the farmer. The willingness-to-pay for AYCI is much larger than the price instruments at about $22 per acre. However, as result of the yield basis risk, willingness-to-pay for AYCI is slightly below the value of IYCI, even though the AYCI premium is actuarially fair and its maximum trigger yield is higher than IYCI. This indicates AYCI is also an effective risk management instrument, but somewhat less effective than IYCI. When AYCI is included in the portfolio, futures and options are again used to hedge price risk in the absence of the government program, but their positions are generally smaller than in the case of IYCI, because more yield risk is left unprotected. Once again, the value of futures and options is quite small relative to the value of AYCI at less than $1 per acre.

Participating in the government deficiency payment program can eliminate downside price variability, but it also increases the farmer's income risk through additional exposure to yield risk given the negative price-yield correlation and the relatively large yield risk. The risk management impact of the government program depends on the level of unprotected yield risk in the sense that if a lot of yield risk is left unprotected, the elimination of the downside price variability through program participation actually increases income risk. However, when there is little yield risk left unprotected, the program can reduce income risk through reducing price risk.

The government program provides a high level of expected subsidy through the deficiency payment, and the willingness-to-pay to include it in the portfolio is nearly as high as the expected subsidy value when at least one other risk management instrument is present to help manage the income risk. This implies that the risk management value of the government program is relatively small. Indeed, when the government program is the only risk management instrument in the portfolio, its value is near zero despite the subsidy. This is because of the increased yield risk exposure from the elimination of the negatively correlated price movements.

When all instruments are included in the portfolio, the farmer's optimal choice is to participate in the government program, take a small long futures position, write a small number of put options, and choose the IYCI trigger yield at the maximum level.

These results are based on the particular set of parameters specified for the base model. Some of the parameters are very specific to the representative farmer, geographical region, and crop year, such as the farmer's risk preference, yield basis risk level, relative variability of price and yield, and price-yield correlation. These parameters may differ across farmers, regions and time, and the results may change accordingly. In the next chapter, a comparative static analysis is conducted to investigate results when the parameters deviate from their base values.

Chapter VI

ECONOMIC IMPACTS OF ALTERNATIVE RISK STRUCTURES AND PREFERENCES

The use of different risk management instruments and their welfare effects were studied in Chapter V for a farmer in southwest Iowa, whose farm-level yield variance, yield basis risk, and price-yield correlation were representative of medium levels in that region. In addition, the farmer's risk preference is represented by a constant relative risk averse (CRRA) utility with $RR = 2$. In this chapter, the implication of alternative risk structures and risk preferences on the use of alternative risk management instruments are explored along with the resulting welfare effects.

The use and value of the risk management instruments may differ significantly as a result of changes in risk preferences, and/or the joint distribution of prices and yields faced by the farmer. The alternative parameter values studied in this chapter are listed in Table 6.1.

Price-yield correlation can have a significant impact on income risk and, as a result, affect the use and value of alternative risk management instruments. Based on historical data for southwest Iowa, the price-yield correlation for the representative farm is set at -0.46. However, the price-yield correlation for other corn growing areas may be much smaller than southwest Iowa which is located in the heart of the corn belt where

Table 6.1 Risk Structure and Risk Preference Parameters

Parameter	Notation	Base Value	Alternative Values
Price-yield correlation	ρ_{PY}	-0.46	0
Relative risk aversion	*RR*	2	1, 3
Farm/county yield standard deviation	*R*	1.20	1.40, 1.00
Farm-county yield correlation	ρ_{IC}	0.83	0.94, 0.63

production levels can significantly impact price levels. In order to study the impacts of lower price-yield correlations on the use and value of the risk instruments, the model is evaluated with price-yield correlation set at zero.

Risk preferences for the representative farm exhibit CRRA. In the base model, CRRA=2 and the utility function is of the form $u(\pi) = -\pi^{-1}$. The level of risk aversion may impact the use of the risk management instruments as well as the associated welfare effects. To explore the impacts of the level of risk aversion on the use and value of the risk management instruments, the base model is evaluated for different levels of risk aversion. A more risk averse farmer's utility function is represented by setting $RR = 3$, so that $u(\pi) = -0.5\pi^{-2}$; and a less risk averse farmer's utility function is represented by setting $RR = 1$, so that $u(\pi) = ln(\pi)$.

The volatility of yields may differ greatly across farms even in close geographic proximity. The standard deviation of yields for the representative farm is set at 1.2 times the county yield standard deviation. In the southwest Iowa study area, high risk farms have a standard deviations about 1.4 times the county level; and low risk farms exhibit yield standard deviations about the same level as the county yield. To examine the impacts of the level of yield volatility on the performance of the risk instruments, the individual yield standard deviation is set at 1.0 and 1.4 times the county yield standard deviation and the changes in the optimal use and welfare of the instruments are examined.

Finally, the correlation between farm- and county-level yields (yield basis risk) affects decisions when AYCI is included in the portfolio instead of IYCI. To explore the effects of yield basis risk on the performance of the instruments, the farm-county yield correlation is decreased to 0.63 (an increase in yield basis risk) and increased to 0.94 (a decrease in yield basis risk), and the change in the use of the instruments and farmer welfare are examined. These levels reflect the range of yield basis risk for farms located in the study area in southwest Iowa.

The remainder of this chapter is divided into four sections. In the first section, we study the impact of the price-yield correlation level. Next, we examine the impact of changes in the risk preferences. In the third section, the impact of different yield risk structures, including both farm-level yield volatility and yield basis risk are examined. The chapter concludes with a section summarizing the analysis.

6.1 Price-Yield Correlation

Price-yield correlation plays a key role in determining the use of risk management instruments and farmer welfare. The analysis in Chapter V assumed cash price and county yield were negatively correlated. To determine the impacts of the price-yield correlation on participation levels and farmer welfare, the analysis is repeated here for the case of zero price-yield correlation.

The joint price-yield distributions are generated using the procedure outlined in Chapter IV with the same parameter values, except that the correlation imposed between the cash price and the county yield is set to zero. The marginal distributions of each random variable remain unchanged. The sample correlations for the simulated joint distribution are shown in appendix D. Although the price-yield correlation is specified to be zero, simulation error results in a very small level of positive correlation.

The optimal market positions and willingness-to-pay are reported in Table 6.2. The zero price-yield correlation results in some significant changes compared to the negative price-yield correlation case. As in the negative correlation case, the farmer continues to choose the maximum crop insurance trigger yield and always participates in the government program when available. However, with no price-yield correlation, the farmer generally takes a significant short position in the futures market because futures are no longer used to cross hedge yield risk and are used to hedge price risk directly. The options position is highly sensitive to the inclusion of crop insurance and government program in the portfolio. Adding crop insurance causes the farmer to switch from selling to buying put options; while adding the government program causes the farmer to once again sell puts. This is as expected because when yield risk is managed by crop insurance, put options are bought to manage the price risk; and the government program is a substitute of puts, so the use of which is accompanied by selling puts.

Table 6.2 Optimal Positions and WTP with Zero Price-Yield Correlation

	Portfolio					
	No Price Instrument	Futures	Futures and Options	Govt.	Futures and Govt.	Futures, Options and Govt.
Without Crop Insurance						
Futures	0	-0.086	-0.893	0	-0.129	-0.585
Options	0	0	-0.796	0	0	-1.019
Govt.	0	0	0	1	1	1
$E(\pi)$	292.24	292.24	292.24	324.93	324.93	324.93
$Stdv(\pi)$	101.98	103.65	96.11	93.07	92.05	92.97
Willingness-to-pay	0.00	0.13	7.34	33.76	33.96	36.21
With IYCI						
Futures	0	-0.658	-0.577	0	-0.194	-0.366
Options	0	0	0.169	0	0	-0.350
Govt.	0	0	0	1	1	1
IYCI	0.75	0.75	0.75	0.75	0.75	0.75
$E(\pi)$	286.96	286.96	286.96	319.64	319.64	319.64
$Stdv(\pi)$	78.59	68.82	68.76	67.68	66.12	65.92
Willingness-to-pay	28.96	31.75	31.77	57.58	57.80	57.87
With AYCI						
Futures	0	-0.684	-0.520	0	-0.230	-0.325
Options	0	0	0.316	0	0	-0.183
Govt.	0	0	0	1	1	1
AYCI	0.90	0.90	0.90	0.90	0.90	0.90
$E(\pi)$	292.24	292.24	292.24	324.93	324.93	324.93
$Stdv(\pi)$	82.25	72.04	72.08	71.10	69.18	69.02
Willingness-to-pay	24.14	29.91	30.00	57.11	57.50	57.53

Note: The participation levels for futures and options and the trigger yield level of crop insurance are all reported as a percent of the expected yield; and income mean, standard deviation, and willingness-to-pay levels are reported in dollars.

When both price and yield management instruments are included in the portfolio, the price-yield correlation has less effect on the market positions than the case when pricing instruments or crop insurance are used in isolation. The willingness-to-pay for risk management instruments is generally higher with zero price-yield correlation than with negative correlation. With zero price-yield correlation, the cash market income is more volatile with a standard deviation of $101.98 in contrast to $89.20 in the negative price-yield correlation case.

There are two cases where the willingness-to-pay for alternative instruments are significantly different when the price-yield correlation is zero compared to the base case. First, when futures are the only risk management instrument in the portfolio, willingness-to-pay is less than in the negative correlation case. The reason is that yield is more volatile than price, so that the risk management value of using futures to cross hedge yield risk in the negative price-yield correlation case is higher than the value from hedging price risk when there is no price-yield correlation.

Second, when the government program is the only instrument in the portfolio, its value is higher than the expected subsidy when there is no price-yield correlation, because it now reduces risk as well as providing a subsidy to the farmer. In the negative price-yield correlation case, the value of the program is almost zero because its subsidy value is offset by the increased income variability which results from the elimination of price variability by the program and increasing yield risk exposure.

The optimal portfolio with no price-yield correlation is to sell futures and put options at 37% and 35% of expected yield, participate in the government program, and use IYCI with a trigger yield at the maximum 75% of expected yield level. The willingness-to-pay measure is $57.87 per acre.

6.2 Risk Preferences

The use of futures, options, or AYCI impacts the risk associated with the income distribution while the government program and IYCI impact both mean income and the risk associated with the income distribution. Farmers with different risk preferences will value mean income and income variability with different weights. As a result, farmer risk preferences impact both the use of risk instruments and the resulting welfare for every portfolio.

The optimal futures and options positions, the optimal trigger yields for crop insurance, and the willingness-to-pay for farmers with alternative risk preferences are reported in Tables 6.3, 6.4, and 6.5, respectively. Futures and options are not reported separately in order to simplify the presentation of results. For convenience, the base values when *RR* is 2 are again provided in the tables.

The direction of change in futures and options positions depends on the portfolio. The magnitudes of the changes are large in a number of instances, which suggests the level of participation in futures and options can be very sensitive to risk attitudes.

A ceteris paribus decrease in *RR* tends to make the IYCI trigger levels go below the maximum level, while the AYCI trigger yield remains at the maximum level. The reduction in risk aversion reduces the benefits of risk reduction enough that the premium loading in IYCI causes the farmer to select a trigger level below the 75% level.

Table 6.3 Futures and Options Positions for Alternative Risk Preferences

Case	Futures, and Options		Futures,Options and Govt.		Futures,Options and IYCI		Futures,Options, Govt. and IYCI		Futures,Options and AYCI		Futures,Options, Govt.and AYCI	
	Futures	Options	Futures	Options	Futures	Options	Futures	Options	Futures	Options	Futures	Options
Negative Price-Yield Correlation												
Base (RR=2)	0.28	0.13	0.47	-0.50	-0.01	0.52	0.21	-0.01	0.01	0.21	0.19	-0.27
RR = 1	0.48	0.55	0.66	0.02	-0.00	0.54	0.22	-0.02	0.02	0.48	0.19	-0.05
RR = 3	0.15	-0.04	0.24	-0.99	0.08	0.65	0.36	0.24	0.01	0.03	0.28	-0.30
Zero Price-Yield Correlation												
Base (RR=2)	-0.89	-0.80	-0.59	-1.01	-0.58	0.17	-0.37	-0.35	-0.52	0.32	-0.33	-0.18
RR = 1	-0.80	-0.38	-0.49	-0.56	-0.66	0.13	-0.43	-0.39	-0.64	0.25	-0.41	-0.22
RR = 3	-0.95	-0.98	-0.71	-1.44	-0.44	0.34	-0.09	-0.00	-0.41	0.37	-0.11	0.39

Note: Participation levels are reported as the percent of expected farm-level yield hedged on the futures, or options market.

Table 6.4 Trigger Yield Levels for Alternative Risk Preferences

	Portfolio							
Case	IYCI	Futures, Options and IYCI	Govt. and IYCI	Futures, Options, Govt. and IYCI	AYCI	Futures, Options and AYCI	Govt. and AYCI	Futures, Options, Govt. and AYCI
Negative Price-Yield Correlation								
Base(RR=2)	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
RR = 1	0.70	0.73	0.73	0.71	0.90	0.90	0.90	0.90
RR = 3	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
Zero Price-Yield Correlation								
Base(RR=2)	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
RR = 1	0.75	0.75	0.72	0.72	0.90	0.90	0.90	0.90
RR = 3	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90

Note: Trigger yields are reported as the percent of expected farm-level yield.

Table 6.5 Willingness-to-Pay for Alternative Risk Preferences

	Portfolio										
Case	Futures and Options	Govt.	Futures, Options and Govt.	IYCI	Futures, Options and IYCI	Govt. and IYCI	Futures, Options, Govt. and IYCI	AYCI	Futures, Options, and AYCI	Govt. and AYCI	Futures, Options, Govt. and AYCI
Negative Price-Yield Correlation											
Base (RR=2)	$5.95	$0.35	$32.53	$25.66	$26.38	$51.45	$51.76	$22.38	$22.52	$49.23	$50.13
RR = 1	1.47	28.88	32.69	7.30	7.68	37.37	37.53	8.98	9.28	39.98	40.17
RR = 3	8.83	0.00	31.02	45.39	46.34	67.97	68.36	35.23	35.23	58.18	60.92
Zero Price-Yield Correlation											
Base (RR=2)	$7.34	$33.76	$36.21	$28.96	$31.77	$57.58	$57.87	$24.14	$30.00	$57.11	$57.53
RR = 1	3.06	34.91	35.28	8.99	10.89	40.64	40.86	10.69	13.39	43.71	44.03
RR = 3	10.96	25.11	35.75	49.07	52.44	75.79	75.97	32.69	44.80	70.35	70.40

Because there is no premium loading in AYCI, it is still optimal to select a trigger yield at the maximum level even though the value of the risk reduction is lower.

The government program provides a subsidy value to the farmer but, as discussed before, actually increases income variability in the base model where price and yield are negatively correlated. As a result, when the farmer becomes more risk averse and no other instrument is available to manage the income risk, the farmer no longer participates in the government program because the cost of the increased variability exceeds the subsidy benefit. However, the more risk averse farmer does participate in the government program when the price-yield correlation is zero or when at least one other instrument is in the portfolio.

Willingness-to-pay generally decreases as the level of risk aversion decreases, because the benefits of risk reduction decline as risk aversion falls. Once again, exceptions occur when the government program is included in the portfolio without any crop insurance. In this case, willingness-to-pay actually increases (decreases) as risk aversion decreases (increases). This is because participation in the program, in the absence of crop insurance, results in an increase in income variability to the farmer and the decrease (increase) in risk aversion reduces (increases) the cost of the additional risk the farmer must bear to capture the subsidy. The change in willingness-to-pay ranges from \$0.16 to \$28.53 per acre as the relative risk aversion level increases or decreases by 1.

The optimal risk management strategy for farmers with high and medium levels of risk aversion is to participate in futures, options, the government program and IYCI.

Farmers with low level of risk aversion substitute AYCI in the portfolio for IYCI. Although IYCI provides better yield risk management effect than AYCI, it imposes an actuarially unfair premium loading. The low risk averse farmers care more about mean income and less about income risk less which makes AYCI more valuable.

6.3 Yield Risk

Even in the same geographic region, farmers may have different individual yield distributions due to different soil characteristics, management practices, and weather related factors, such as rainfall, hail, or flood. A farmer's individual yield distribution may impact the use of risk instruments and their resulting welfare.

Farm-level yield risk, represented by the standard deviation of farm-level yield, and yield basis risk, represented by the correlation between farm- and county-level yields, represent two important characteristics of the farmer's yield distribution. Changes in the farm yield risk will affect income risk and so the use and value of crop insurance may be impacted. In addition, changes in farm yield risk will affect the relative variability of price and yield, which may affect the use and value of price instruments when the price and yield are negatively correlated.

