Risk-Returns of Forward Contracting Southern Row Crops with Crop Revenue Insurance

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Agricultural Economics

by

Chandan Bhattarai
Agriculture and Forestry University
Bachelor of Science in Agriculture, 2019

August 2023
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

____
Andrew McKenzie, Ph.D.
Thesis Director

____
Alvaro Durand-Morat, Ph.D.
Committee Member

____
Hunter Biram, Ph.D.
Committee Member

ABSTRACT

This study evaluated the risk and return associated with various levels of forward contracting for southern row crops, specifically corn, soybean, and rice, in conjunction with different coverage levels of the Revenue Protection (RP) crop insurance program and government support plans. Forward contracting is a strategy to manage price risk by transferring ownership of physical grain from a seller to a buyer at a pre-agreed time. RP is a return-based crop insurance program offering coverage levels ranging from 50-85 percent in 5 percent increments, which allows producers to hedge against yield or price risks. Additionally, the study analyzed the effectiveness of the Agricultural Risk Coverage (ARC) and Price Loss Coverage (PLC) commodity programs, both of which fall under Title I of the 2014 farm bill, to support farmers during return or price declines. Finally, expected-utility conceptual framework and certainty equivalent were utilized to quantify the risk and return during different time, level of forward contracting and different level of RP for producers.

ACKNOWLEDGEMENTS

I would like to extend my hearty thanks to my major advisor, Professor Dr. Andrew McKenzie, for his continuous, guidance, and support throughout the research period. I am also thankful to my advisory committee members, Dr. Alvaro Durand-Morat, and Dr. Hunter Biram, for their academic and moral support throughout my research. Their insightful feedback, encouragement, and supervision have helped me in improving my research work.

My profound gratitude is extended to Dr. John Anderson and Dr. Lanier Nalley for their academic, moral and administrative support throughout my study period at University of Arkansas. I would also like to thank entire Department of Agricultural Economics and Agribusiness (AEAB) for providing with an exceptional learning environment and an opportunity to broaden my understanding of American and global agricultural insights.

I express my deep appreciation and admiration towards my parents for teaching me good values and constantly motivating me in every aspect of my life. I also extend my heartfelt gratitude to my brother, Pankaj Bhattarai, and sister-in law, Sadikshya Aryal Bhattarai, for their unwavering support, encouragement, patience, and affection. Their constant love and support have been a source of strength for me.

I would like to express my heartfelt gratitude and appreciation to my wife - Aastha, for being my constant source of support, encouragement, and love. Her untiring belief in me has given me the confidence to pursue my dreams and face any challenge that comes my way. I feel blessed to have her in my life, and I cannot thank her enough for all that she has done for me.

I am grateful to have such wonderful friends who have made Fayetteville feel like a second home to me. Their warmth, kindness, and hospitality have been instrumental in making my transition to this city a smooth and enjoyable one. I feel blessed to have such a supportive network

of friends who have become like family to me. Thank you all for your generosity, your friendship, and for helping me to create so many fond memories in Fayetteville. Your presence in my life is truly a gift that I will cherish always.

Chandan Bhattarai

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Agricultural products are subject to high production, market, and financial risk (Velandia et al., 2009). Agricultural producers actively utilize various risk management tools and strategies developed over time to mitigate the high risks involved in agriculture. These risk-mitigating decisions can be diverse with crop insurance tools and government farm support plans (Maples et al., 2022). Managing these risks is crucial to operating a successful farm or ranch, and farmers can use various strategies and tools. For example, farmers can manage production or yield risk by utilizing instruments or strategies, such as yield-based crop insurance and diversifying their operations. In addition, managing market or price risks involves utilizing tools or techniques such as futures hedging, forward contracting, and spreading out sales. (Velandia et al., 2009). The use of contracts has become an increasingly important part of the agricultural industry in the United States over the past few decades. According to Burns and MacDonald (2018), 33 percent of US agricultural production has been under contract since the mid-1990s.

Forward contracting is a common practice among farmers to market their crops during the pre-harvest window. It is a way for farmers to lock in prices for their crops before they are harvested, providing them with a degree of price certainty (Jacobs et al., 2015). Forward contracting is a valuable tool for field crop farmers as they reduce price risk, securing a buyer for their products and enabling higher returns. By forward contracting, farmers can secure a buyer for their products and receive a guaranteed price, which reduces the risk of price volatility and market uncertainty.

Forward contracts are typically agreed upon before planting or harvest and usually cover no more than one marketing year. Forward contracts allow farmers to plan their production and manage their risk exposure with greater confidence, knowing they have a buyer for their products at a predetermined price. This practice is particularly relevant for crops such as corn, soybeans, and rice, grown in large quantities in Arkansas. One of the main reasons for the popularity of forward contracting is the existence of a weather risk premium in forward contract grain prices offered by elevators (Li et al., 2018). This premium can allow farmers to capture higher prices for their crops.

Forward contracts offer advantages such as reduced-price risk. However, this also poses a risk for farmers as they may face penalties for non-delivery if crop yields are lower than expected. The more aggressively farmers forward contract grain during the summer by legally committing to deliver higher percentages of their expected production, the greater their yield risk and the higher the penalty charged by elevators for non-delivery. Farmers can manage this risk by carefully selecting the quantity to forward the contract, purchasing crop revenue insurance, and diversifying their marketing strategies to include other market channels in case the contracted volume falls short. Crop revenue insurance provides farmers coverage for crop return loss due to weather events, pests, or diseases. Crop revenue insurance covers losses from both yield and price risk, and one potential benefit is that when there is a crop shortfall, and non-production occurs, the crop revenue insurance payout will cover the elevator fees for non-delivery.

CHAPTER II

LITERATURE REVIEW

Futures Price and its Dynamics

A commodity futures price establishes the purchase or sale price at a future date. Futures contracts are agreements between buyers and sellers to exchange a commodity at a set price and date in the future. The interaction of supply and demand, based on the commodity's underlying supply and demand conditions, determines the price of a futures contract in the futures market.