Change in yield basis risk can affect the use of risk management instruments in several ways. As the correlation between farm and county yields decreases (increases), AYCI is less (more) effective at controlling yield risk, which can affect the use and value of AYCI as well as the pricing instruments in the portfolio. In addition, as the correlation between farm and county yields declines (increases), the correlation between price and farm yield will decline (increase) in the negative price-yield correlation case, which may affect the optimal use of the instruments and the resulting welfare.

The impacts of alternative yield distributions on the futures and options positions, the crop insurance trigger yield selection, and the willingness-to-pay are reported in Tables 6.6, 6.7, and 6.8 respectively.

Farm-level Yield Risk

In the case of negative price-yield correlation, the farmer continues to select the maximum trigger yield level for different levels of yield variability. The futures and options positions change as the yield variability increases, but the direction of the change depends on the risk instruments included in the portfolio. The magnitudes of the changes are significant in some portfolios suggesting participation levels in futures and options can be highly sensitive to the level of yield variability.

Willingness-to-pay increases with yield variability when crop insurance is included in the portfolio because the crop insurance becomes more valuable. However, willingness-to-pay decreases as yield variability increases when crop insurance is not included in the portfolio, because the pricing instruments become less effective in managing the increased yield risk.

When yield variability is low, IYCI is replaced in the optimal portfolio by AYCI so that the optimal portfolio consists of AYCI, futures, options and the government program. When the yield is not very risky, the farmer is not willing to pay the

Table 6.6 Futures and Options Positions for Alternative Yield Risks

Case	Portfolio: Futures, and Options		Futures,Options and Govt.		Futures,Options and IYCI		Futures,Options, Govt. and IYCI		Futures,Options and AYCI		Futures,Options, Govt. and AYCI	
	Futures	Options	Futures	Options	Futures	Options	Futures	Options	Futures	Options	Futures	Options
Negative Price-Yield Correlation												
Base	0.28	0.13	0.47	-0.50	-0.01	0.52	0.21	-0.01	0.01	0.21	0.19	-0.27
Low Risk	0.48	0.54	0.60	-0.06	-0.08	0.50	0.14	-0.04	-0.09	0.37	0.09	-0.14
High Risk	0.12	-0.06	0.35	-0.79	0.04	0.51	0.24	-0.06	0.03	-0.05	0.26	-0.42
High Basis Risk	0.28	0.35	0.33	-0.47	-0.22	0.31	-0.01	-0.25	-0.64	-0.35	-0.34	-0.89
Low Basis Risk	0.28	-0.19	0.44	-0.82	-0.05	0.37	0.15	-0.22	-0.15	0.22	0.03	-0.38
Zero Price-Yield Correlation												
Base	-0.89	-0.80	-0.59	-1.01	-0.58	0.17	-0.37	-0.35	-0.52	0.32	-0.33	-0.18
Low Risk	-1.13	-0.96	-0.68	-0.93	-0.63	0.14	-0.41	-0.38	-0.63	0.26	-0.42	-0.25
High Risk	-0.63	-0.59	-0.46	-1.02	-0.53	0.18	-0.32	-0.34	-0.41	0.31	-0.23	-0.15
High Basis Risk	0.02	0.23	0.11	-0.39	-0.37	0.50	-0.21	-0.11	-0.29	-0.82	0.06	-0.34
Low Basis Risk	0.00	0.21	0.16	-0.20	-0.51	0.24	-0.31	-0.31	-0.52	0.24	-0.32	-0.30

Note: Participation levels are reported as the percent of expected farm-level yield hedged on the futures, or options market.

Table 6.7 Trigger Yield Levels for Alternative Yield Risks

	Portfolio							
Case	IYCI	Fut., Opt., and IYCI	Govt., and IYCI	Fut., Opt., Govt., and IYCI	AYCI	Fut., Opt. and AYCI	Govt., and AYCI	Fut., Opt., Govt., and AYCI
Negative Price-Yield Correlation								
Base	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
Low Risk	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
High risk	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
High Basis	0.75	0.75	0.75	0.75	0.71	0.86	0.90	0.90
Low Basis	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
Zero Price-Yield Correlation								
Base	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
Low Risk	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
High risk	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90
High Basis	0.75	0.75	0.75	0.75	0.57	0.70	0.90	0.90
Low Basis	0.75	0.75	0.75	0.75	0.90	0.90	0.90	0.90

Note: Trigger yields are reported as the percent of expected farm-level yield.

Table 6.8 Willingness-to-Pay for Alternative Yield Risks

Case	Futures, and Options	Govt.	Futures, Options, and Govt.	IYCI	Futures, Options, and IYCI	Govt., and IYCI	Futures, Options, Govt. and IYCI	AYCI	Futures, Options, and AYCI	Govt., and AYCI	Futures, Options, Govt. and AYCI
	Portfolio										
Negative Price-Yield Correlation											
Base	$5.95	$0.35	$32.53	$25.66	$26.38	$51.45	$51.76	$22.38	$22.52	$49.23	$50.13
Low Risk	6.12	9.79	33.45	17.95	18.89	45.80	45.96	16.97	17.71	46.32	46.51
Hi. Risk	4.28	0.01	31.42	33.08	33.61	57.25	57.73	25.54	25.60	50.49	52.85
Hi. Basis	2.72	20.37	29.79	26.46	27.48	52.98	53.09	5.70	11.25	40.74	41.56
Lo. Basis	6.99	0.22	31.69	25.35	25.81	50.51	50.94	28.46	28.96	54.40	54.80
Zero Price-Yield Correlation											
Base	$7.34	$33.76	$36.21	$28.96	$31.77	$57.58	$57.87	$24.14	$30.00	$57.11	$57.53
Low Risk	7.98	36.25	37.89	21.44	24.58	51.72	52.10	20.17	25.41	53.18	53.78
Hi. Risk	5.82	29.50	34.10	35.96	38.45	63.34	63.55	25.13	32.63	59.81	60.05
Hi. Basis	3.42	31.93	34.58	28.01	30.91	57.10	57.28	6.50	11.47	45.80	46.60
Lo. Basis	3.26	32.60	34.58	28.35	31.03	57.12	57.33	31.62	34.51	61.34	61.58

actuarially unfair premium in order to use IYCI when he can use AYCI paying only the actuarially fair premium.

The change in positions and willingness-to-pay in the zero price-yield correlation case is similar to the negative correlation case. One exception is that the futures position consistently increases as the yield variability decreases for all portfolios; because without the negative correlation, futures are used to hedge price risk directly and the increase in price variability relative to yield variability increases the demand for futures.

Yield Basis Risk

The farmer chooses the maximum IYCI trigger yield regardless of the level of yield basis risk. The AYCI trigger yield is also generally at the maximum level, except for a few cases where the farm-county yield correlation is low and the government program is not included in the portfolio.

The change in optimal futures and options positions as the yield basis changes depends on the portfolio. Changes in futures and options positions in portfolios that don't include AYCI are the result of changes in the correlation between price and farm yield. When AYCI is included in the portfolio, the resulting changes occur because of the combined impact of changes in price-yield correlation and the farm-county yield correlation. Not surprisingly, the changes in the AYCI portfolio tend to be of larger magnitude than in portfolios with IYCI.

The willingness-to-pay measures with IYCI in the portfolio changes insignificantly with the basis risk. When AYCI is included in the portfolio, the willingness-to-pay measure declines (increases) as the yield basis increases (decreases), and the magnitudes of the changes are significant relative to the changes in the IYCI portfolios. In the AYCI portfolios, the higher farm-county yield correlation improves the ability of AYCI to manage yield risk which significantly increases the value of the risk management instrument. As a result, when the basis risk is low, portfolios containing AYCI outperform those with IYCI, and the optimal portfolio for a low basis risk farmer includes AYCI, futures, options and the government program.

In case of zero price-yield correlation, the changes in positions and willingness-to-pay are generally similar to the negative correlation case. However, there is little change in the value of the pricing instruments when crop insurance is not in the portfolio. When the price-yield correlation is zero, changes in the farm-county yield correlation have little impact on the correlation between price and farm yield, therefore on the pricing instruments' ability to manage risk.

6.4 Summary and Conclusion

Two potentially important factors that affect the optimal use of risk management instruments and the resulting farmer welfare are: (1) the relative variability of price and yield because income risk is a function of the product of price and yield and the relative importance of reducing price and yield risks depend on the relative level of the two types of risks; and (2) the correlation between price and yield, which impacts the level of income risks and also may provide cross-hedging opportunities for price and yield instruments.

When the price-yield correlation is zero, the optimal futures position is to go short, in contrast to the long position in the negative correlation case. When both price and yield instruments are included in the portfolio, the optimal positions are less affected by the price-yield correlation, but the welfare level is higher for the zero correlation case because the cash market income is more volatile, allowing larger gains from reducing income risk.

Changes in risk preferences affect the relative importance of mean income and income risk in determining farmer welfare. Because IYCI has an actuarially unfair premium loading, and the government program has an implicit subsidy, portfolios including IYCI and/or the government program are more sensitive to a change in risk preferences.

Increases in yield variability increase the value associated with both types of crop insurance and decrease the value of pricing instruments. Changes in yield basis risk affect the cross-hedging ability of the instruments as a result of the change in correlation between cash price and farm-level yield whenever cash price and county yield are correlated. However, this impact is small. An increase in yield basis risk significantly decreases the value of AYCI regardless of the price-yield correlation. These results are consistent with Miranda's study.

IYCI generally provides better risk protection to farmers than AYCI because yield basis risk reduces AYCI's effectiveness in managing yield risk. However, in cases when 1) the farmer has a low level risk aversion, 2) yield variability is low, and/or 3) yield basis risk is low, AYCI enters the optimal portfolio instead of IYCI. The reason is the actuarially unfair premium loading imposes cost to the farmer to use IYCI, and when AYCI can provide similar risk management gains or the importance of yield risk declines enough, the farmer prefers AYCI.

Chapter VII

ECONOMIC EVALUATION OF CROP INSURANCE CONTRACT DESIGN

7.1 Introduction

It is widely recognized that farmers are subject to high income risk in the production of many agricultural commodities, and a major component of the income risk originates with crop yields. Futures and options can be used to manage price risk, and the government deficiency payment program can also manage price risk as well as subsidize farmer income. A more urgent need facing farmers is the lack of a well functioning instrument to manage yield risk.

Crop insurance has the potential to help farmers manage yield risk. However, the current crop insurance program established in 1980, has never been financially sound. Many operational and structural modifications have been discussed in an effort to improve the program. Examples include differentiating high risk farmers from low risk farmers, modifying reinsurance mechanisms, and altering contract designs.

The objective of this chapter is to study the effectiveness of the two currently available yield index designs for crop insurance: IYCI and AYCI. The performance of each yield index will be evaluated for a number of alternative contract design specifications. The tradeoff between the premium loadings inherent to the IYCI index and the yield basis risk associated with the AYCI index will also be evaluated.

Feasibility of Current Crop Insurance Programs

Because of the level of yield volatility and the significant probability of very small yield realizations, crop insurance may play an important role in reducing income risk and increasing farmer welfare. The analysis reported in the previous two chapters shows the value of crop insurance is significantly higher than futures and options for some farmers.

Crop insurance has been provided since the 1930s, and has been widely used across the US for most major crops since 1980 in the form of MPCI. However, for a number of reasons, including problems associated with moral hazard and adverse selection, the FCIC has accumulated a deficit of about $3.3 billion from 1980 to 1994, in addition to direct government subsidization of the program. From 1981 through 1994, the ratio of indemnifications paid to premiums collected was 1.4. Congress has required the program to reduce its projected indemnification/premium ratio to 1.1, so that at least 91% of anticipated claims can be covered by premiums collected, the so called "91-percent adequacy" requirement. The urgency of finding more efficient ways to deliver economically feasible crop insurance programs has increased in recent years.

The indemnity payment of IYCI, a stylized form of MPCI, is determined by each individual farmer's yield. Because each farmer can manipulate his yield distribution through management decisions after purchasing crop insurance (moral hazard), and because each individual has better information about the yield distribution than the insurance companies (adverse selection), IYCI is difficult to implement. Besides moral hazard and adverse selection, the indemnity for IYCI is different for each individual farmer based on his realized yield, which increases operating costs. In addition, weather-related, and in some cases insect- and disease-related hazards can cause significant yield reduction over large geographically contiguous areas, thereby increasing the chance that a substantial number of farmers in specific regions claim large indemnification payments in the same year. This geographic correlation between indemnity payouts can subject crop insurance agencies to catastrophic risk. Moral hazard, adverse selection, high operating cost, and catastrophic risk have each contributed to the financial difficulties surround the current form of IYCI.

New alternative forms of crop insurance have been proposed by economists and politicians in an attempt to improve the financial situation of FCIC. The Group Risk Plan (GRP), a form of AYCI, is one alternative design which has been developed and is currently being tested in the field.

AYCI has the potential to reduce moral hazard and adverse selection problems that have hindered IYCI because indemnities do not depend on the farmer's yield. Rather, indemnities depend on area yield which the farmer has little ability to influence. Furthermore, the farmer will have little, if any informational advantage over the insurance provider regarding area yields which reduces the adverse selection problem. In addition, it is easier to administer a program indexed by an area yield than a program which uses a separate index for each individual farm, which should result in lower transaction costs for AYCI.

A disadvantage of the AYCI index is that the indemnity payment is based on an area yield index which may not be highly correlated with the farmer's yield. Using an area yield index makes it possible for a farmer to have a large yield shortfall and receive no indemnity payment if there is no short fall in the area yield index.

The risk management potential and cost of any form of crop insurance depends on design parameters of the contract, the income distribution faced by the farmer, and the availability of other risk management instruments. Next we discuss the major design features that characterize the currently available crop insurance instruments.

Crop Insurance Contract Design Parameters

The design features of current forms of crop insurance contracts have evolved over time. Various features, such as the maximum trigger yield level, have resulted from difficulties in administering a financially feasible program that, at the same time, offers an attractive risk management instrument to farmers.

One important contract parameter is the yield index used to calculate the indemnity payment. The individual yield index (IYCI) and area yield index (AYCI) offer two alternative options which have significantly different implications for performance, cost, and administration of the insurance contracts. The relative performance of the two indices also depends on a number of key design features.

Because the indemnification payout is based directly on the farmers yield, IYCI has the potential to provide a very efficient mechanism to manage yield risk. Unfortunately, moral hazard, adverse selection, catastrophic risk, and administrative difficulties have resulted in operating costs that exceed actuarially fair premium levels by a significant amount for some farmers. To counteract these difficulties, maximum trigger yield restrictions and/or increased premium rates have been instituted. Restricting the maximum trigger yield level (currently 75% of expected yield in IYCI) can reduce the moral hazard incentive thus limiting potential losses to insurance providers. At high trigger yield levels, the farmer has a high probability of making a claim so he may make inferior management decisions which lower expected yields and/or increase yield risks. However, at low trigger yield levels there is a lower probability of claiming the indemnification and the farmer is less likely to alter management decisions. The disadvantage of restricting the trigger yield level is that the risk management capability of the insurance instrument is reduced, which may lead to reduced farmer welfare.

In the area yield plan, GRP restricts the maximum trigger yield to 90% of expected yield. However, moral hazard and adverse selection are not likely to be significant problems for AYCI because the indemnity payment is unlikely to be affected by individual farmers' management decisions, and individual farmers will generally have little informational advantage regarding the distribution of area yields. Therefore, the reasons for placing restrictions on trigger yield levels are less clear for an insurance contract that uses an area yield index.

In contrast to IYCI, low levels of moral hazard, adverse selection, and administrative cost should allow AYCI to be offered with few, if any, trigger yield restrictions at premium rates that are close to being actuarially fair. The disadvantage to farmers, relative to IYCI, is that the area yield index introduces yield basis risk, i.e., less than perfect correlation between farm yield and the area yield index. The yield basis risk associated with AYCI reduces the effectiveness of the insurance contract in managing individual yield risk. The economic implications of these tradeoffs is an empirical issue we will address shortly.

The current farms of AYCI and IYCI contracts restrict the amount of acreage insured in the program to a farmer's base acreage, which corresponds roughly to 100% of planted acres. An alternative crop insurance contract design would allow farmers to select the number of acres covered by crop insurance. Under this design, a farmer may select to insure a number of acres greater or less than the level of planted acreage. Choosing the number of acres to insure is analogous to selecting the number of bushels to buy or sell in the futures and options markets.

Once again, moral hazard and adverse selection difficulties may make it impractical to allow farmers to choose IYCI acreage coverage levels greater than planted acreage. However, as discussed above, these issues are less of a concern in AYCI and allowing a flexible level of acreage coverage is a feasible design alternative which may increase the ability to manage risk.