Futures markets play a critical role in the US and international commodity markets by providing a mechanism for buying and selling commodity contracts for potential physical delivery at future dates (Schnepf, 2005). Several commodity exchanges trade agricultural commodity futures contracts, and each exchange publishes information on contract specifications, trading hours, and other details. Cash and futures contract prices are firmly linked, and speculators provide a critical function in futures markets by expanding the trading volume and liquidity of daily futures market transactions.

Commodity prices exhibit systematic and random variation over time (Tomek & Kaiser, 2014; Abbot et al., 2008). The price change is due to supply and demand, market sentiments, government policies, and weather conditions (Schnepf, 2005). The futures price of agricultural commodities tends to be higher during the summer than in the later period of the year. Seasonality in the production of agricultural commodities causes changes in supply during different phases of the year. Crop price seasonality follows the crop's marketing year. Prices will show highs and lows within a season relative to the average price. Figures 1 – 3 illustrate seasonality in new crop futures prices - December for corn, and November for soybeans and rice – over the 2002 – 2022 sample period and obtained from Barchart.com. Although, the Efficient Markets Hypothesis would predict that new crop futures prices should not exhibit seasonality, (Li et al., 2018) show that new crop futures tend to be higher during summer months. New crop corn and soybean futures prices depicted in Figures 1 – 2 support this notion, however, higher new crop rice futures prices tend to be observed closer to harvest time. This would suggest that potentially higher returns could be locked in for corn and soybeans – but not for rice – during the pre-harvest summer months by either hedging directly in futures markets or indirectly using forward contracts offered by grain elevators. Pre-harvest grain forward contract prices are highly correlated with new crop grain futures prices because grain elevators benchmark their forward contract price offers to farmers for harvest delivery based upon new crop futures. The price differential between harvest delivery forward and futures contracts –is determined by the elevator’s expectation of the harvest basis in their local area.

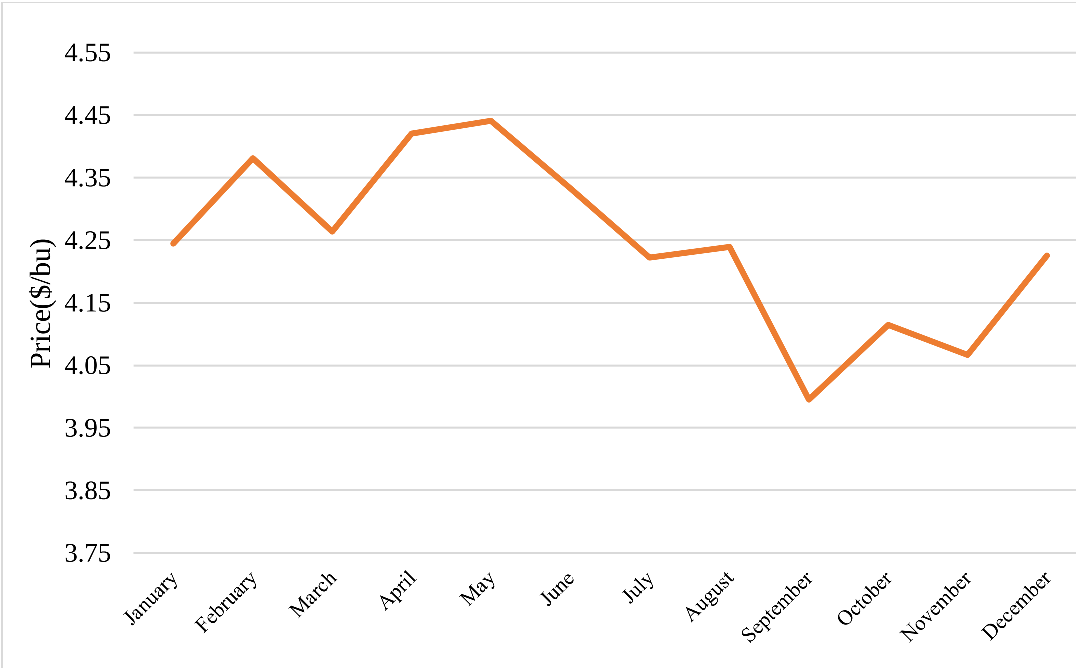


Figure 1 Monthly Average Corn Futures Price ($/bu)

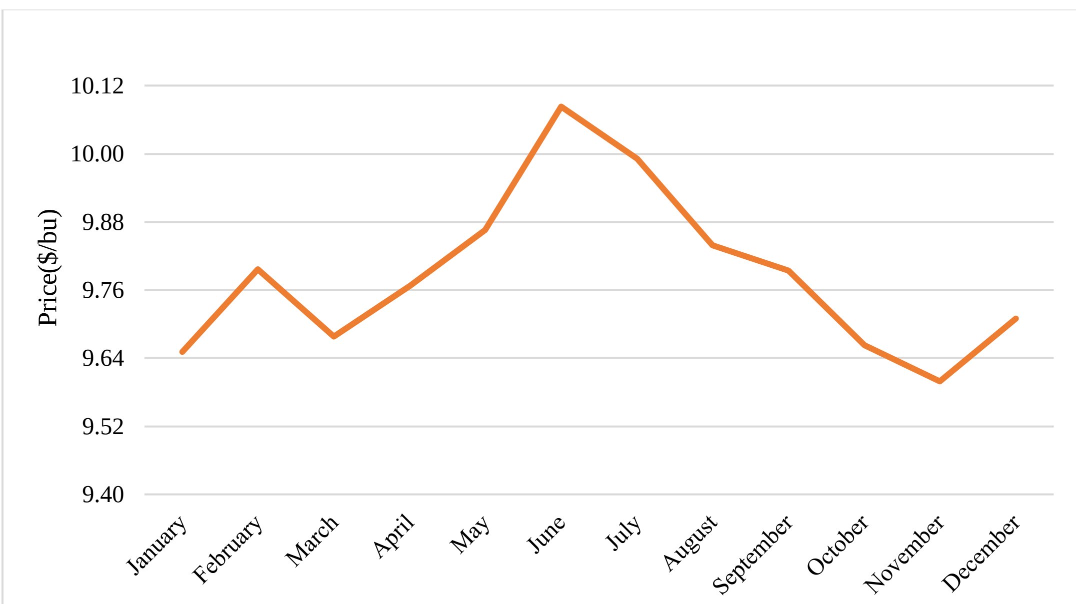


Figure 2 Monthly Average Soybeans Futures Price ($/bu)

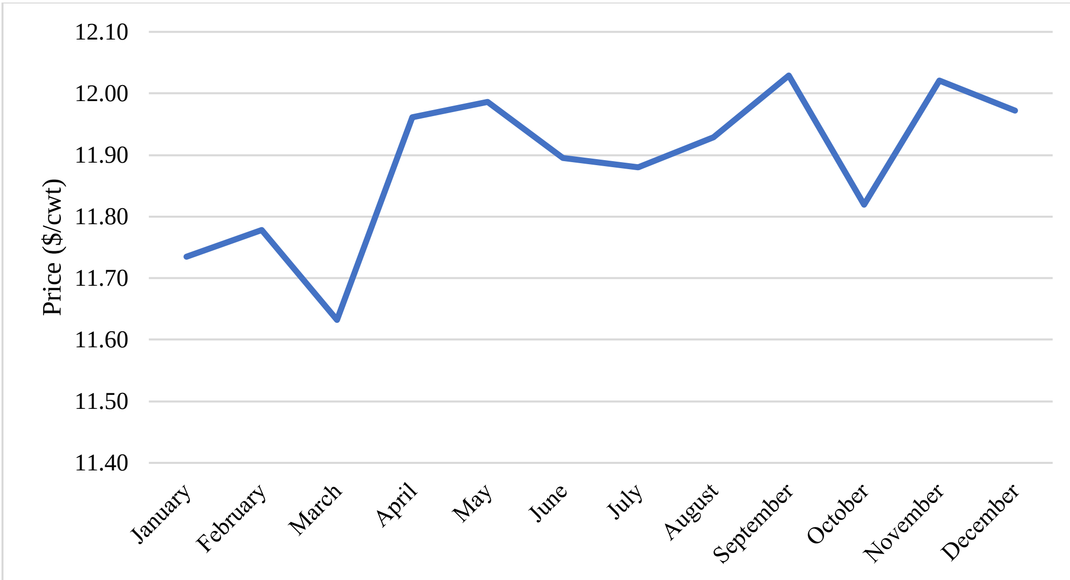


Figure 3 Monthly Average Rice Futures Price ($/cwt)

Modern Farm Safety Net Policy

The 2014 farm bill, officially known as the Agricultural Act of 2014, includes various programs to support farm income. These include commodity programs that aim to support the prices of major crops, subsidized crop insurance programs, disaster assistance programs, and marketing assistance loan programs. The two main commodity programs available to producers are the Price Loss Coverage (PLC) program and the Agricultural Risk Coverage (ARC) program. These programs offer price and revenue support to farmers, respectively. They replaced the Direct Payment and Countercyclical Payment programs that were previously in place. According to the United States Department of Agriculture (2018), the commodity programs have had average annual expenditures of over $7 billion nationwide, which accounts for 2.4 percent of all agricultural receipts (Schnepf, 2017).

The Agricultural Improvement Act of 2018, also known as the 2018 farm bill, renewed the commodity program set in place in the 2014 farm bill. The Agriculture Risk Coverage (ARC) program is on a commodity-by-commodity basis, and producers can choose which commodities to put in Agriculture Risk Coverage program and which commodities to put in PLC. The commodity program pays each program on historical base acres, which may differ from actual planted acres. One change made on the 2018 farm bill was to the commodity program decision-making process, allowing producers to re-select which program to enroll their crops in for the 2019 and 2020 crop years, and beginning with the 2021 crop, producers can choose to enroll each commodity into the PLC or ARC program on an annual basis.

Price Loss Coverage (PLC)

According to the 2014 farm bill, the PLC program pays farmers based on the national price level of the crop, with a reference price set by law for each covered commodity. The commodity program subtracts the actual national MYA price from the reference price, which is determined by the higher value between the national average market price and the national average loan rate. No payments are made if the actual price exceeds the reference price. If the reference price is higher than the actual national MYA price, the payment rate is computed by multiplying the difference between the reference price and the national average market price by a fixed farm-specific historical payment yield, then by 85 percent of historical base acres. The 2018 farm bill permits an elevator mechanism to raise the PLC reference price to 115 percent of its statutory level, called the effective reference price. This price is determined by the 5-year Olympic average of national prices or the statutory reference price, capped at 115 percent of the statutory price.

In contrast, the 2014 farm bill allowed for a one-time update of program payment yields, while the 2018 bill allowed for an update using a formula that replaces farm yields below 75 percent of the county average. The commodity program utilizes base acres to compute program payments, which can be updated using a proportion of the 4-year average of acres planted to a specific commodity or all covered commodities from 2009-2012. The 2018 farm bill removes any base acres continuously planted to grass, pasture, or left fallow between 2009 and 2017 (Lubben, 2015; Agricultural Improvement Act of 2018; Farm Service Agency, 2014).