The remainder of the chapter evaluates the participation incentives and welfare levels for IYCI and AYCI designs. The effects of trigger yield restrictions and acreage coverage restrictions are evaluated for different levels of price-yield correlation and different risk management portfolios. The next section explores the participation and welfare effects of IYCI and AYCI in the absence of price instruments under alternative coverage restrictions and yield basis risk. Changes in the crop insurance participation and welfare levels as a result of including futures and options contracts in the portfolio are evaluated in section 7.3. Section 7.4 then considers the implications of adding a government deficiency payment program to the portfolio containing crop insurance. A number of remaining design issues are discussed in section 7.5; and finally, section 7.6 concludes the chapter by highlighting the major policy implications.

7.2 Crop Insurance

The risk management performance of IYCI and AYCI depends on the specification of contract designs, such as coverage restrictions, and the characteristics of the farmer's yield distribution, such as yield basis risk. In this section, the impacts of coverage restrictions and yield basis risk on the relative performance of IYCI and AYCI are studied.

Economic Impacts of Coverage Restrictions

Current crop insurance contract designs specify the maximum trigger yield to be 75% of expected yield for IYCI and 90% of expected yield for AYCI. These restrictions may impact each instrument's ability to manage risk, as well as farmer welfare, because they limit the portion of the farmer's yield distribution that can be protected by the insurance instrument.

Under the current contract designs, the insured acreage is restricted to be roughly 100% of the planted acreage. Eliminating the 100% restriction and allowing farmers to choose the acreage coverage at any level may also improve contract performance and farmer welfare.

The trigger yield and acreage coverage restrictions in the current contract designs place an opportunity cost on the farmer relative to the unrestricted case. In addition, the relative performance, in terms of welfare effects, may differ significantly under the restrictions. The opportunity costs of trigger yield levels and acreage coverage restrictions in terms of farmer welfare are evaluated in this section.

The optimal trigger yield and willingness-to-pay measures are shown in the top half of Table 7.1 for a variety of trigger yield restrictions ranging from 75% of expected yield to the maximum possible yield level. The maximum trigger yields in the current IYCI and AYCI program are 75% and 90% of expected yield respectively. The maximum possible yield levels from the simulated yield distributions are 143% of the expected yield for IYCI and 134% of the expected yield for AYCI. Crop insurance is the only risk management instrument held in the portfolio, the premium for IYCI is 35% above the actuarially fair premium and the AYCI premium is actuarially fair, and the insured acreage is restricted to 100% of planted acreage.

If the trigger yield is selected at the maximum yield, yield risk is completely eliminated by IYCI. When the premium cost is set at the actuarially fair level or higher, the farmer would not choose any trigger yield above the maximum yield level, because further increasing the trigger yield will result in increasing the indemnity by a constant, while the corresponding premium will increase by an equivalent, or larger, constant. Therefore, setting the maximum trigger level at the maximum yield essentially places no restriction on the trigger yield. A similar argument holds for AYCI.

Table 7.1 Participation and Willingness-to-pay with Coverage Restrictions

Max. Trigger Yield Restr.	Negative Price-Yield Correlation						Zero Price-Yield Correlation					
	IYCI			AYCI			IYCI			AYCI		
	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP
Restricted Insured Acreage												
None	0.868	1.000	$26.37	1.216	1.000	$26.74	0.918	1.000	$30.47	Max.	1.000	$33.49
1.20	0.868	1.000	26.37	1.200	1.000	26.72	0.918	1.000	30.47	1.200	1.000	32.79
1.00	0.868	1.000	26.37	1.000	1.000	24.92	0.918	1.000	30.47	1.000	1.000	28.12
0.90	0.868	1.000	26.37	0.900	1.000	22.38	0.900	1.000	30.45	0.900	1.000	24.14
0.75	0.750	1.000	25.66	0.750	1.000	18.32	0.750	1.000	28.96	0.750	1.000	19.75
Unrestricted Model												
None	0.879	0.951	$26.39	1.324	0.853	$27.04	0.933	0.965	$30.48	Max.	1.040	$33.49
1.20	0.879	0.951	26.39	1.200	0.890	26.90	0.933	0.965	30.48	1.200	1.065	32.85
1.00	0.879	0.951	26.39	1.000	1.090	24.98	0.933	0.965	30.48	1.000	1.156	28.34
0.90	0.879	0.951	26.39	0.900	1.157	22.54	0.900	1.016	30.45	0.900	1.316	24.28
0.75	0.750	1.184	25.88	0.750	1.489	19.08	0.750	1.298	29.51	0.750	1.398	20.39

Note: All parameters are set at the values used in the base model. Trigger yield levels are expressed as a percent of expected yield and insured acreage is expressed as a percent of base acreage.

With negative price-yield correlation, the optimum IYCI trigger yield is 86.8% of expected yield, which leaves a large portion of yield variability left unprotected. This is partly a result of the premium loading. If the trigger yield is selected at a level higher than 86.8% of expected yield, the marginal increase in expected utility from reducing income risk will be lower than the marginal decrease in expected utility from lowering the income level as a result of the higher premium cost. In this case, the trigger yield only becomes a constraint when it set below 86.8%. Trigger yield restrictions set above 86.8% of expected yield impose no opportunity cost to this farmer. The current 75% restriction imposes an opportunity cost of only $0.71 per acre.

The optimum AYCI trigger yield is 121.6% of expected yield which is close to the maximum level. The AYCI premium is actuarially fair, so the farmer can use the instrument to eliminate risk without any reduction in expected income. The optimal trigger yield still remains lower than the maximum yield because, with the negative price-yield correlation, income risk is actually reduced by leaving a portion of yield variability. Any trigger yield restriction below 121% of expected yield imposes an opportunity cost to the farmer. The current 90% trigger yield restriction imposes an opportunity cost of $4.36 per acre.

Under the current trigger yield restrictions IYCI is the preferred instrument, providing a willingness-to-pay measure of $3.28 per acre more than AYCI. In contrast, when the trigger yield is not restricted, AYCI is the preferred instrument with a willingness-to-pay measure $0.37 per acre higher than IYCI. This suggests that if the trigger yield restrictions are removed, or at least increased, the AYCI can be an acceptable or even preferable alternative to IYCI.

As discussed earlier, eliminating the trigger yield restriction from IYCI may be difficult given the transaction costs inherent to an individual yield index. However, eliminating the trigger yield restriction in a contract that uses an area yield index may be feasible. When the IYCI trigger yield restriction is left at the 75% level, but the AYCI trigger yield is left unrestricted, AYCI is the preferred instrument and provides a willingness-to-pay measure $1.08 per acre above IYCI.

With no price-yield correlation, the optimum trigger yield increases to 92% of expected yield for IYCI and to the maximum yield for AYCI. The willingness-to-pay measures are higher than with negative price-yield correlation because the cash market income is more volatile, increasing the value of the crop insurance instruments.

With no price-yield correlation, the willingness-to-pay measure for AYCI with no trigger yield restriction is $3.02 per acre higher than IYCI, in contrast to the negative price-yield correlation case where it was only $0.37 per acre higher. Under the current trigger yield restrictions, the willingness-to-pay for IYCI is $4.82 per acre above AYCI. In both the zero and negative price-yield correlation cases, removing the trigger yield restrictions for AYCI results in higher farmer welfare than the actuarially unfair IYCI with or without trigger yield restrictions.

The optimal insured acreage and trigger yield levels, and the corresponding willingness-to-pay levels are listed in the bottom half of Table 7.1 for both IYCI and AYCI, when the number of acres covered by crop insurance (insured acreage) is also allowed to be chosen by the farmer.[20] The maximum trigger yield restrictions range from 75% of expected yield to the maximum yield level.

When price and yield are negatively correlated, the optimal trigger yield for IYCI is 87.9% of expected yield and the optimal insured acreage is 95.1% of planted acreage. Once again, the actuarially unfair premium, along with the negative price-yield correlation, contributes to the relatively low trigger yield and is an incentive to insure less than 100% of planted acreage.

For AYCI, the optimum trigger yield is 132.4% of expected yield and the optimal insured acreage is 85.3% of planted acreage. The trigger yield is slightly below the maximum yield and insured acreage is below the planted acreage as a result of the negative price-yield correlation. When there is no instrument available to manage price risk, the farmer has an incentive to leave a portion of the yield variability uninsured to offset the risk associated with the negatively correlated price. Without trigger yield or insured acreage restrictions, the willingness-to-pay for AYCI is $0.65 above IYCI.

When trigger yield restrictions are imposed, the insured acreage level increases. The increased insured acreage level is a substitute for the reduced trigger yield level. At the current level of trigger yield restrictions, the farmer's optimal insured acreage is larger than 100% of base acreage and IYCI is preferred to AYCI.

---

[20] From the general model (5.1), we can see that the position can also be interpreted as the percentage of selected price index to the predetermined price level (p_l), ie. expected cash price. In this research, the position is interpreted as the insured acreage.

Imposing the insured acreage restriction results in an opportunity cost to the farmer. However, the opportunity costs appear to be relatively small. With no trigger yield restrictions, the decrease in willingness-to-pay from restricting insured acreage to equal planted acreage is only $0.02 per acre for IYCI and $0.30 per acre for AYCI. Under the current trigger yield restrictions, the decrease in willingness-to-pay is $0.22 per acre for IYCI and $0.16 per acre for AYCI. These results also suggest that adjusting the level of insured acreage is not as effective as relaxing trigger yield restrictions to improve farmer welfare.

When the price and yield are not correlated, the insured acreage tends to increase along with the willingness-to-pay from the negative correlation case. As in negative price-yield correlation case, IYCI is preferred to AYCI under current trigger yield restrictions even if the insured acreage is not restricted.

Economic Impacts of Yield Basis Risk

The transaction costs associated with IYCI have resulted in a number of restrictions on contract design. In an effort to cover these costs, the IYCI premium is set at a level greater than the expected indemnification level for the typical farmer. The result is a decrease in participation and welfare for many farmers.

The low level of transaction costs associated with contracts using an area yield index allow the AYCI premium to be set close to the actuarially fair level. However, the existence of yield basis risk reduces the ability of AYCI to manage yield risk.

The tradeoff between higher IYCI premiums and the reduced ability of AYCI to manage yield risk as a result of higher yield basis risk is evaluated in this section. For each level of yield basis risk in AYCI, there exists a IYCI premium level which makes the farmer equally well off participating in IYCI as in the actuarially fair AYCI.

No Trigger Yield Restriction

The AYCI basis risk, welfare-equivalent IYCI premium and corresponding willingness-to-pay are listed in the top half of Table 7.2 for both negative and zero price-yield correlation cases. Crop insurance is the only risk management instrument allowed in the portfolio and there are no restrictions on the level of trigger yield. The tradeoff between yield basis and IYCI premium is show graphically in Figure 7.1.

Table 7.2 Welfare-Equivalent IYCI Premiums for Alternative AYCI Basis Levels

Negative Correlation			Zero Correlation		
IYCI Premium	WTP	Basis Risk	IYCI Premium	WTP	Basis Risk
No Trigger Yield Restrictions					
4.336	$13.16	0.63	2.415	$18.92	0.63
1.329	26.74	0.83	1.220	33.45	0.83
1.066	32.06	0.94	1.048	38.89	0.94
Under Current Restrictions					
22.142	$ 5.70	0.63	17.491	$ 6.50	0.63
1.663	22.38	0.83	1.816	24.14	0.83
1.094	28.46	0.94	1.049	31.62	0.94

Note: Yield basis risk is measured by the farm- and county-level yield correlation. Premium levels are expressed as a percent of the actuarially fair premium. WTP is willingness-to-pay in dollars.

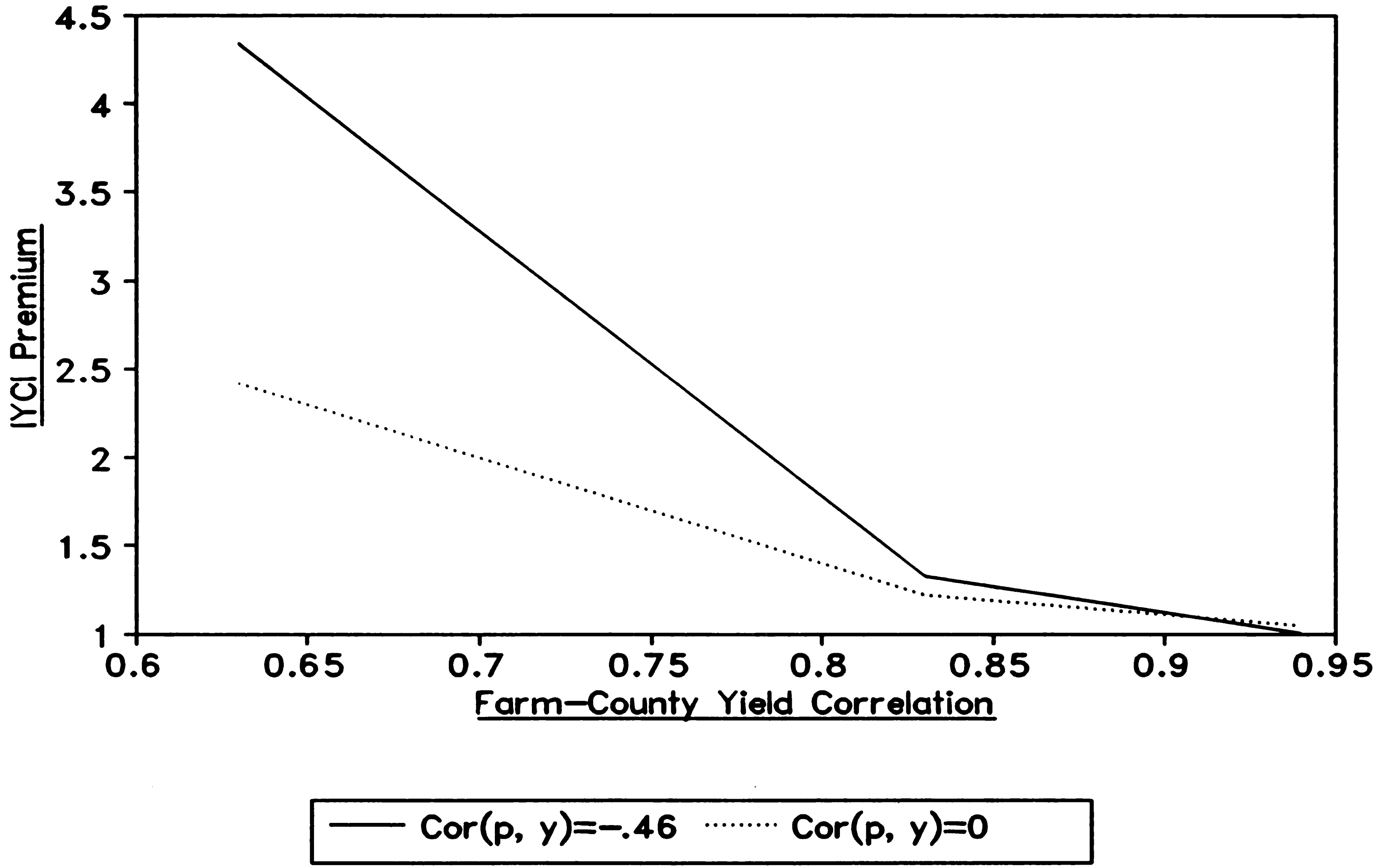

Figure 7.1 Tradeoff Curve Between the AYCI Basis Risk and the IYCI Premium without Trigger Yield Restriction

In the case of negative price-yield correlation, the IYCI premium that produces the same welfare level as AYCI ranges from 107% of the actuarially fair premium at a low level of basis risk (farm-county yield correlation of 0.94) to 434% at high level of basis risk (farm-county yield correlation of 0.63).

Notice that, when the yield basis risk is at the average level (farm-county yield correlation of 0.83), the corresponding IYCI premium is 133% of the actuarially fair premium, close to the 135% base premium level assumed in the previous analysis. This suggests that, with no trigger yield restrictions, a farmer with the average level of yield basis risk would be nearly indifferent between actuarially fair AYCI and IYCI under the 135% IYCI premium. The cost to a farmer of the basis risk in AYCI is roughly the same as the 35% IYCI premium loading.

A farmer in the high yield basis risk class (0.63) would prefer IYCI until the premium rises above 434% of the actuarially fair level; while a farmer in the low basis risk class (0.94) would prefer AYCI unless IYCI can charge a premium close to the actuarially fair level. Thus, without trigger yield restrictions, farmers with high levels of yield basis risk would prefer IYCI, while farmers with low basis risk will prefer AYCI.

When price and yield are not correlated, the welfare-equivalent IYCI premium decreases, suggesting that AYCI becomes a relatively more attractive instrument than in the negative price-yield correlation case. Farmers with the medium level of basis risk would prefer AYCI when the IYCI premium is above 122% of the actuarially fair level.

Thus, at the base 135% IYCI premium rate, AYCI would be the preferred instrument with no price-yield correlation.

Current Restrictions

The relative performance of IYCI and AYCI are evaluated again for different levels of AYCI basis risk under the existing trigger yield and insured acreage restrictions. The previous analysis found that the relative performance of AYCI compared to IYCI becomes poorer as restrictions were placed on trigger yield and insured acreage. The welfare-equivalent IYCI premiums for different levels of basis risk under current trigger yield and insured acreage restrictions are reported at the bottom of Table 7.2. Figure 7.2 shows this tradeoff between the IYCI premium and the level of basis risk.

The IYCI premium levels are higher than the corresponding values when no trigger yield restrictions are present, which is consistent with the previous results. When the yield basis risk is high, AYCI with a trigger yield restriction of 90% of expected yield provides the same welfare as IYCI with a premium 22 times the actuarially fair level, in contrast to 4 times the actuarially fair level with no trigger yield restriction.

At the average level of yield basis risk, IYCI is preferred to AYCI at the current IYCI 35% premium loading for both zero and negative price-yield correlation. This is in contrast to the case with no trigger yield restrictions where AYCI is slightly preferred to IYCI. One implication of the results is that constraints on the trigger yield level reduce the attractiveness of AYCI relative to IYCI.

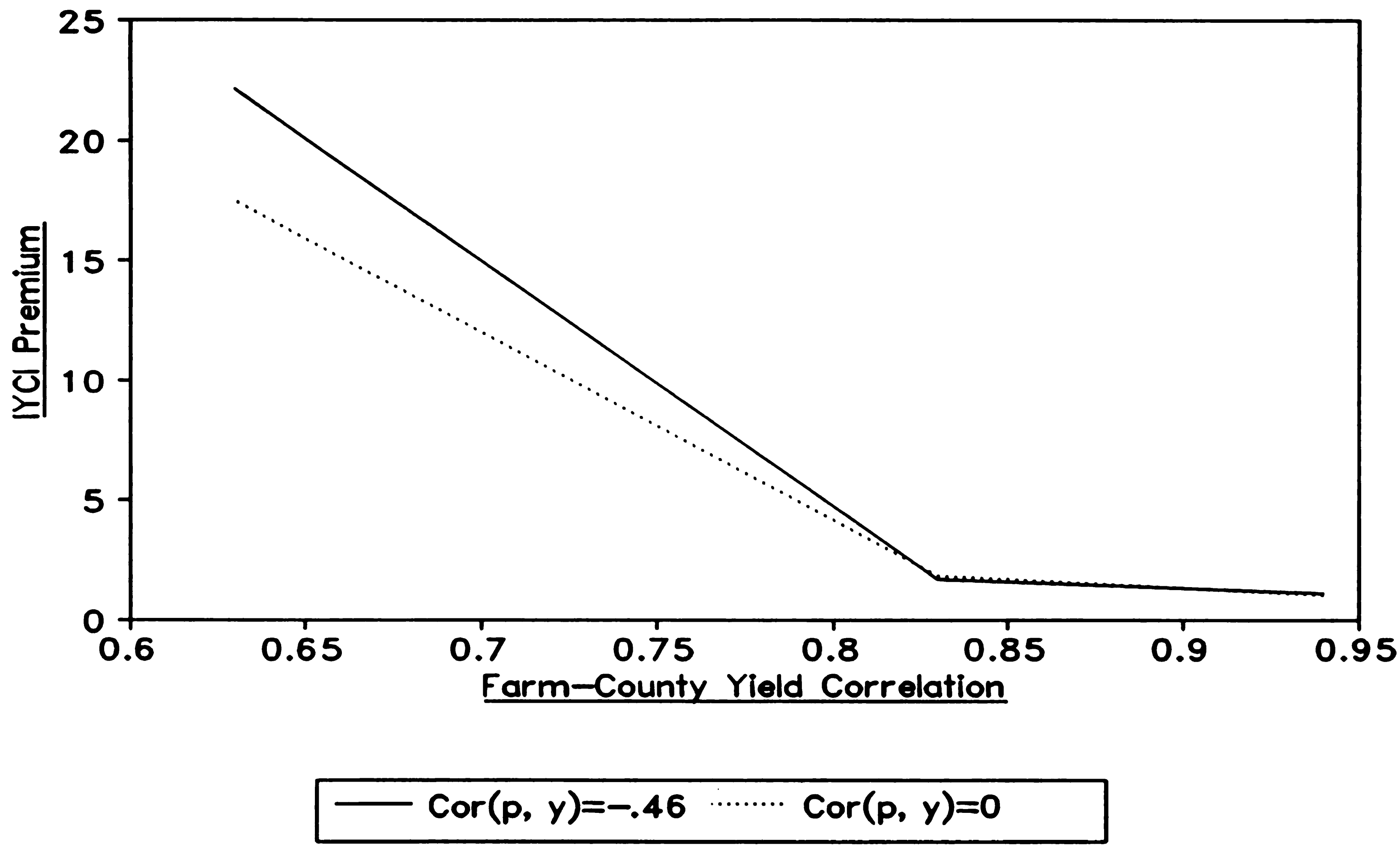

Figure 7.2 Tradeoff Curve between the AYCI Basis Risk and the IYCI Premium under the Current Trigger Yield Restrictions

This section has examined the relative performance of IYCI and AYCI under a number of alternative contract designs. The results indicate that, because of the high costs associated with IYCI, AYCI has the potential to be a preferred instrument, despite the yield basis risk associated AYCI.

Restricting the maximum trigger yield reduces the effectiveness of AYCI relative to IYCI. Under current trigger yield restrictions, IYCI is generally preferred to AYCI by the farmer with average yield basis risk. AYCI eliminates most of the moral hazard and adverse selection problems that have plagued IYCI and there appears to be little argument for restricting AYCI trigger yield levels. Removing AYCI trigger yield restrictions results in a contract design that, at average levels of yield basis, is generally preferred to the IYCI with a 35% premium loading and also avoids some of the transaction costs associated with IYCI.

The current insured acreage restriction (100% of planted acres) imposes little cost on the farmer and has little impact on the relative performance of AYCI to IYCI. There is a substitution effect between insured acres and the trigger yield because allowing farmers to select the insured acres above (below) 100% of the base acreage increases (decreases) the indemnity payment proportionally, but the substitution effect is weak.

7.3 Futures and Options

The previous section examined the performance of IYCI and AYCI when crop insurance was the only instrument available to manage income risk. When price and yield are correlated, crop insurance can be used to manage the price risk in addition to the yield risk faced by the farmer.

Adding instruments into the portfolio which are designed to manage price risk changes the role of crop insurance in the portfolio to one which focuses more directly on managing yield risk. This may change the performance of AYCI and IYCI. In this section, the economic performance of IYCI and AYCI are evaluated when futures and options are included in the farmer's portfolio.

Economic Impacts of Coverage Restrictions

The selected trigger yields and willingness-to-pay measures under alternative trigger yield restrictions are reported in the top half of Table 7.3 for portfolios containing crop insurance, futures and options. The amount of insured acreage is set at the base acreage level (planted acres), the AYCI premium is actuarially fair, and the IYCI premium is set 35% above the actuarially fair premium.

With no trigger yield restrictions and negative price yield correlation, the optimal trigger yield for both IYCI and AYCI increase slightly when futures and options are added to the portfolio. Futures and options are used to reduce the price risk faced by the farmer, reducing the need to cross hedge the price risk with the crop insurance instrument. This allows the farmer to increase the trigger yield level and reduce the level of yield risk.

The addition of futures and options also increases the willingness-to-pay at each trigger yield level although the increases are relatively small ranging from \$0.15 to \$2.15

Table 7.3 Participation and Willingness-to-pay with Futures and Options

Max. Trigger Yield	Negative Price-Yield Correlation						Zero Price-Yield Correlation					
	IYCI			AYCI			IYCI			AYCI		
Restr.	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP
Restricted Insured Acreage												
None	0.895	1.000	$27.47	Max.	1.000	$28.89	0.929	1.000	$33.41	Max.	1.000	$37.49
1.20	0.895	1.000	27.47	1.200	1.000	28.55	0.929	1.000	33.41	1.200	1.000	36.80
1.00	0.895	1.000	27.47	1.000	1.000	25.43	0.929	1.000	33.41	1.000	1.000	33.15
0.90	0.895	1.000	27.47	0.900	1.000	22.52	0.900	1.000	33.37	0.900	1.000	30.00
0.75	0.750	1.000	26.38	0.750	1.000	18.74	0.750	1.000	31.77	0.750	1.000	24.90
Unrestricted Model												
None	0.880	1.058	$27.49	Max.	1.006	$28.89	0.939	0.968	$33.41	Max.	1.045	$37.52
1.20	0.880	1.058	27.49	1.200	1.034	28.56	0.939	0.968	33.41	1.200	1.067	36.92
1.00	0.880	1.058	27.49	1.000	1.161	25.63	0.939	0.968	33.41	1.000	1.248	33.66
0.90	0.880	1.058	27.49	0.900	1.181	22.72	0.900	1.028	33.37	0.900	1.355	30.75
0.75	0.750	1.318	26.93	0.750	1.506	19.21	0.750	1.316	32.36	0.750	1.676	26.28

Note: All parameters are set at the values used in the base model. Trigger yield levels are expressed as a percent of expected yield and insured acreage is expressed as a percent of base acreage.

per acre with negative price-yield correlation. The increase in willingness-to-pay is larger when the trigger yield is higher for both IYCI and AYCI, suggesting that price instruments and crop insurance compliment each other.

The increase in willingness-to-pay for AYCI is higher than for IYCI when the trigger yield is high. However, when the trigger yield is low, the increase in willingness-to-pay for IYCI is higher than for AYCI. These results suggest including the pricing instruments in the portfolio further improves the performance of AYCI relative to IYCI, when the trigger yield restrictions are removed.

When price and yield are not correlated, the optimal trigger yield changes very little when futures and options are added to the portfolio. With no price-yield correlation, crop insurance could not be used to cross hedge price risk and so the addition of the pricing instruments to the portfolio has little impact on the use of the crop insurance instrument.

In contrast to the negative price-yield correlation case, the increase in willingness-to-pay when future and options are added to the portfolio is consistently higher for AYCI than IYCI. The reason is that the added value to the AYCI portfolio is decreasing with the decrease in trigger yield when prices and yields are negatively correlated but increasing in the no correlation case. This suggest adding futures and options to the portfolio improves the relative performance of AYCI to IYCI regardless of the trigger yield restrictions when there is no price-yield correlation.

The optimal insured acreage position, the optimal trigger yield, and willingness-to-pay for alternative maximum trigger yield restriction levels are reported in the bottom half of Table 7.3. The level of insured acreage increases slightly when futures and options are added to the portfolio. The size of the increase is larger when price and yield are negatively correlated than in the zero correlation case. Once again, when price and yield are negatively correlated, adding the price instruments to the portfolio reduces the cross-hedging role of crop insurance. This allows additional yield variability to be eliminated with the crop insurance instrument.

The unrestricted trigger yield selections increase insignificantly when adding futures and options while the insured acreage increases more than those in Table 7.1, suggesting that increasing insured acreage improves the risk management effectiveness of the crop insurance when futures and options are available.

While in many cases the optimal insured acreage differs significantly from base acreage, the opportunity cost of restricting the level of insured acres to the base acreage level remains small even when futures and options are added to the portfolio, ranging from \$0.00 to \$1.38 per acre. Thus, restricting insured acreage to base acreage imposes little cost on the farmer.

Economic Impacts of Yield Basis Risk

The addition of futures and options into the portfolio may affect the relative performance of IYCI and AYCI under alternative basis risk levels. These effects are studied in this section.

No Trigger Yield Restriction

The top half of Table 7.4 shows the welfare-equivalent IYCI premium for alternative levels of AYCI yield basis for both negative and zero price-yield correlations when there is no trigger yield restriction and futures and options are included in the portfolio.

Table 7.4 Welfare-Equivalent IYCI Premiums for Alternative AYCI Basis Levels with Futures and Options

Negative Correlation			Zero Correlation		
IYCI Premium	WTP	AYCI Basis	IYCI Premium	WTP	AYCI Basis
No Trigger Yield Restriction					
3.444	$15.16	0.63	2.879	$19.27	0.63
1.278	28.89	0.83	1.185	37.49	0.83
1.057	34.50	0.94	1.052	42.01	0.94
Under Current Restrictions					
5.946	$11.25	0.63	7.110	$11.47	0.63
1.717	22.52	0.83	1.514	30.00	0.83
1.115	28.96	0.94	1.100	34.51	0.94

Note: Futures and options are included in the portfolio with crop insurance. Yield basis risk is expressed by the farm- and county-level yield correlation; WTP is the willingness-to-pay in dollars.

Naturally, the willingness-to-pay for price and yield risk instruments in Table 7.4 is higher than the willingness-to-pay for crop insurance alone in Table 7.2. For the average level of yield basis risk (.83), adding futures and options to the portfolio increases willingness-to-pay by $2.15 and $3.99 per acre for the negative and zero price-yield correlation cases, respectively.

When price and yield are negatively correlated, the welfare-equivalent IYCI premium is lower with futures and options in the portfolio. This indicates that, when the price-yield correlation is negative, the relative performance of AYCI improves when the price instruments are included in the portfolio. With price instruments available, AYCI can be used to manage yield risk more directly which allows the farmer to select a larger trigger yield and eliminate a larger portion of the yield risk. Adding the price instruments to the portfolio also allows IYCI to be used to manage yield risk more directly; however, the transaction costs built into the IYCI premium impose an additional cost as the farmer increases the trigger yield, providing a relative advantage to AYCI.

With no price-yield correlation, adding futures and options to the portfolio results in a small change in the welfare-equivalent IYCI premium. At the average level of basis risk, the welfare-equivalent premium decreases by 3.5 percent of the actuarially fair premium with futures and options added to the portfolio.

Current Restrictions

The welfare-equivalent IYCI premiums and willingness-to-pay for alternative levels of yield basis risk when futures and options are included in the portfolio, and both IYCI and AYCI are under current maximum trigger yield restrictions, are shown at the bottom of Table 7.4. The willingness-to-pay measures increase when futures and options are added to the portfolio. In general, the increases are in the $3 to $6 per acre range.

However, for average and low levels of yield basis risk, the increases are less than \$0.50 per acre when price and yield are negatively correlated. Because AYCI does not manage yield risk efficiently for high basis risk farmers, futures and options are again used to cross hedge yield risk, and the risk management value of futures and options is relatively high when combined with AYCI for high basis risk farmers.

At high levels of yield basis risk (0.63), adding futures and options to the portfolio causes a significant decrease in the welfare-equivalent IYCI premium, because, futures and options are used to manage price risk in the portfolio with IYCI, and their added risk management value is less than that with AYCI. Therefore, a lower IYCI premium is needed to obtain the equivalent welfare level. Thus, adding futures and options improves the relative performance AYCI when the yield basis risk is high. However, IYCI still significantly outperforms AYCI when the yield basis risk is high, as evidenced by the level of welfare-equivalent IYCI premium (5.9 and 7.1 with negative and zero price-yield correlation, respectively).

At average and low levels of yield basis risk, the welfare-equivalent IYCI premiums show relatively small increases when price and yield are negatively correlated, suggesting a decrease in the relative performance of AYCI when futures and options are added. Likewise, with no price-yield correlation and average yield basis, the welfare-equivalent IYCI premium increases. However, when the price-yield correlation is zero and there is little yield basis risk, the welfare-equivalent IYCI premium actually decreases slightly.

The results suggest the addition of futures and options to the portfolio can impact the relative performance of AYCI to IYCI, but the impact depends ambiguously on the level of yield basis risk. However, at the average level of yield basis risk IYCI still outperforms AYCI under current trigger yield restrictions when futures and options are added to the portfolio.

7.4 Government Program

The current government deficiency payment program provides a mechanism to manage price risk. The deficiency payment program has many of the same characteristics as a put option in terms of reducing price risk. The program also provides an implicit subsidy to farmers who participate in the program. Including the government program in the portfolio with crop insurance may impact the use of the insurance instrument as well as the welfare of farmers. In addition, the relative performance of IYCI and AYCI may change as a result of adding the deficiency payment program to the portfolio.

Economic Impacts of Coverage Restrictions

The selected trigger yields and willingness-to-pay measures under alternative trigger yield restrictions are reported in the top half of Table 7.5 for portfolios that include the government deficiency payment program. The insured acreage level is set at the base acreage and the IYCI premium loading is 35%.