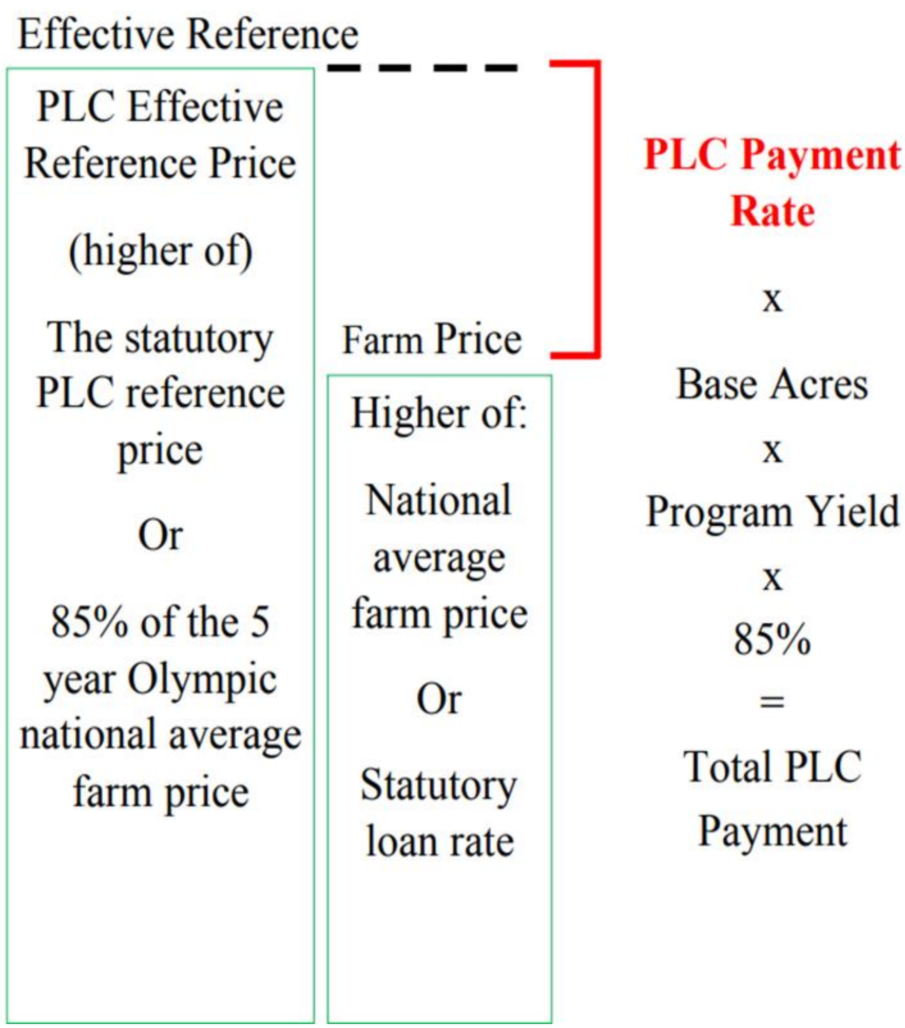


Figure 4 PLC Payment Formula

Agriculture Risk Coverage (ARC)

The ARC program is a commodity program comprising two separate programs - ARC-CO and ARC-IC, with less than 1 percent of nationwide commodity program acres enrolled in the ARC-IC option (Angadjivand, 2018). The ARC-CO, hereafter called the ARC program, pays farmers when a covered commodity's actual county crop revenue falls below the ARC county-level guarantee. The actual county revenue and the revenue guarantee are determined based on county-level yield data for the physical location of the base acres on the farm and tract. ARC payments are not dependent on planting a covered commodity or the applicable base crop on the farm.

The ARC benchmark revenue is calculated as the five-year Olympic average Marketing Year Average (MYA) price multiplied by the five-year Olympic average county yield. The benchmark yields and MYAs are calculated using the five years preceding the year prior to the program year. The ARC guarantee is then determined by multiplying the ARC benchmark revenue by 86%.

The actual crop revenue is determined by multiplying the applicable actual county yield by the MYA price for the program year. County yields for the benchmark and actual revenues are based on the physical location and historical irrigated percentage of base acres on the farm and tract. If a farm has base acres physically located in more than one county or has a historical irrigated percentage for the covered commodity, the benchmark and actual crop revenues are weighted and summarized based on those aspects at the farm level.

The ARC-CO payment is calculated as 85% of the base acres of the covered commodity multiplied by the difference between the county guarantee and the actual county crop revenue for the covered commodity. Payment rates may not exceed 10% of the ARC-CO benchmark revenue.