Table 7.5 Participation and Willingness-to-pay with the Government Program

Max. Trigger Yield Restr.	Negative Price-Yield Correlation						Zero Price-Yield Correlation					
	IYCI			AYCI			IYCI			AYCI		
	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP	Trigger	Ins.Acre.	WTP
Restricted Insured Acreage												
None	0.906	1.000	$52.89	Max.	1.000	$56.89	0.905	1.000	$58.85	Max.	1.000	$64.33
1.20	0.906	1.000	52.89	1.200	1.000	56.46	0.905	1.000	58.85	1.200	1.000	63.75
1.00	0.906	1.000	52.89	1.000	1.000	52.67	0.905	1.000	58.85	1.000	1.000	60.09
0.90	0.900	1.000	52.89	0.900	1.000	49.23	0.900	1.000	58.85	0.900	1.000	57.11
0.75	0.750	1.000	51.45	0.750	1.000	44.58	0.750	1.000	57.58	0.750	1.000	52.66
Unrestricted Model												
None	0.887	1.064	$52.92	Max.	1.046	$56.92	0.910	0.982	$58.85	Max.	1.054	$64.37
1.20	0.887	1.064	52.92	1.200	1.084	56.56	0.910	0.982	58.85	1.200	1.082	63.83
1.00	0.887	1.064	52.92	1.000	1.282	53.34	0.910	0.982	58.85	1.000	1.269	60.66
0.90	0.887	1.064	52.92	0.900	1.354	50.04	0.900	0.998	58.85	0.900	1.373	57.91
0.75	0.750	1.349	52.25	0.750	1.661	46.17	0.750	1.286	58.08	0.750	1.705	54.17

Note: All parameters are set at the values used in the base model. Trigger yield levels are expressed as a percent of expected yield and insured acreage is expressed as a percent of base acreage.

With negative price-yield correlation, the optimal trigger yield increases slightly when the government program is included in the portfolio unless the maximum trigger yield is a constraint. The willingness-to-pay measures, which include the implicit program subsidy, are increased significantly when the government program is included in the portfolio.

When price and yield are not correlated, the unrestricted trigger yield decreases slightly for IYCI and remains unchanged for AYCI at the maximum trigger yield constraint when the government program is added to the portfolio. The willingness-to-pay measures increase less than in the negative correlation case. The increase in willingness-to-pay measures are larger for AYCI than for IYCI which indicates adding the government program to the portfolio improves the relative performance of AYCI.

With the government program included in the portfolio, the willingness-to-pay for the AYCI portfolio remains below that for the IYCI portfolio under current trigger yield restrictions. However, the difference in welfare from the two yield indices is significantly reduced when the government program is added to the portfolio. When price and yield are negatively correlated, the difference in willingness-to-pay at current trigger yield restriction levels is \$2.22 per acre with the government program in the portfolio as opposed to \$3.28 per acre in the crop insurance only portfolio and \$3.86 in the futures, options, and crop insurance portfolio.

The optimal insured acreage and trigger yield levels, and willingness-to-pay for alternative trigger yield restriction levels are reported in the bottom half of Table 7.5, when the insured acreage is allowed to be selected. Once again, the optimal insured acreage levels are significantly above the base acreage level when the trigger yield restrictions are set at low levels. However, the opportunity costs of the restriction are relatively small, ranging from $0.00 to $1.59 per acre. The opportunity costs are highest at low trigger yield levels, and approach zero as the trigger yield restrictions are removed. Once again, there appears to be little gain in relaxing the current restrictions on insured acreage.

Economic Impacts of Yield Basis Risk

The risk management performance of AYCI under alternative yield basis risk levels relative to the performance of IYCI is studied in this section when the government program is included in the portfolio.

No Trigger Yield Restriction

The welfare-equivalent IYCI premiums for alternative levels of AYCI yield basis risk and willingness-to-pay measures are shown in the top half of Table 7.6 when there are no trigger yield restrictions and the government deficiency payment program is included in the portfolio with crop insurance. The insured position is fixed at the base acreage level.

The willingness-to-pay is significantly higher when the government program is included in the portfolio instead of futures and options. The major reason for the increase is the government program provides an implicit subsidy of about $33 per acre.

Table 7.6 Welfare-Equivalent IYCI Premiums for Alternative AYCI Basis Levels with Government Program

Negative Correlation			Zero Correlation		
IYCI Premium	WTP	AYCI Basis	IYCI Premium	WTP	AYCI Basis
No Trigger Yield Restrictions					
2.149	$44.33	0.63	1.998	$49.80	0.63
1.196	56.89	0.83	1.153	64.33	0.83
1.054	61.44	0.94	1.016	68.79	0.94
Under Current Restriction					
2.449	$40.74	0.63	2.657	$45.80	0.63
1.528	49.23	0.83	1.388	57.11	0.83
1.118	54.40	0.94	1.013	61.34	0.94

Note: Government program is included in the portfolio with crop insurance. Yield basis risk is expressed by the farm- and county-level yield correlation; WTP is the willingness-to-pay.

The welfare-equivalent IYCI premium is reduced when the government program is included in the portfolio, below the levels when futures and options were included in the portfolio. This suggests that including the deficiency payment program in the portfolio improves the performance of AYCI relative to IYCI. At the average level of yield basis risk, the farmer will prefer AYCI to IYCI at the 35% IYCI premium loading. The main reason is that, because mean income is increased by the subsidy implicit in the government program, the farmer cares less about the risk due to the CRRA preference. The basis risk associated with AYCI is relatively less important than IYCI actuarially unfair premium loading.

Current Restrictions

The tradeoff between IYCI and AYCI is studied again under the current trigger yield restrictions. The welfare-equivalent IYCI premium and willingness-to-pay measures are shown in the bottom half of Table 7.6.

Adding the government program to the portfolio decreases the welfare-equivalent premiums for farmers with average or high levels of yield-basis risk relative to those in the crop insurance only portfolio and the crop insurance, futures and options portfolio. At low levels of yield-basis risk, adding the government program to the portfolio increases (decreases) the welfare-equivalent premiums slightly relative to the other portfolios when the yield-basis risk is negative (zero).

The most significant decreases are realized by farmers with high levels of yield-basis risk; again, because the mean income increase causes the farmer to care less about income risk and the high yield basis risk doesn't harm AYCI as much as before. However, IYCI still strongly outperforms AYCI when basis risk is high. While adding the government program to the portfolio improved the relative performance of AYCI, IYCI is still preferred by farmer's with the average level of yield-basis risk at the 35% IYCI premium loading. Once again, farmers with low levels of yield-basis risk favor AYCI.

7.5 Other Contract Design Parameters

In the previous sections, we studied participation and welfare effects for a number of alternative design parameters including the yield index, maximum trigger yield restriction, and insured acreage restriction. There are other contract design parameters that may affect the risk management performance of crop insurance, such as the premium rate and the price index used to value yield shortfalls.

The IYCI premium needs to be set above the actuarially fair level for the typical farmer to help the program become financially feasible. The cost of the premium loading is that the higher premium will cause farmers to buy less insurance (select lower trigger yield), exposing them to higher yield risk and a lower farmer welfare level. The premium for AYCI could be slightly above the actuarially fair level because there might be some transaction costs to implement the scheme. However, without moral hazard, adverse selection, and high operating cost, the transaction costs associated with AYCI are generally low which keeps the premium at levels close to actuarially fair.

The price index used to calculate the indemnity payout is another parameter that must be specified for both IYCI and AYCI. The specification of the price index may have implications for the risk management performance for each contract. Numeric analysis was undertaken for a number of alternative price indices: the expected cash price at harvest, the expected futures price at harvest, the realized cash price at harvest, and the realized futures price at harvest. The results suggest that using stochastic prices, such as cash price or futures price at harvest, is generally dominated by using deterministic prices, such as expected cash price or futures price, although by a very small margin.

Interestingly, allowing the representative farmer to select a deterministic price index level has an identical effect to allowing them to select an insured acreage level because each of the levels is a multiplying factor to the indemnity received less premium cost in our model. Therefore, the results regarding the insured acreage level apply here. Under current trigger yield restrictions, a higher deterministic price is preferred for both IYCI and AYCI, but the welfare gain is small.

7.6 Summary and Conclusion

Historically, crop insurance programs have been designed around individual farm yield indices (IYCI) to determine indemnification payouts. Transaction costs associated with moral hazard, adverse selection, spatial correlation, implementation, and measurement have combined to hinder the financial soundness of these programs. Efforts to reduce these transaction costs have resulted in restrictions on insurance contract design. These restrictions have still failed to result in a financially sound program and have reduced the attractiveness of the crop insurance instruments to farmers. Premiums above the actuarially fair level for most farmers have been used to help finance the programs.

Recently, experimental crop insurance programs have been developed which use area yield indices (AYCI) to determine indemnification payouts in an effort to reduce the problems associated with IYCI. If the use of an area yield index can reduce these problems sufficiently, AYCI can be offered at premium levels that are close to actuarially fair levels.

The primary disadvantage of AYCI is that farmer yield is generally not perfectly correlated with the area yield index, which reduces the ability of the instrument to manage individual farm yield. However, the current AYCI design features also include a number of design restrictions which are similar to IYCI. Because AYCI does not face the same transaction difficulties as IYCI, it may be feasible to eliminate some restrictions and improve the performance of AYCI. Two of the restrictions examined are the maximum trigger yield level and amount of insured acreage.

The results suggest that IYCI is preferred to AYCI under the current levels of trigger yield restrictions by farmers with average yield basis risk. However, removing the AYCI trigger yield restrictions makes AYCI preferred to IYCI with a 35% premium loading. The use of the area yield index essentially eliminates the adverse selection and moral hazard problems associated with the individual yield index, allowing relaxation of trigger yield restriction in AYCI.

Current restrictions on insured acreage levels were found to have relatively small impacts on farmer welfare and the relative performance of IYCI and AYCI. The opportunity costs of the current 100% insured acreage restrictions are highest when the trigger yields are restricted to low levels, but essentially disappear as the trigger yield restrictions are removed. Thus, there appears to be little gain from removing the restrictions on insured acreage, particularly if the trigger yield restrictions are relaxed for AYCI.

Adding futures and options or a government deficiency payment program into the portfolio increases farmer welfare and improves the relative performance of AYCI for high levels of yield-basis risk. The government program improves the relative performance of AYCI more than futures and options at high levels of yield basis risk.

However, IYCI is still preferred to AYCI under current trigger yield restrictions by farmers with average yield basis risk, even when the government program is included in the portfolio.

The major policy implication is that AYCI can be an attractive substitute for IYCI if the trigger yield restrictions are removed for AYCI. There appears to be no clear reason to institute the current restrictions on trigger yield levels when an area yield index is used to determine indemnity payouts.

The results depend significantly on the level of yield basis risk with AYCI becoming more desirable as the yield basis risk decreases. Consequently, the more localized the area yield index, the more desirable AYCI becomes in general. This suggests an area index which is defined over a broad geographic region will decrease the competitiveness of the AYCI instrument relative to an index defined over a smaller geographical region.

Chapter VIII

ECONOMIC EVALUATION OF THE GOVERNMENT DEFICIENCY PAYMENT PROGRAM

Recent political debates have focused on the reduction and/or elimination of the government deficiency payment and target price programs provided by USDA. The issue facing farmers in this discussion is not increased exposure to price risk, because futures and options can be used to manage price risk. The real loss to farmers from elimination or reduction of the government program is the implicit subsidy, which for the base case was estimated to be about $33 per acre in 1994.

Current federal budget difficulties have increased discussions about the need for and level of subsidization provided to farmers. The government subsidy level will inevitably be reduced in the future. In our model, based on the farm programs in place during 1994, the level of subsidy can be reduced by increasing set aside acreage and flexible acreage, and/or reducing the level of the target price. These design changes not only impact the level of subsidy but also the risk reduction effect from participation in the program. As a result, changes in the program design may have significant impacts on participation in the program and other instruments, as well as on farmer welfare.

The design parameters of the government deficiency payment program are often adjusted each year. The previous analysis used 1994 program specifications. The impacts of the changes in the 1994 program design on participation and farmer welfare are studied in this chapter. The target price, p_T, acreage reduction amount, r, and flexible acreage, q, values which are considered in this chapter are listed in Table 8.1.

Table 8.1 Alternative Government Program Design Parameters

Parameter	Notation	1994 Value	Changes Evaluated	
Target price	p_T	\$2.75/bu	-\$0.10	-\$0.25
Flexible acreage	q	15%	+15%	-15%
Acreage reduction program	r	0	+5%	+10%

Each design parameter is changed individually while holding all the remaining parameters at their values in the base model. The target price, p_T, is decreased by \$0.10 and by \$0.25 per bushel. The flexible acreage is decreased to 0% and increased to 30% of base acreage, to evaluate a range of possible levels. The acreage reduction program (ARP) is increased to both 5% and 10% of base acreage which encompass requirements in recent years.

Changes in the design of government program only affect cases where the program is included in the portfolio, so only these cases are analyzed and reported. There are six portfolios studied in this section: 1) government program only; 2) government program, futures, and options; 3) government program and IYCI; 4) government program and AYCI; 5) government program, futures, options, and IYCI; and 6) government program, futures, options, and AYCI, respectively.

8.1 Change in Target Price

The change in target price level directly affects the expected subsidy to farmers, the cost to the government, and the farmer's income risk. In 1994, the target price was set at $2.75/bu for corn, higher than the expected cash price of $2.48/bu. Participation in the program essentially eliminates all price variability below the target price level, and also increases the expected price the farmer receives.

The impacts of decreasing the target price on market positions and farmer welfare are studied in this section. Market participation levels and the resulting willingness-to-pay levels associated with alternative target prices are reported in Tables 8.2 and 8.3 respectively. For convenience, the results from the 1994 base model are also reported in each table.

Two general results are immediately apparent from the tables. First, the willingness-to-pay levels indicate that participating in the government deficiency payment program is always preferred to not participating, when the target price changes within the allowed range. And second, the trigger yield is always selected at the maximum level, 75% for IYCI and 90% for AYCI, whenever crop insurance is available.

A ceteris paribus decrease in the target price leads to a decrease in futures and option positions. As the target price decreases, the farmer tends to sell more put options and buy less (or sell more) futures. The reason for the change with no price-yield correlation is that a decrease in the target price increases price variability so that the farmer tends to sell more futures to manage the price risk. While in the negative

Table 8.2 Participation Levels for alternative Target Price Levels

Case	Portfolio									
	Futures, Options and Govt.		Govt. and IYCI	Govt. and AYCI	Futures, Options, Govt. and IYCI			Futures, Options, Govt. and AYCI		
	Futures	Options	IYCI	AYCI	Futures	Options	IYCI	Futures	Options	AYCI
Negative Price-Yield Correlation										
Base	0.47	-0.50	0.75	0.90	0.21	-0.01	0.75	0.19	-0.27	0.90
p_T - \$0.10	0.25	-0.79	0.75	0.90	0.10	-0.11	0.75	0.11	-0.33	0.90
p_T - \$0.25	0.19	-0.71	0.75	0.90	-0.00	-0.12	0.75	0.02	-0.36	0.90
Zero Price-Yield Correlation										
Base	-0.59	-1.02	0.75	0.90	-0.37	-0.35	0.75	-0.33	-0.18	0.90
p_T - \$0.10	-0.68	-1.12	0.75	0.90	-0.44	-0.40	0.75	-0.40	-0.24	0.90
p_T - \$0.25	-0.80	-1.19	0.75	0.90	-0.54	-0.42	0.75	-0.50	-0.26	0.90

Note: Participation levels are reported as the percent of the expected farm-level yield hedged on the futures, options market, or chosen as the trigger yield for crop insurance.

Table 8.3 Willingness-to-Pay for Alternative Target Price Levels

Case	Portfolio					
	Govt. Only	Futures, Options and Govt.	Govt. and IYCI	Govt. and AYCI	Futures, Options, Govt. and IYCI	Futures, Options, Govt. and AYCI
Negative Price-Yield Correlation						
Base	\$0.35	\$32.53	\$51.45	\$49.23	\$51.76	\$50.13
p_T - \$0.10	0.24	24.41	45.67	43.06	45.83	43.76
p_T - \$0.25	0.13	16.41	38.52	35.36	38.55	35.80
Zero Price-Yield Correlation						
Base	\$33.76	\$36.21	\$57.58	\$57.11	\$57.87	\$57.53
p_T - \$0.10	25.55	28.98	51.35	50.52	51.79	51.15
p_T - \$0.25	15.29	20.76	43.51	42.12	44.28	43.24

correlation case, a decrease in the target price increases price variability and less futures are bought to cross hedge the yield risk.

Willingness-to-pay generally decreases as the target price decreases, primarily because the value of implicit subsidy is reduced. In the negative price-yield correlation case, when the government program is the only instrument in the portfolio, the decrease in willingness-to-pay is only \$0.22 per acre when the target price is reduced \$0.25 per bushel, because the gain in risk reduction nearly offsets the loss in subsidy value due to the negative price-yield correlation. In the portfolios that contain other risk instruments, the decrease in willingness-to-pay ranges from \$12.93 to \$16.12 per acre when the target price drops \$0.25 per bushel.

In the zero price-yield correlation case, when the government program is the only instrument in the portfolio, the willingness-to-pay drops \$18.47 per acre when the target price is reduced \$0.25 per bushel. This is much more than in the negative correlation case because the decrease in the target price now decreases both the risk management value of the program and the subsidy. When other risk management instruments are included in the portfolio, the willingness-to-pay drops by levels similar to in the negative price-yield correlation case, ranging from \$13.59 to \$15.45 per acre as the target price decreases \$0.25 per bushel.

The results show that farmer welfare change in response to a change in the target price is generally robust to the price-yield correlation when other instruments are included in the portfolio. This is because the welfare change comes mainly from the implicit subsidy which is independent of the correlation, while the income risk is managed using other instruments. However, the welfare change becomes sensitive to the price-yield correlation when the government program is the only instrument in the portfolio, because the correlation affects the risk distribution and the government program is inflexible and ineffective in managing income risk.

8.2 Change in Flexible Acreage

Like the target price, a change in flexible acreage can impact the subsidy level and risk management capability of the government program. However, unlike the target price, a change in flexible acreage does not impact the level of subsidy per bushel but, instead, affects the number of acres eligible to receive the deficiency payment. As a result, increasing flexible acres impacts both the level of subsidy per base acre to the farmer as well as the proportion of production that receives the minimum price from the deficiency payments.

The impacts of changing flexible acreage on market positions and farmer welfare are studied in this section. Market participation levels and the resulting willingness-to-pay levels associated with alternative flexible acreage levels are reported in Tables 8.4 and 8.5 respectively. For convenience, the results from the base model under the 1994 program design are again reported in the tables. Once again, the crop insurance trigger yield is always selected at the maximum level, and the farmer always participates in the government program.

A ceteris paribus change in flexible acreage leads to a change in futures in the opposite direction and a change in options in the same direction. That is, when flexible

Table 8.4 Participation Levels for Alternative Flexible Acreage Levels

Case	Portfolio									
	Futures, Options and Govt.		Govt. and IYCI	Govt. and AYCI	Futures, Options, Govt. and IYCI			Futures, Options, Govt. and AYCI		
	Futures	Options	IYCI	AYCI	Futures	Options	IYCI	Futures	Options	AYCI
Negative Price-Yield Correlation										
Base	0.47	-0.50	0.75	0.90	0.21	-0.01	0.75	0.19	-0.27	0.90
q + 15%	0.44	-0.41	0.75	0.90	0.13	-0.00	0.75	0.16	-0.18	0.90
q - 15%	0.51	-0.59	0.75	0.90	0.21	-0.18	0.75	0.22	-0.36	0.90
Zero Price-Yield Correlation										
Base	-0.59	-1.02	0.75	0.90	-0.37	-0.35	0.75	-0.33	-0.18	0.90
q +15%	-0.61	-0.92	0.75	0.90	-0.40	-0.26	0.75	-0.36	-0.09	0.90
q - 15%	-0.56	-1.10	0.75	0.90	-0.33	-0.45	0.75	-0.29	-0.28	0.90

Note: Participation levels are reported as the percent of the expected farm-level yield hedged on the futures, options market, or chosen as the trigger yield for crop insurance.

Table 8.5 Willingness-to-Pay for Alternative Flexible Acreage Levels

	Portfolio					
Case	Govt. Only	Futures, Options and Govt.	Govt. and IYCI	Govt. and AYCI	Futures, Options, Govt. and IYCI	Futures, Options, Govt. and AYCI
Negative Price-Yield Correlation						
Base	$0.35	$32.53	$51.45	$49.23	$51.76	$50.13
q + 15%	0.29	27.55	47.02	44.64	47.14	45.18
q - 15%	0.42	37.53	55.82	53.74	56.41	55.09
Zero Price-Yield Correlation						
Base	$33.76	$36.21	$57.58	$57.11	$57.87	$57.53
q + 15%	28.48	30.94	52.66	51.84	53.15	52.60
q - 15%	38.88	41.49	62.43	62.26	62.62	62.47

acreage is increased (decreased), the farmer tends to sell less (more) options and buy less (more) or sell more (less) futures. As discussed earlier, the government program is a substitute for options and futures. When the flexible acreage increases (decreases), less (more) put options will be sold, and less (more) futures will be bought in the negative price-yield correlation case, and more (less) futures will be sold in the zero price-yield correlation case. However, the change in the positions are all small.

The willingness-to-pay for the portfolio decreases as the flexible acreage percentage increases, because there is less acreage that can claim the deficiency payment which reduces the implicit subsidy inherent in the government program.

In the negative price-yield correlation case, when the government program is the only instrument in the portfolio, then the willingness-to-pay change is only $0.07, as a result of the subsidy/risk tradeoff discussed earlier. With other risk instruments in the portfolio, the willingness-to-pay increases between $4.37 and $5.00 per acre when the flexible acreage percentage decreases 15% and declines between $4.43 and $4.98 per acre when the flexible percentage increases 15%. In this case, futures and options can substitute for the government program in managing risk, so the change in subsidy is the main cause of the willingness-to-pay change.

In the zero price-yield correlation case, when the government program is the only instrument in the portfolio, the change in willingness-to-pay is much higher than the negative correlation case, about $5.00 per acre, when the flexible acreage changes by 15% of the base acreage. When at least one other risk management instrument is included in the portfolio, the change in the willingness-to-pay ranges from \$4.75 to \$5.28 per acre, slightly higher than the negative price-yield correlation case.

For both negative and zero price-yield correlation cases, the changes in futures and options positions and willingness-to-pay for a 15% increase in flexible acreage are smaller than the corresponding changes caused by a \$0.25 per bushel decrease in the target price. These results show that decreasing the target price to the level of expected cash price reduces farmer welfare more than increasing flexible acreage to 30%, because the government subsidy is reduced more.

8.3 Change in Acreage Reductions

The ARP is the proportion of land that must be left idle in order for the farmer to participate in the program. If the ARP is zero, as in the 1994 base case, the program provides subsidy and price risk protection to the farmer for free. As with flexible acreage, change in ARP does not affect the subsidy per bushel directly, but the subsidy per base acre. Furthermore, it affects the output levels because it requires a portion of land to be removed from production.

The impacts of increasing ARP on market positions and farmer welfare are studied in this section. Market participation levels and the resulting willingness-to-pay levels associated with alternative ARP levels are reported in Tables 8.6 and 8.7 respectively. For convenience, the results for the 1994 base model are again reported in these tables.

Table 8.6 Participation Levels for Alternative ARP Levels

Case	Portfolio									
	Futures, Options and Govt.		Govt. and IYCI	Govt. and AYCI	Futures, Options, Govt. and IYCI			Futures, Options, Govt. and AYCI		
	Futures	Options	IYCI	AYCI	Futures	Options	IYCI	Futures	Options	AYCI
Negative Price-Yield Correlation										
Base	0.47	-0.50	0.75	0.90	0.21	-0.01	0.75	0.19	-0.27	0.90
r + 5%	0.45	-0.47	0.75	0.90	0.16	-0.07	0.75	0.18	-0.25	0.90
r + 10%	0.42	-0.44	0.75	0.90	0.15	-0.06	0.75	0.17	-0.23	0.90
Zero Price-Yield Correlation										
Base	-0.59	-1.02	0.75	0.90	-0.37	-0.35	0.75	-0.33	-0.18	0.90
r + 5%	-0.56	-0.95	0.75	0.90	-0.35	-0.33	0.75	-0.31	-0.17	0.90
r + 10%	-0.53	-0.90	0.75	0.90	-0.33	-0.31	0.75	-0.30	-0.16	0.90

Note: Participation levels are reported as the percent of the expected farm-level yield hedged on the futures, options market, or chosen as the trigger yield for crop insurance.

Table 8.7 Willingness-to-Pay for Alternative ARP Levels

	Portfolio					
Case	Govt. Only	Futures, Options and Govt.	Govt. and IYCI	Govt.1 and AYCI	Futures, Options, Govt. and IYCI	Futures, Options, Govt. and AYCI
Negative Price-Yield Correlation						
Base	\$0.35	\$32.53	\$51.45	\$49.23	\$51.76	\$50.13
r + 5%	0.15	22.81	39.53	37.53	39.79	38.31
r + 10%	0.00	14.29	28.40	26.65	28.62	27.32
Zero Price-Yield Correlation						
Base	\$33.76	\$36.21	\$57.58	\$57.11	\$57.87	\$57.53
r + 5%	24.56	26.68	45.67	45.23	45.93	45.62
r + 10%	16.43	18.17	34.47	34.07	34.72	34.43

Once again, the trigger yield is always selected at the maximum level when crop insurance is available. However, unlike the previous cases, when only the government program is included in the portfolio, the ARP is set at 10% of the base acreage, and price and yield are negatively correlated, the farmer becomes indifferent about whether participating in the program or not because the program now brings zero welfare gain to him/her. When other instruments are included in the portfolio, the farmer continues to participate in the government program.

A 10% acreage increase in ARP induces changes in futures and options positions and the direction of the changes is sensitive to both the price-yield correlation and the portfolio. The changes can be partly explained by the substitution relationship between the government program and futures and options in managing price risk, just as in the flexible acreage change case. Furthermore, the reduced output from the land removed under ARP introduces additional opportunity cost to the farmer, which contributes to the differences in market position changes relative to the flexible acreage case. However, the changes are all small compared with the changes caused by a $0.25 per bushel decrease in the target price or a 15% increase in flexible acreage.

The willingness-to-pay decreases as the ARP increases, and the decrease is more rapid than for a comparable increase in flexible acreage because the increase in ARP not only reduces the subsidy effect of the government program, but also increases the opportunity cost of the land removed from the program.

In the case of negative price-yield correlation, when the government program is the only instrument in the portfolio, the decrease in willingness-to-pay is only $0.35 per acre when the ARP increases by 10%. Although the decrease is small in this case, the willingness-to-pay for the government program drops to zero. However, with other risk instruments in the portfolio, the decrease in willingness-to-pay ranges between $18.24 and $23.14 per acre.

With no price-yield correlation, the willingness-to-pay decreases as the ARP increases because the subsidy value decreases, risk management value decreases, and the opportunity cost of setting land aside increases. The magnitude of the change is similar to the negative correlation case when at least one other instrument is included in the portfolio, ranging from $18.04 to $23.15 per acre as the ARP increases to 10% of base acreage. This is because other pricing instruments help manage the change in risk exposure caused by the change in the government program, so that the welfare change is basically caused by the subsidy change which is independent of the price-yield correlation. However, the change in willingness-to-pay is much larger than the negative correlation case when the government program is the only instrument in the portfolio, $17.33 per acre. This is because the farmer's risk exposure is reduced as APR increases in the negative price-yield correlation case which help offsets the negative welfare effect of subsidy reduction.

The results suggest farmer welfare is more sensitive to a change in the ARP than to a change in flexible acreage because of the decreased production from the set aside acreage. Unlike the target price and flexible acreage, ARP imposes costs to the farmer. As ARP increases beyond a particular point, e.g. 10% in the negative price-yield correlation case, the set-aside cost begins to dominate the benefit from subsidy and risk management, and the farmer may choose not to participate in the program.

8.4 Summary

Under the 1994 design, the government deficiency payment program provides a significant subsidy to the farmer, which usually makes it more valuable than the other pricing instruments that offer little, if any, profit opportunities. However, the farmer is only allowed to choose between participating or not in the program, so that the government program provides little flexibility to deal with the farmer's risk management needs. As a result, the program provides significantly more welfare gain when at least one other instrument is included in the portfolio to help manage risk.

Farmer welfare declines as the target price decreases, the flexible acreage increases, and/or the ARP increases. Welfare changes significantly with the change in target price, and is relatively more sensitive to ARP changes than to flexible acreage changes. The change in futures, options and crop insurance participation levels when the government program parameters change is primarily caused by the substitution effect between the program and futures and options, and the change is generally small.

A special result from increasing ARP is that production is reduced. Because it is believed that the low market price is caused by over-supply, increasing ARP is expected to help reduce supply and increase the market price. The increased market price will then reduce the subsidy per bushel the farmer receives and the government pays, and also cause a positive externality to farmers not participating in the program.

However, as the domestic market gets more open to the world market promoted by international agreements, such as NAFTA and GATT, it gets harder to raise the market price by unilateral production reduction. In this case, a percentage increase in ARP won't increase market price much because the reduced supply is easily offset by imports, so that little cost to the government is saved above that obtained from an increase in flexible acreage, while the loss to the farmer is much higher. Therefore, decreasing the target price is the more effective and safe way to reduce the government subsidy while still providing the program as an alternative risk management instrument to farmers.

Farmer welfare changes are generally robust to the level of price-yield correlation as the government program policy changes in the portfolio setting. In the portfolio setting, other instruments in the portfolio help manage risk changes that result from a change in the program, and the welfare change is basically the result of the expected subsidy change, which is independent of the price-yield correlation. However, when the government program is used in isolation the farmer welfare change is sensitive to the price-yield correlation. In this case the welfare change is a result of changes in both subsidy and risk reduction/increasing effect, and the latter is greatly affected by the price-yield correlation.

Chapter IX

CONCLUSION

Risk is one of the most important factors that affect production and marketing decisions in the agricultural sector. Price and yield risk are two major sources of income risk. Because of the existence of market instruments and government programs, such as, futures, options, crop insurance and deficiency payment programs, farmers can manage much of this income risk.

This dissertation studies a representative farmer's decision to use futures, options, crop insurance, and a government deficiency payment program when he faces both price and yield risks. The results show the optimal use of the instruments depends on the instruments included in the portfolio. This suggests models which consider incomplete portfolios of risk instruments may provide misleading results.

Even though FCIC realizes financial loss in providing crop insurance and a premium loading is imposed on typical farmers, the fact is that FCIC has been subsidized by the government, and the government deficiency payment program also provides a subsidy to farmers. These programs impose large costs to the federal government. In the current political and budget environment, it appears the subsidy inherent in the design of the current programs will be reduced or eliminated at some time in the future. Thus, the impacts of design changes in the crop insurance and deficiency payment program on farmer behavior and welfare are explored in this study.

Expected utility is chosen to characterize farmer decision making under risk in this research. Numerical methods are used to solve the farmer's expected utility problem in order to study the farmer's incentive to use the risk management instruments, measure farmer welfare, and evaluate implications of policy changes.

Cash price, futures price, farm-level yield and county-level yield are all stochastic when the farmer makes his marketing decisions. Previous research has shown that these prices and yields follow complex joint distributions that make modelling the farmer's decision problem analytically difficult. A bivariate ARCH model with seasonality is used to describe prices while a deterministic trend model with nonnormal errors is used to characterize yields. A joint distribution for the prices and yields is generated numerically using Taylor's method.

The data used to parameterize the model are representative of a corn farm in southwest Iowa in the 1994 crop year. The simulated 1994 joint distribution of price yield has a negative price-yield correlation, higher yield risk than price risk in terms of the coefficient of variation, and a yield basis risk represented by a farm-county yield correlation of 0.84. These three attributes have very important impacts on the role, the participation decisions, and the welfare value of each risk management instrument.

The optimal portfolio for the representative farm in the base model includes futures, options, government program and IYCI. Under the base model conditions, the government deficiency payment program is valuable because it provides an implicit subsidy to farmers; IYCI outperforms AYCI; and both types of crop insurance are more valuable than futures and options.

There is a substitution relationship between futures and options, and between options and the government deficiency payment program. The optimal positions of these instruments depend on the design specification of other instruments in the portfolio. For example, the options position is very small in the base solution, however, as the government program design changes so that the target price is lowered or ARP or flexible acreage increases, the options position increases significantly.

The correlation between price and yield is another important parameter in the model. In areas like southwest Iowa where corn is planted densely and yields are high, the output level in the area may influence market price causing the correlation to be negative; while in areas that corn is planted less densely and/or yields are lower, the correlation may be close to zero. Both negative and zero correlation cases were considered in this research. The major impact of going from negative to zero price-yield correlation is that optimal futures positions switch from long to short and farmer welfare is increased when crop insurance is included in the portfolio. Also, when the government program is used in isolation, its value is almost zero in the negative price-yield correlation case because participating in the program actually increases the income variability which nearly offsets the value of the subsidy. However, the program value is over $33 per acre in the zero correlation case, because it reduces income variability and provides an implicit subsidy at the same time.