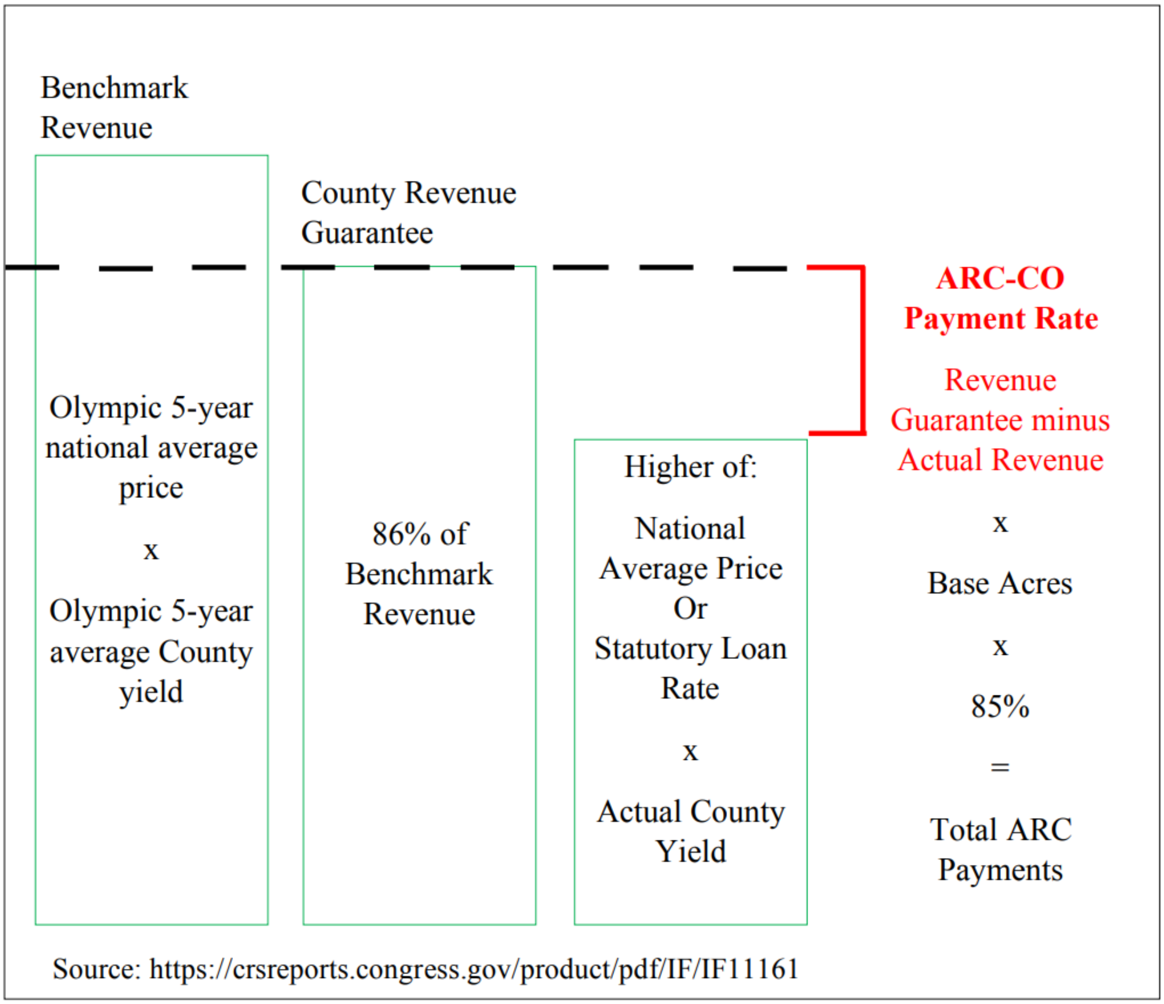
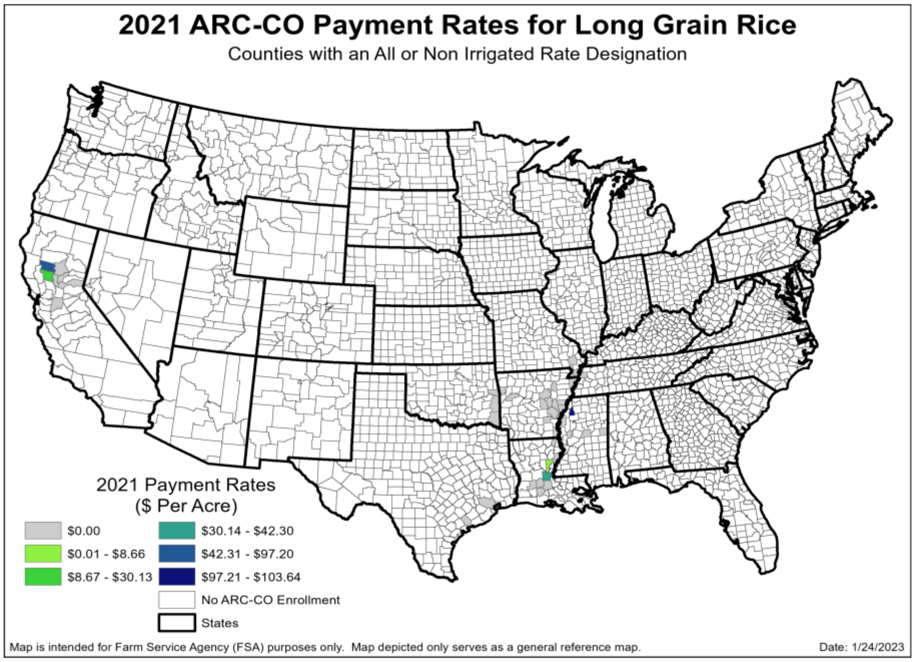
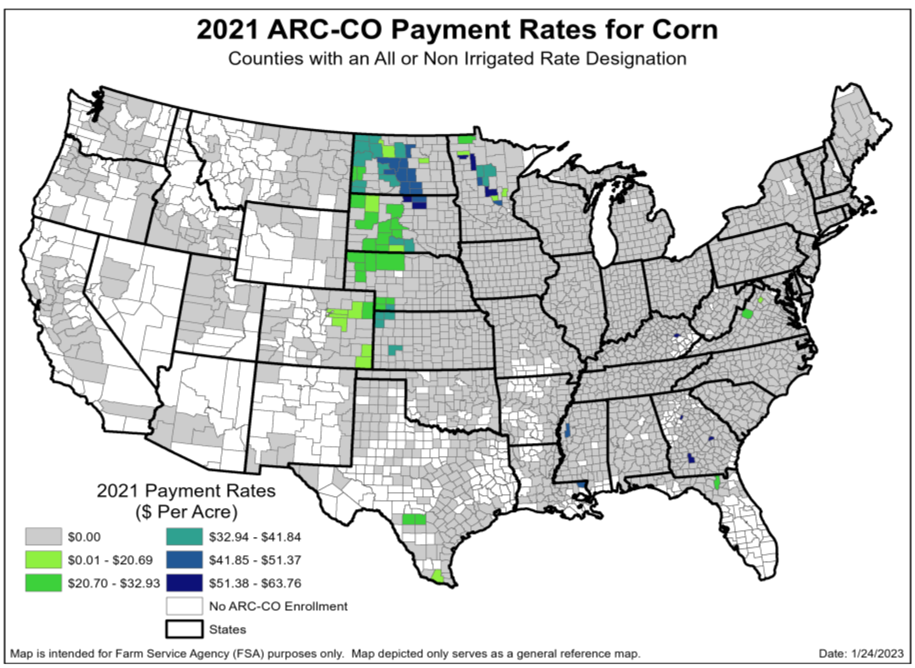