The farmer's income risk structure and risk preference also impact the use and the value of the instruments. Generally, the more risk averse the farmer is, the higher he values the risk reducing effect of each instrument, but the less he cares about the income mean change brought about by the instrument. The change in farm yield variability changes the relative importance of reducing price risk and yield risk, and consequently changes the relative value of price and yield instruments. In addition, the change in yield basis risk changes the risk management effectiveness of AYCI. For example, a farmer whose absolute relative risk aversion is low, farm yield variability is low, and/or yield basis is low, prefers AYCI is to IYCI.

The current form of IYCI, Multiple Peril Crop Insurance, is facing financial problems, because of the existence of moral hazard, adverse selection, high operating cost, and geographical yield correlation. The high cost of providing IYCI has led policy makers to implement a form of AYCI which reduces moral hazard, adverse selection and operating cost. Unfortunately, yield basis risk may prevent AYCI from providing effective yield risk reduction. A comparison between IYCI and AYCI under alternative crop insurance contract designs was also conducted in this research.

The results show that under the current contract specifications AYCI is generally inferior to IYCI because of the yield basis risk. However, AYCI has the potential to outperform IYCI when: 1) basis risk level is decreased, 2) IYCI premium loading is increased, and/or 3) the AYCI trigger yield restriction is removed. The farmer's yield basis risk level can be reduced when the insurance area is more localized, because the effect of the stochastic factors, such as weather and soil type, is more homogeneous.

Increases in the IYCI premium may occur because FCIC faces financial loss currently even with a government subsidy. It seems reasonable to remove or relax the AYCI trigger yield restriction, because the restriction is not necessary with little moral hazard or adverse selection problems. The results also show that allowing farmers to select insured acreage or the price index used to value yield shortfalls may slightly increase the welfare of IYCI and AYCI, but the improvement is generally small.

The impact of changes in the government program on farmer welfare is also studied in this research. The value of the government program decreases significantly as the target price decreases, the flexible acreage increases, or the ARP increases, primarily because of the reduction in government subsidy. However, the same percentage increase in flexible acreage causes less welfare loss than ARP because ARP imposes extra cost to the farmer as a result of the set-aside requirement. Although the risk management effect of the government program is also affected by the change in these parameters, the effect is relatively less important than its subsidy reduction because the value of the government program comes mainly from its subsidy, and the use of futures and options can adjust to manage the risk affected by the change in the parameters.

This research computes optimal risk management decisions for a competitive farm in a market structure with futures, options, deficiency payment program, and crop insurance in a portfolio, when both price and yield are uncertain. The impact of the farmer's optimal decisions and welfare for alternative crop insurance and government program designs are also studied. Sensitivity analysis is conducted on various parameters that describe the characteristics of the representative farmer, so that the results can be generalized to farmers in other regions and with different characteristics.

The results can be used as a reference by farmers in their risk management decision making, by government policy makers as they revise the existing farm and crop insurance programs, by economists in farm risk analysis, and by others such as, food processors, traders, insurance agents, and environmentalists, who are interested in changes in farm production and marketing strategies when relevant government policies change.

This research considers only one crop in a one period static setting. Though restrictive, it provides some basic results on farmer's risk management behavior. Future research should generalize the result to include multiple crops, and/or a multiple year dynamic analysis, where the correlation among prices and yields for different crops, the effect of crop rotations, discount rate and timing of market transactions will all affect the decisions on risk management instruments.

APPENDICES

APPENDIX A

STATISTICAL HYPOTHESIS TESTING

Phillips-Perron Unit Root Test

There are three models in Table 4.1. The first one has no trend while the other two have differently specified trends. If the data have unit roots, the αs in those models should equal one.

Perron suggests that equation (c) be run first, and if the $Z(\Phi_3)$ is small, which means the hypothesis that $\beta=0$ and $\gamma=1$ can't be rejected, $Z(\Phi_2)$ should then be checked. If $Z(\Phi_2)$ is small, the hypothesis that $\mu=0$, $\beta=0$ and $\gamma=1$ can't be rejected for this model. However, the conclusion of a unit root still can't be drawn yet, because model (c) is not correctly specified.

Also, the small $Z(t_{\tilde{\beta}})$, large $Z(t_{\tilde{\mu}})$, and ambiguous $Z(t_{\tilde{\gamma}})$ and $Z(\tilde{\gamma})$ indicate the hypotheses $\beta=0$ can't be rejected at 10%, $\mu = 0$ can be rejected at 5%, and $\gamma=1$ can be rejected at 10% but not at 5% for this model. Therefore, equation (b) is checked.

$Z(\Phi_1)$ can be obtained through the regression of equation (b). If $Z(\Phi_1)$ is small, the hypothesis that $\mu^* = 0$ and $\gamma^* = 1$ cannot be rejected, then equation (a) should be checked. $Z(\Phi_1)$ is large enough to reject the hypothesis at 5% level which suggests either $\mu^* = 0$, or $\gamma^* = 1$, or both, is violated, but doesn't tell which case is true. So, $Z(\gamma^*)$, $Z(t_{\gamma^*})$ and $Z(t_{\mu^*})$ are checked. The large $Z(t\mu^*)$ rejects the hypothesis $\mu^* = 0$, but $Z(\gamma^*)$ and $Z(t_{\gamma^*})$ are not large enough to reject the unit root hypothesis $\gamma^* = 1$ at 5% level.

LR Test for Seasonalities in Futures and Cash Prices

The Log-likelihood Ratio (LR) test states that the twice of the difference between the log-likelihoods of the unrestricted model and the restricted model is χ^2 distributed with the number of restrictions as the degree of freedom.

$$H_0\!: \phi_1 = \psi_1 = 0 \qquad H_a\!: \phi_1 \neq 0 \text{ or } \psi_1 \neq 0$$
$$\mathrm{LR} = 2(L_U - L_R) \sim \chi^2(2)$$

where L_U and L_R are the log-likelihoods of the unrestricted model and the restricted model respectively.

Starting from I = 6, equation (4.3) are repeatedly run for I = 5,4,3,2 and 1, the log-likelihoods and LR tests are listed in Table B.1.

Table A.1 LR Tests for Degrees of Frequencies in Seasonality

I	Log-likelihood	LR	Prob	H_0
Futures Price				
6	-548.183	5.103	.078	$\phi_6 = 0 \ \psi_6 = 0$
5	-550.734	0.266	.875	$\phi_5 = 0 \ \psi_5 = 0$
4	-550.868	4.860	.088	$\phi_4 = 0 \ \psi_4 = 0$
3	-553.298	5.340	.069	$\phi_3 = 0 \ \psi_3 = 0$
2	-555.968	4.184	.123	$\phi_2 = 0 \ \psi_2 = 0$
1	-558.060			
Cash Price				
6	-562.683	4.724	.094	$\phi_6 = 0 \ \psi_6 = 0$
5	-565.045	5.416	.067	$\phi_5 = 0 \ \psi_5 = 0$
4	-567.753	5.140	.077	$\phi_4 = 0 \ \psi_4 = 0$
3	-570.323	0.108	.948	$\phi_3 = 0 \ \psi_3 = 0$
2	-570.376	4.846	.087	$\phi_2 = 0 \ \psi_2 = 0$
1	-572.799			

The null hypothesis of no seasonality versus the alternative of one degree of seasonality can be rejected at 5% significant level. All other levels of seasonality can be rejected in pairwise test against the preceding lower degrees of seasonality which provides some evidence that the seasonal factor may be characterized by a first order frequency of sine and cosine variables.

Autocorrelation Test

It is necessary to introduce Ljung-Box Q test (Harvey, 1990, p212) before investigating the model specifications, because it is an important statistic used to tests whether the model is correctly specified.

The Ljung-Box Q statistic is defined as:

$$Q = T(T+2)\sum_{\tau=1}^{D} \frac{r_\tau^2}{T-\tau} \qquad \textbf{(A.1)}$$

where T is the sample size, D is the level of autocorrelation being tested, and r_τ is the τth sample autocorrelation in the residuals. The null hypothesis, H_0, is that there is no autocorrelation in the residuals at lag D. Under the null hypothesis, Q has a χ^2 distribution with D degrees of freedom asymptotically. A high value of Q leads to a rejection of the null hypothesis.

When testing the autocorrelation in the standardized squared residuals for an ARCH model, each residual is squared first, and then divided by its conditional variance.

The bivariate deterministic variance model with first degree seasonality is estimated first and Ljung-Box Q statistics suggest there are autocorrelations in the standardized squared residuals of futures prices at lag 1. As a result, an ARCH(1) model with the seasonality component is estimated. All the three ARCH(1) coefficients at lag 1 in the variance-covariance equations are significant at the 10% level.

However, while the lower level ARCH effects are eliminated by ARCH(1) specification, the statistics still show there exist higher level ARCH effects in the futures price equation. The model is then specified with ARCH(9) for the futures price variance equation while keeping the cash price variance and covariance equations ARCH(1). The estimated ARCH coefficients at lag 2, 4, 5, 6, 7, and 8 are zeroes when restricted to be non-negative, and all the diagnostic tests suggest there is no autocorrelations left unexplained in the variance process.

APPENDIX B

SIMULATING BIVARIATE NORMAL DISTRIBUTIONS

The technique of adjoining two standard normal variables is illustrated below.

X is a vector of bivariate independent standard normal variable, and Y is a vector of bivariate standard normal variable with correlation ρ. We want to find a transform matrix M so that $MX \equiv Y$.

$$X = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right) \tag{B.1}$$

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right) \tag{B.2}$$

M is a lower triangular transform matrix that has the form of (B.3):

$$M = \begin{bmatrix} M_{11} & 0 \\ M_{21} & M_{22} \end{bmatrix}, \tag{B.3}$$

Let $\qquad MX \equiv Y,$

Then

$$MX \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, M \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} M' \right). \tag{B.4}$$

We need

$$MM = \begin{bmatrix} M_{11}^2 & M_{11}M_{21} \\ M_{11}M_{21} & M_{21}^2 + M_{22}^2 \end{bmatrix} = \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}, \tag{B.5}$$

and then, solve equation (B.5), we have

$$
\begin{aligned}
M_{11} &= 1 \\
M_{21} &= \rho \\
M_{22} &= \sqrt{1-\rho^2}
\end{aligned}
\quad . \tag{B.6}
$$

Consequently,

$$
\begin{aligned}
M &= \begin{bmatrix} 1 & 0 \\ \rho & \sqrt{1-\rho^2} \end{bmatrix}, \\
Y = MX &= \begin{bmatrix} X_1 \\ \rho X_1 + \sqrt{1-\rho^2}\, X_2 \end{bmatrix}.
\end{aligned}
\tag{B.7}
$$

The technique of adjoining two non-standard normal variables with zero mean is similar.

$$
X = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix} , \begin{bmatrix} \sigma_1^2 & 0 \\ 0 & \sigma_2^2 \end{bmatrix} \right) \tag{B.8}
$$

where σ_i^2 is the variance of the ith variate, i = 1,2.

$$
Y = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix} , \begin{bmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{bmatrix} \right) \tag{B.9}
$$

$$
\begin{aligned}
M &= \begin{bmatrix} 1 & 0 \\ \rho\dfrac{\sigma_2}{\sigma_1} & \sqrt{1-\rho^2} \end{bmatrix}, \\
Y = MX &= \begin{bmatrix} X_1 \\ \rho\dfrac{\sigma_2}{\sigma_1} X_1 + \sqrt{1-\rho^2}\, X_2 \end{bmatrix}.
\end{aligned}
\tag{B.10}
$$

APPENDIX C

HYPERBOLIC SINE TRANSFORMATION

Definition

Johnson (1949) found that the inverse hyperbolic sine transformation (IHST) can transform a skewed and/or kurtotic distribution into a normal distribution.

The hyperbolic sine transformation (HST) is defined as:

$$y = \sinh(x) = \frac{e^{2x} - 1}{2e^{x}} \tag{C.1}$$

so that the inverse of this function, IHST, is:

$$x = \sinh^{-1}(y) = \ln(\sqrt{2y^2 + 1} + y) \tag{C.2}$$

Burbidgee, Magee, and Robb (1988) modified this transformation to allow normality as a special case. They defined the modified IHST as below so that as θ approaches zero, x approaches y.

$$x = \frac{\sinh^{-1}(\theta y)}{\theta} \tag{C.3}$$

This modified version is used to estimate the yield model.

Properties of HST

The HST can be shown to be an even function of θ, which means the function has the same value for both θ and $-\theta$, so that only the magnitude, and not the sign, of the parameter θ affects the shape of the transformed distribution. From equation (4.9) we know:

$$e = \frac{\sinh(\theta(\upsilon+\delta))}{\theta} = \frac{e^{2\theta(\upsilon+\delta)}-1}{2\theta e^{\theta(\upsilon+\delta)}} \tag{C.4}$$

We want to prove that :

$$\frac{\sinh(\theta(\upsilon+\delta))}{\theta} = \frac{\sinh(-\theta(\upsilon+\delta))}{-\theta} \tag{C.5}$$

which is equivalent to:

$$\frac{e^{2\theta(\upsilon+\delta)}-1}{2\theta e^{\theta(\upsilon+\delta)}} = \frac{e^{-2\theta(\upsilon+\delta)}-1}{-2\theta e^{-\theta(\upsilon+\delta)}} \tag{C.6}$$

Multiplying both the top and bottom of the right hand side of equation (C.6) by $e^{2\theta(\upsilon+\delta)}$ to obtain:

$$\frac{e^{2\theta(\upsilon+\delta)}}{e^{2\theta(\upsilon+\delta)}} \cdot \frac{e^{-2\theta(\upsilon+\delta)}-1}{-2\theta e^{-\theta(\upsilon+\delta)}} = \frac{1-e^{2\theta(\upsilon+\delta)}}{-2\theta e^{\theta(\upsilon+\delta)}} \tag{C.7}$$

After multiplying the top and bottom of the right side of equation (C.7) by -1, it becomes exactly the left side of (C.6).

Second, we can show that the HST of a normal distributed variate becomes more and more leptokurtic as the magnitude of θ increases. Some numerical evidence is provided in the paper of Burbidge, Magee and Robb (1988). In addition, a simulation was conducted to obtain 5000 HS transformations from a standard normal variate when restricting the skewness parameter δ to be zero. The statistics of the nonnormal variates corresponding to a series of θ values ranging from -3 to 3 are provided in Table C.1.

As expected from the above proof, these simulated data are symmetric around their mean, 0, which is also the mean of the standard normal distribution. As θ deviates from 0, the mean, standard deviation, skewness and kurtosis are found to be nonzero. The differences in the mean and skewness as θ deviates from zero are trivial when considering the wide dispersion of the simulated data in these cases, while the change of kurtosis is drastic. So, θ can be thought of as the kurtosis parameter in the yield model.

Introducing the skewness parameter, δ, doesn't change the characteristics of HST as an even function of θ, but it affects the skewness as well as the kurtosis. Table C.2 shows the statistics describing the simulated HST distributions when $\delta \neq 0$. The data

Table C.1 Distribution Statistics of HST of a Standard Normal Variable (δ=0)

θ	min	max	mean	standard deviation	skewness	kurtosis
-3.0	-5587	13945	6.7933	291.9	29.860	1340.43
-2.0	-259.9	478.2	0.3098	13.98	13.042	455.33
-1.0	-16.11	21.86	0.0302	1.777	0.8529	19.219
-0.5	-5.50	6.46	0.0174	1.147	0.0852	4.3934
-0.1	-3.54	3.87	0.0148	1.005	0.0127	3.0617
-0.03	-3.48	3.79	0.0147	1.001	0.0110	3.0260
-0.005	-3.47	3.78	0.0147	1.000	0.0108	3.0226
-0.0005	-3.47	3.78	0.0147	1.000	0.0108	3.0225
0	-3.47	3.78	0.0147	1.000	0.0108	3.0225
0.0005	-3.47	3.78	0.0147	1.000	0.0108	3.0225
0.005	-3.47	3.78	0.0147	1.000	0.0108	3.0226
0.03	-3.48	3.79	0.0147	1.001	0.0110	3.0260
0.1	-3.54	3.87	0.0148	1.005	0.0127	3.0617
0.5	-5.50	6.46	0.0174	1.147	0.0852	4.3934
1.0	-16.11	21.86	0.0302	1.777	0.8529	19.219
2.0	-259.93	478.2	0.3098	13.98	13.042	455.33
3.0	-5587	13945	6.7933	291.9	29.860	1340.43

show that when θ is close to zero, the distribution is close to normal. Although it skews to the right as δ getting larger, it is still very symmetric at the level of -3. As θ increases, the distribution tends to skew to the left as δ becomes negative and to the right as δ increases. When θ is -0.5, the distribution is almost the same as that of θ = 0.5, again consistent with the properties of an even function, where the slight difference is caused by simulation error. Generally, the simulation results show that distribution skews more and more to the right as δ getting larger.