Figure 5 ARC Payment Formula



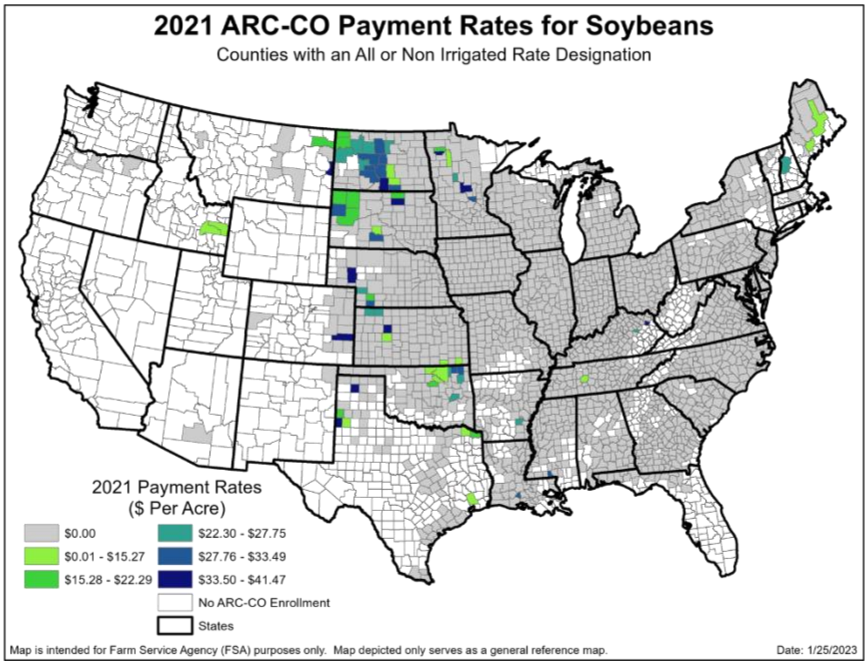
Source: USDA_FSA(2023, https://www.fsa.usda.gov/programs-and services/arcplc_program/program-payment-maps/index)

Figure 6 ARC-CO Payment Rates for Long Grain Rice 2021



Source: USDA_FSA(2023, https://www.fsa.usda.gov/programs-and-services/arcplc_program/program-payment-maps/index)

Figure 7 ARC-CO Payment Rates for Corn 2021



Source: USDA_FSA(2023, https://www.fsa.usda.gov/programs-and-services/arcplc_program/program-payment-maps/index)

Figure 8 ARC-CO Payment Rates for Soybeans 2021

The Farm Safety Net in Arkansas

The agriculture industry in Arkansas utilizes government programs, such as subsidies and commodity program payments, to sustain their operations. In 2017, Arkansas received 7% of nationwide farm support, accounting for only 2.4% of total receipts (NASS, 2019). The Rural and Farm Finance Policy Analysis Center (RAFF) (2023) estimated that 30% of Arkansas's net cash farm income comes from government program payments, excluding crop insurance indemnity payments. The farm safety net has been helpful for Arkansas farmers, enabling them to free up cash flow and continue expanding and improving their operations (Wilson, 2019).

Arkansas has received payments under the PLC and ARC commodity programs since the passage of the 2014 farm bill. Over the 2015-2022 period, Arkansas producers received $2.034 billion in PLC payments and $227 million in ARC payments (RAFF, 2023). The prevalence of rice production in the state has made the PLC program more significant than ARC payments since the passage of the 2014 bill, resulting in most payments being made under the PLC program. According to Hardke (2019), Arkansas is responsible for producing more than 49 percent of the entire US rice crop, making it the largest rice-producing state in the nation.

Crop Insurance History

The Federal Crop Insurance program was authorized in the 1930s but was limited in availability for many years. The 1980 Federal Crop Insurance Act expanded coverage to more crops and regions to protect all farmers and introduced the premium subsidy. The program operates as a public-private partnership, with private companies selling and servicing insurance policies and the government reimbursing administrative and operating expenses and providing the premium subsidy. Today, the federal crop insurance program is one of the primary risk management tools available to US farmers, covering over 130 crops. The program protects against yield losses, price declines, and revenue losses and is available to all farmers, regardless of farm size or type. The program is administered by the USDA Risk Management Agency (RMA), which sets premium rates and policy terms and conditions and ensures compliance with program regulations (Glauber, 2013).

The Federal Crop Insurance Program has undergone significant changes since its inception in the 1930s. Total insured acres for major crops have also increased from less than 30% before 1990 to over 80% of eligible acres now covered (Du et al., 2014). The program has over two million insurance policies in fifty states and covers over 745 million acres, with a total liability worth over $42 billion in 2023 (USDA RMA,2023).

Crop Insurance Demand

Biram et al. (2022) used an Expected Utility framework to evaluate the optimal risk management strategy for farmers in the Corn Belt and Mississippi Delta regions. They found that it was optimal for farmers to enroll in RP crop insurance, despite having revenue protection through ARC, and to choose coverage levels that extended into the range of coverage provided by ARC. Using this framework, the authors evaluated the expected value of different insurance options and determined the optimal coverage level for farmers to manage price and yield risk.

Maples et al. (2022) developed an analytical model to investigate the effect of crop insurance and Farm Bill program choice on producer demand for hedging. They confirmed previous findings that various forms of crop insurance impact the optimal hedge. They argued that yield protection insurance is found to be a complement to hedging, but it does not affect hedging demand in high-yield risk counties, while return protection with harvest price exclusion (RP-HPE) was found to have the most significant influence on decreasing hedging demand and served as a substitute for hedging across all locations.

Forward Contracting

Coble et al. (2000) investigated the demand for futures hedging in agriculture, considering the impact of subsidized crop insurance and using hedging as a substitute. They argued that since return insurance products can mitigate both yield and price risks, examining how the availability of subsidized insurance affects the demand for futures contracting is crucial. They also looked at how hedging, which can act as a substitute for crop insurance, affects the demand for insurance. Finally, using an expected utility framework, they developed a model that maximizes expected utility by choosing the quantity of production hedge, given that the producer is already insured.

Walters & Preston (2013) examined the return risk impacts of crop insurance and futures contracting for a corn producer using a portfolio approach. They analyzed how different crop insurance coverage and hedging levels impact return risk. The results showed that combining crop insurance and hedging provides further risk reduction and increases expected income. However, the study has some limitations, such as being specific to spring futures prices and only analyzing one crop, corn. They suggested the need for further research on return risk impacts from different crops and regions, the impact of the natural hedge on return risk reduction, and optimal hedging levels.

CHAPTER III

CONCEPTUAL FRAMEWORK

This chapter explains the Expected Utility Theory (EUT) and its application used in the study. First, the axioms of Expected Utility Theory (EUT) viz: Completeness, Transitivity, Independence, and Continuity are presented, along with an explanation of the variables conceptually involved in the utility calculations and certainty equivalent.

Expected Utility Theory

Expected Utility Theory (EUT) is a theoretical framework for decision-making that suggests that people choose based on the expected benefits they will receive from each option. EUT assumes that people are logical and aim to maximize their expected utility, given that they have all the information they need about the available options. The EUT was introduced by John von Neumann and Oskar Morgenstern in their 1944 book, "Theory of Games and Economic Behavior," to explain decision-making behavior under uncertainty (Biram, 2019).

According to EUT, individuals decide based on each option's expected utility (EU). The EU of an option is the sum of the varying monetary outcomes of each possible outcome weighted by its probability. The expected utility theory (EUT) model considers the different components (risk attitude and risk perception) that influence a decision maker's utility by representing them in an equation.

Each individual's unique utility function reflects individual preferences and experiences. Therefore, each individual's risk attitude depends on the shape of the utility function. Based on risk attitude, individuals can be grouped into risk averse, risk neutral, and risk loving.

Risk-neutral individuals are indifferent between a particular outcome and a risky one with the same expected value. They value gains and losses equally, and their utility function is linear.

Risk-loving individuals are those who are more sensitive to potential gains than losses. They prefer a risky outcome over a certain one with the same expected value. They are willing to pay a premium for uncertainty. Their utility function is typically convex, reflecting the increasing marginal utility of wealth. Risk-averse individuals are those who are more sensitive to potential losses than gains. They prefer a particular outcome over a risky one with the same expected value. In other words, they are willing to pay a premium for certainty. Their utility function is typically concave, reflecting the diminishing marginal utility of wealth.

The relationship between wealth and utility can be used to explain risk attitudes. When an individual is risk averse, they prefer a particular outcome with a lower expected payoff to a risky outcome with a higher expected payoff. As a result, the utility they gain from a particular outcome is higher than the expected utility they would gain from the risky outcome. The risk attitude of the individual can be mathematically explained as follows:

$$U'(W) > 0$$

where U(W) is the utility function of wealth W and U' (W) is the first derivative of the given utility function.

The first derivative of the utility function represents the marginal utility wealth, the additional utility gained from consuming one more unit of the wealth. However, the shape of the function can change depending on how the marginal utility changes with increasing consumption. To determine the shape of the utility function, one must consider the second derivative of the utility function.

$$U''(W) > 0$$

$$U''(W) = 0$$

$$U''(W) < 0$$

The second derivative of the utility function represents the rate of change of the marginal utility. If the second derivative is positive, the marginal utility is increasing at an increasing rate, which implies that the utility function is convex. Therefore, the individual is risk-loving if the second derivative is zero, which means that the marginal utility of wealth is constant, which implies that the utility function is linear and the individual is risk neutral. On the other hand, if the second derivative is negative, the marginal utility decreases at an increasing rate, implying that the utility function is concave and the individual is risk averse.

According to Hardaker, Huirne, and Anderson (2015), it is possible to determine an individual's level of risk aversion by using the Arrow-Pratt coefficient, also known as the coefficient of absolute risk aversion. This coefficient measures the curvature of an individual's utility function, determining their risk aversion degree. The higher the coefficient, the more risk-averse an individual is. The Arrow-Pratt coefficient can be estimated as follows:

$$R_A(W) = -\frac{U''(W)}{U'(W)}$$

The relative risk aversion coefficient R_r can be estimated as follows:

$$R_r(W) = -W\frac{U''(W)}{U'(W)}$$

The model considers a producer who is also risk-averse and who must choose the different levels – in terms of the percentage of expected harvest production to forward contract in conjunction with different crop insurance coverage levels – over the pre-harvest marketing window. This model will also account for the collective impact of crop insurance and participation in government support programs (ARC, PLC).

Forward Contract, RP, and ARC Under Expected Utility Theory

We assume that a row crop producer is making a level of the forward contract of grain decision based on the predicted county yield. Regarding farm commodity and crop insurance programs, soybean and corn crops are assumed to be eligible for Agricultural Risk Coverage (ARC) and Return Protection (RP) crop insurance, while rice is assumed to be eligible for Price Loss Coverage (PLC) and RP crop insurance. In addition, the producers are assumed to maximize the expected return defined over end-of-season called as net return per acre.

A representative Arkansas row crop producer's net returns can be written as follows:

$$NR_m = FC_m + NFC_m + G^{g \in \{ARC,PLC\}} + I - P - ND_m - C \qquad (1)$$

Where FC_m is the revenue from forward contracting grain in month m, NFC_m is the revenue from grain not forward contracted and sold in the harvest time cash market, $G^{g \in \{ARC,PLC\}}$ represents government support payments for either ARC or PLC, I and P are crop revenue insurance indemnities and premiums respectively, ND_m reflects a penalty for non-delivery of grain on the forward contract, and C is farm production costs.

Specifically, the revenue from forward contract grain is calculated as follows:

$$FC_m = \alpha Y^{APH} \times P_m^f \qquad (2)$$

FC_m is the revenue from the forward contract of grains for the, α is the percentage of forward contracted grain Y^{APH}, Y^{APH} is the expected harvest time county yield, and $P_m^f$is the forward contract price established by forward contracting. Therefore, the quantity of forward contracted grain is equivalent to αY^{APH}.

Revenue from non-forward contracted grain sold at harvest time is calculated as

$$NFC_m = \begin{cases} (\alpha Y^{APH} - Y^f) \times P^h, & when\ Y^f > \alpha Y^{APH} \\ 0, & when\ Y^f < \alpha Y^{APH} \end{cases} \quad (3)$$

NFC_m is the revenue generated from the residual non-forward contracted grain at the time of forward contracting in, P^h is the harvest cash price, and Y^f is the harvest time farm yield.