Clearly, the collaborative effects of all the three parameters, ς^2, θ and δ, are complicated, and the shape of yield distribution is jointly determined by all the parameters. Care must be taken not to compare individual parameters without conditioning on the remaining parameters in the transformation.

Table C.2 Distribution Statistics of the HST of a Standard Normal Variable

θ	δ	min	max	mean	st.dev.	skewness	kurtosis
.0005	-3.000	-6.474	0.7782	-2.9854	1.000	0.010577	3.0226
	-1.000	-4.474	2.7783	-0.9853	1.000	0.010728	3.0226
	-0.500	-3.974	3.2783	-0.4853	1.000	0.010766	3.0226
	-0.050	-3.524	3.7284	-0.0353	1.000	0.010800	3.0226
	0.050	-3.424	3.8284	0.0647	1.000	0.010808	3.0226
	0.500	-2.973	4.2785	0.5147	1.000	0.010842	3.0226
	1.000	-2.473	4.7787	1.0148	1.000	0.010880	3.0226
	3.000	-0.473	6.7795	3.0149	1.000	0.011032	3.0227
.5	-3.000	-25.41	0.7980	-4.7853	2.778	-1.46827	6.5396
	-1.000	-9.255	3.7620	-1.1615	1.293	-0.76958	4.7880
	-0.500	-7.154	4.9564	-0.5547	1.176	-0.37809	4.3745
	-0.050	-5.650	6.2951	-0.0393	1.140	0.03736	4.3662
	0.050	-5.357	6.6334	0.0740	1.141	0.13312	4.4266
	0.500	-4.196	8.3741	0.5905	1.312	0.55390	4.9672
	1.000	-3.154	10.812	1.2007	1.312	0.95891	5.9137
	3.000	-0.478	29.606	4.8669	2.853	1.70710	8.7932
-.5	-3.000	-27.78	0.7778	-4.837	2.828	-1.529	7.326
	-1.000	-10.13	3.722	-1.183	1.312	-0.8057	5.147
	-0.500	-7.844	4.906	-0.5733	1.191	-0.4061	4.569
	-0.050	-6.206	6.233	-0.05615	1.154	0.01468	4.426
	0.050	-5.888	6.568	0.05747	1.154	0.1113	4.461
	0.500	-4.627	8.293	0.5747	1.197	0.5341	4.907
	1.000	-3.499	10.71	1.185	1.323	0.9388	5.788
	3.000	-0.6627	29.33	4.840	2.871	1.681	8.592

Derivation of ML Function with HST Yield

Starting from the HST yield model, which is equation (4.9), we want to maximize the log likelihood density function of the nonnormal disturbance e_t :

$$Max \sum_{t=1}^{T} \ln[g(e_t)] \tag{C.8}$$

in which, $g(e_t)$ is the ~~probability density function~~ of e_t. Also, from equation (4.10) we know if e_t comes from the HST of the normal variate υ_t whose mean is zero and variance is ς^2_t, then the density function of υ_t is $f(\upsilon_t)$.

$$f(\upsilon_t) = \frac{1}{\sqrt{2\pi\varsigma^2}} e^{-\frac{\upsilon_t^2}{2\varsigma^2}} \tag{C.9}$$

where υ_t is the IHST of e_t. From equation (C.2) and (C.3) we have:

$$\begin{aligned} \upsilon_t &= h(e_t) \\ &= \frac{1}{\theta}\sinh^{-1}(\theta e_t) - \delta \\ &= \frac{1}{\theta}\ln[\theta e_t + \sqrt{(\theta e_t)^2 + 1}] - \delta. \end{aligned} \tag{C.10}$$

Now, let G(·) and F(·) are the cumulated density functions of e_t and υ_t respectively, then,

$$\begin{aligned} g(e_t) &= \frac{dG(e_t)}{de_t} \\ &= \frac{dF(h(e_t))}{de_t} \\ &= \frac{dF(\upsilon_t)}{d\upsilon_t}\frac{dh(e_t)}{de_t} \\ &= f(\upsilon_t)h'(e_t) . \end{aligned} \tag{C.11}$$

We take derivative of equation (C.10) with respect to e_t:

$$h'(e_t) = \frac{1}{\theta}\,\frac{\theta + \dfrac{2\theta^2 e_t}{2\sqrt{(\theta e_t)^2+1}}}{\theta e_t + \sqrt{(\theta e_t)^2+1}} \tag{C.12}$$

$$= \frac{1}{\sqrt{(\theta e_t)^2+1}} \; .$$

When (C.9), (C.11) and (C.12) are substituted into (C.8), the MLE model becomes

$$Max \;\sum_{t=1}^{T} -\frac{1}{2}[\ln(2\pi) + \ln\varsigma^2 + \frac{v_t^2}{\varsigma^2} + \ln((\theta e_t)^2+1)] \;, \tag{C.13}$$

which is equivalent to

$$Max \;\sum_{t=1}^{T} -\frac{1}{2}[\ln\varsigma^2 + \frac{v_t^2}{\varsigma^2} + \ln((\theta e_t)^2+1)] \;. \tag{C.14}$$

APPENDIX D

CORRELATION MATRICES WITH ZERO PRICE-YIELD CORRELATION

Table D.1 Correlation Matrices of Simulated Prices and Yields with $\rho_{pY}=0$

	Low Yield Correlation				Medium Yield Correlation				High Yield Correlation			
	f	p	Y^I	Y^C	f	p	Y^I	Y^C	f	p	Y^I	Y^C
Low Risk												
f	1.00	.843	.026	.027	1.00	.843	.055	.027	1.00	.843	.027	.027
p		1.00	.017	.010		1.00	.039	.010		1.00	.018	.010
Y^I			1.00	.623			1.00	.830			1.00	.941
Y^C				1.00				1.00				1.00
Medium Risk												
f	1.00	.843	.029	.027	1.00	.843	.051	.027	1.00	.843	.026	.027
p		1.00	.018	.010		1.00	.035	.010		1.00	.016	.010
Y^I			1.00	.627			1.00	.831			1.00	.941
Y^C				1.00				1.00				1.00
High Risk												
f	1.00	.843	.032	.027	1.00	.843	.048	.027	1.00	.843	.024	.027
p		1.00	.018	.010		1.00	.031	.010		1.00	.014	.010
Y^I			1.000	.628			1.000	.830			1.00	.937
Y^C				1.000				1.000				1.00

BIBLIOGRAPHY

BIBLIOGRAPHY

Ahsan, S. M., A. A. G. Ali, and N. J. Kurian "Toward a Theory of Agricultural Insurance", *American Journal of Agricultural Economics*, 65(1982), P520-529

Anderson, J. R., J. L. Dillon, and J. B. Hardaker *Agricultural Decision Analysis*, Ames, IA: The Iowa State University Press, 1977

Ardeni, Pier G. "Does the Law of One Price Really Hold for Commodity Prices?" *American journal of Agricultural Economics* 71(August 1989), P661-669

Arrow, K. J. *Essays in the Theory of Risk Bearing*, Chicago: Markham, 1971

Bachelier, L. J. B. A. *Theorie de la Speculation*, Paris: Gauthier-Villars, 1900

Baillie, R. T., and R. J. Myers "Bivariate GARCH Estimation of the Optimal Commodity Futures Hedge", *Journal of Applied Econometrics*, 6(1991), P109-124

Baquet, Alan E., and J. Skees "Group Risk Plan Insurance: An Alternative Management Tool for Farmers", *CHOICES*, (first quarter 1994)

Bollerslev, T. "Generalized Autoregressive Conditional Heteroskedasticity", *Journal of Econometrics*, 31(1986), P307-327

Bollerslev, T. "Modelling the Coherence in Short-run Nominal Exchange Rates: A Multivariate Generalized ARCH Model." *The Review of Economics and Statistics*, (1990), P498-505

Chambers, R. G. "Insurability and Moral Hazard in Agricultural Insurance Markets", *American Journal of Agricultural Economics*, 71(1989), P604-616

Chavas, J. P. and M. T. Holt "Acreage Decisions Under Risk: The Case of Corn and Soybeans", *American Journal of Agricultural Economics*, 72(1990), P529-538

Coble, K. H., T. O. Knight, R. D. Pope, and J. R. Williams "An Empirical Test for Moral Hazard and Adverse Selection in Multiple Peril Crop Insurance", *Selected Paper at AAEA Annual Conference in Orlando, Florida*, 1993

Danthine, J. P. "Information, Futures Prices, and Stabilizing Speculation", *Journal of Economic Theory*, 17(1978), P79-98

Day, R. H. "Probability Distribution of Field Crops", *Journal of Farm Economics*, 47(1965), P713-741

Dillon, J. L. "Bernoullian Decision Theory: Outline and Problems", *Risk, Uncertainty and Agricultural Economics*, edited by James Roumasset, Ames, IA: Iowa State University Press, 1979

Engle, R. F. "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of U.K. inflation", *Econometrica*, 50(1982), P987-1008

Feder, G., R. E. Just, and A. Schmitz "Futures Markets and the Theory of the Firm under Price Uncertainty", *Quarterly Journal of Economics*, 94(1980), P317-328

GAUSS 2.1, Aptech Systems, Inc., Kent, Washington, 1984-1991

Gordon, J. D. "The Distribution of Daily Changes in Commodity Futures Prices." *Technical Bulletin* 1702 ERS, USDA, (July 1985)

Hadar, J., and W. Russell "Stochastic Dominance and Diversification." *Journal of Economic Theory*, 3(1971), P288-305

Halcrow, H. G. "Actuarial Structures for Crop Insurance" *Journal of Farm Economics*, 31(1949), P418-443

Hall, J. A., B. W. Brorsen, and S. H. Irwin "The Distribution of Futures Prices: A Test of the Stable Paretian and Mixture of Normals Hypotheses", *Journal of Financial Quantitative Analysis*, 24(1989), P105-116

Hansen, L. P. and K.J. Singleton "Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns", *Journal of Political Economics*, 91(1983), P240-265

Hanson, S. D "Price Level Risk Management in the Presence of Commodity Options: Income Distribution, Optimal market Positions, and Institutional value", Unpublished Ph.D Dissertation, Department of Economics, Iowa State University, Ames, Iowa, 1988

Hanson, S. D., and G. W. Ladd "Robustness of the Mean-Variance Model with Truncated Probability Distribution", *American Journal of Agricultural Economics*, 73(1991), P436-445

Holthausen, D. M. "Hedging and the Competitive Firm Under Price Uncertainty", *The American Economic Review*, 69(1979), P989-995

Hull, J. *Options, Futures, and Other Derivative Securities*, Englewood Cliffs, NJ:Prentice hall, 1989

Kang, Taehoon, and B.W. Brorsen. "GARCH Option Pricing with Asymmetry." Working paper, Department of Agricultural Economics, Oklahoma State University, 1993

Lapan, H., G. Moschini, and S. D. Hanson "Production, Hedging, and Speculative Decisions with Options and Futures Markets", *American Journal of Agricultural Economics*, 73(1991), P66-74

Love A. and S. T. Buccola "Joint Risk Preference-Technology Estimation with a Primal System", *American Journal of Agricultural Economics*, 73(1991), P765-774

Markowitz, J. "Portfolio Selection", *Journal of Finance*, 7(1952), P77-91

Meyer, J. "Two-Moment Decision Models and Expected Utility Maximization", *The American Economic Review*, 77(1987), P421-430

Miranda, M. J. "Area-Yield Crop Insurance Reconsidered", *American Journal of Agricultural Economics*, 73(1991), P233-242

Moss, C. B., and J. S. Shonkwiler "Estimating Yield Distributions with a Stochastic Trend and Nonnormal Errors", *American Journal of Agricultural Economics*, 75(1993), P1056-1062

Myers, R. J. "Time Series Econometrics and Commodity Price Analysis: A Review." *Review of Marketing and Agricultural Economics* 62(August 1994):2, P167-182.

Myers, R. J. "The Value of Ideal Contingency Markets in Agriculture", *American Journal of Agricultural Economics*, 70(1988), P252-267

Myers, R. J., and S. D. Hanson. "Pricing Commodity Options When the Underlying Futures Price Exhibits Time-Varying Volatility." *American Journal of Agricultural Economics*, 75(February 1993), P121-130

Nelson, C. H. "The Influence of Distributional Assumption on the Calculation of Crop Insurance Premia", *North Central Journal of Agricultural Economics*, 12(1990), P71-78

Nelson, C. H., and E. T. Loehman "Further Toward a Theory of Agricultural Insurance", *American Journal of Agricultural Economics*, 69(1987), P523-531

Nelson, C. H., and P. V. Preckel "The Conditional Beta Distribution As a Stochastic Production Function", *American Journal of Agricultural Economics*, 71(1989), P370-378

Perron, P. "Tends and Random Walks in Macroeconomic Time Series: Further Evidence from a New Approach." *Journal of Economic dynamics and Control* 12(1988), P277-301

Poitras, G. "Hedging and Crop Insurance", *The Journal of Futures Markets*, 13(1993), P373-388

Pope, R. D. and R. E. Just "On Testing the Structure of Risk Preferences in Agricultural Supply Analysis" *American Journal of Agricultural Economics*, 73(1991), P743-748

Pratt, J. "Risk Aversion in the Small and in the Large", *Econometrica*, 32(1964), P122-136

Robison, L. J., and P. J. Barry *The Competitive Firm's Response to Risk*, New York: Macmilan, 1987

Saha, A., C. R. Shumway, and H. Talpaz "Joint Estimation of Risk Preference Structure and Technology Using Expo-Power Utility", *American Journal of Agricultural Economics*, 76(1994), P173-184

Sakong, Y., D. J. Hayes,a nd A. Hallam "Hedging Production Risk with Options", *American Journal of Agricultural Economics*, 75(1993), P408-415

Samuelson, P. A. "The Fundamental Approximation Theorem of Portfolio Analysis in Terms of Means, Variances, and Higher Moments", *Review of Economic Studies*, 37(1970), P537-542

Sandmo, A. "On the Theory of the Competitive Firm under Price Uncertainty", *American Economic Review*, 61(1971), P65-73

Schweikhardt, D., B. Gardner, J. Hilker, and G. Schwab "Explanation and Worksheet to Evaluate participation Decisions in the 1994 USDA Wheat and Feed Grain Programs", Staff Paper 94-14, Department of Agricultural Economics, Michigan State University, East lansing, Michigan, 1994

Skees, J. R. and M. R. Reed "Rate-making and Farm-Level Crop Insurance: Implications for Adverse Selection", *American Journal of Agricultural Economics*, 68(1986):P653-659

Swinton, S. M., and R. P. King "Evaluating Robust Regression Techniques for Detrending Crop Yield Data with Nonnormal Errors", *American Journal of Agricultural Economics*, 73(1991):P446-451

Szpiro, G. G. " Measuring Risk Aversion: An Alternative Approach" *Review of Economics and Statistics*, 68(1986) P156-159

Taylor, C. R. "Two Practical Procedures for Estimating Multivariate Nonnormal Probability Density Functions." *American journal of Agricultural Economics* 76(February 1994), P128-140

Tobin, J. "Liquidity Preference as Behavior Toward Risk", *Review of Economics Studies*, 25(1958), P65-86

Turvey, C. G., and T. G. Baker "A Farm-Level Financial Analysis of Farmers' Use of Futures and Options Under Alternative Farm Programs", *American Journal of Agricultural Economics*, 72(1990), P946-957

Tsiang, S. " The Rationale of the Mean-Standard Deviation Analysis, Skewness Preference, and the Demand for Money." *American Economic Review*, 62(1972), P354-371

Vercammen, J. "Hedging with Commodity Options when Price Distributions Are Skewed." *American Journal of Agricultural Economics*, 77(1995), P935-945

Vercammen, J. and G. C. van Kooten "Moral Hazard Cycles in Individual-Coverage Crop Insurance." *American Journal of Agricultural Economics*, 76(1994), P250-261

Von Neumann, J., and O. Morgenstern *Theory of Games and Economic Behavior*, Princeton, NJ: Princeton University Press, 1944

Williams, J. R., G. L. Carriker, G. A. Barnaby, and J. K. Harper "Crop Insurance and Disaster Assistance Designs for Wheat and Grain Sorghum", *American Journal of Agricultural Economics*, 75(1993), P435-447

Yang, S., and B. W. Brorsen "Nonlinear Dynamics of Daily Cash Prices", *American Journal of Agricultural Economics*, 74(1992), P706-715

U.S. General Accounting Office. "Crop Insurance Additional Actions Could Further Improve Programs's Financial Condition" Report to the Ranking Minority Member, Committee on Agriculture, Nutrition, and Forestry, U.S. Senate Washington DC GAO/RCED-95-269 September 1995