The penalty per acre for the non-delivery of forward contracted grain is calculated as follows:

$$ND_m = (\alpha Y^{APH} - Y^f) \times P^h, \quad when\ Y^f < \alpha Y^{APH} \quad (4)$$

In practice, when a farmer's harvest time yield Y^f is less than the amount of grain forward contracted αY^{APH}, the contract with respect to the shortfall amount ($Y^f - \alpha Y^{APH}$) may be cancelled and cash settled with the elevator for a small fee (typically 5 – 10 cents per bushel). The per bushel cash settlement is calculated on the difference between the forward contracted price P_m^f and the harvest time cash price P^h. If P_m^f is greater than P^h, then the elevator pays the farmer ($P_m^f - P^h$) x ($Y^f - \alpha Y^{APH}$), and if P_m^f is less than P^h, then the farmer pays the elevator ($P^h - P_m^f$) x ($Y^f - \alpha Y_{APH}$). Therefore, although we refer to ND_m as a penalty, in cases where harvest time prices are lower than the forward contract price, cancellation of the contract due to a shortfall results in a payment to the farmer. However, it should be noted that this payment is less than the forward contracting revenue lost because of non-delivery.

The payment received from different government plans is calculated as

$$G^{ARC} = MIN[MAX[G - (P^{MYA}Y^C), 0], 0.1G]0.85 \quad (5)$$

G^{ARC} is the payment received from ARC, G is the guaranteed county revenue, and P^{MYA} is the MYA price.

$$\text{Guaranteed County revenue } (G) = Z \times P^o Y^o \quad (6)$$

Z is the ARC payment rate, whose value is 0.86, P^o is the Olympic average MYA price, and Y^o is the Olympic average county yield.

$$G^{PLC} = MAX[R - MAX(P^{MYA}, L), 0]0.85Y^f \quad (7)$$

G^{PLC} is the payment received from PLC, R is the reference price, and L is the loan rate.

Insurance indemnities are calculated using the following equation:

$$I = MAX\left[\left[[MAX(P^{f,p}, P^{f,h})Y^{APH}\emptyset] - P^{f,h}Y^f\right], 0\right] \quad (8)$$

where I is the RP indemnity per planted acre, $P^{f,p}$ and $P^{f,h}$ are the futures price at planting and harvesting, respectively, and $\emptyset$ is the insurance coverage level for the farm.

The subsidized insurance premium made by the producers is calculated as follows:

$$P = \emptyset P^{f,p}Y^{APH}A(\emptyset)\big(1 - S(\emptyset)\big) \quad (9)$$

$A(\emptyset)$ is the actuarially fair base premium rate at $\emptyset$ the coverage level, and $S(\emptyset)$ is the subsidy rate at $\emptyset$ the coverage level.

The on-farm costs of production for corn, soybeans, and rice in Arkansas are obtained from the University of Arkansas Crop Enterprise Budget (UADA, 2022).

Risk Aversion Under Certainty Equivalent

The basic idea behind certainty equivalents (CE) is to find the certain income that a decision maker would accept in exchange for a risky alternative. To calculate the CE, a utility function is first specified that captures the decision maker's risk preferences. This study uses a negative exponential function, a common choice for modeling risk aversion. The negative exponential function assumes that the marginal utility of wealth decreases as wealth increases, reflecting the idea that additional wealth has diminishing marginal value. Therefore, the producer is assumed to have absolute relative risk aversion (ARRA) as given by Hardaker *et al.*, (2004) with utility function specified as:

$$U(NR) = -e^{-\theta NR} \quad (10)$$

where NR is mean net returns, and θ is the absolute relative risk aversion coefficient.

Once the utility function is specified, CE of each scenario is calculated. The scenario with the highest CE is considered the most preferred and can be used to rank the scenarios accordingly. For each scenario, the CE is calculated as:

$$CE = \ln \left(\frac{1}{N}\sum_{n=1}^{N} -e^{-\theta NR}\right) / \theta \quad (11)$$

Certainty Equivalent (CE) is the amount of money that a decision maker would be indifferent to receiving with certainty rather than facing a risky prospect. The CE can also be used to compare different risky prospects. The risk aversion coefficient used in this study ranges from 0 (risk-neutral) to 0.0369 (highly risk-averse).

CHAPTER IV

DATA AND METHODS

Stochastic Yield Simulation

The simulation being discussed utilizes 20 years of Arkansas county yield data sourced from the National Agriculture Statistics Service (NASS) for the period ranging from 2002 to 2022. This data is likely representative of the average crop yields across various farms in Arkansas County. Furthermore, the simulation employs pricing data from several sources. It uses 20 years of monthly futures prices obtained from the Barchart.com, as well as annual national cash prices received an annual national Marketing Year Average (MYA) price calculated by the National Agriculture Statistics Service (NASS). The data relating to grain basis is imported from the USDA AMS.

The yields generated from simulation follow a beta distribution, as Nelson and Preckel (1989) recommended for modeling yield risk. On the other hand, prices were generated using a lognormal distribution, given the widespread acceptance of lognormality as a standard for modeling price risk and the consistency of price behavior with lognormality (Goodwin & Ker, 2002). The grain basis and MYA prices were simulated using a truncated normal distribution.

Farm Yield Calculations

A linear trend was estimated using NASS county yield data of corn, rice, and soybeans for Arkansas County, spanning from 2002 to 2022. This trend was utilized to detrend farm-level yields for a farm located at Stuttgart, Arkansas. The linear trend was derived from the following equation:

$$Y^c = \beta_0 + \beta_1 t + \varepsilon \tag{12}$$

Y^c is observed county yield, β_0 is an intercept, β_1 is the linear trend coefficient, ε is a normally distributed error term, and t is the trend variable calculated as t= (T-2001). T is time in years.

The linear trend from the above equation is used to calculate the detrended farm yield using the equation:

$$Y^f = Y^C + \beta(2021 - T) + \varphi \tag{13}$$

where Y^f is the farm yield in year T, and φ is the idiosyncratic yield risk. The idiosyncratic farm yield risk assumes a beta distribution that accounts for a farmer's unique crop yield variability and influences the base premium rate used to calculate the producer's paid premium. Detrended county-level yields are duplicated to generate a representative sample of farm-level yield observations, and beta distribution parameters are set to maintain the same mean as the county-detrended yields.

Following Biram et. al (2022), the range of values for the beta distribution is assumed to have a maximum value of 1.5 times the largest observed county yield, and the minimum is set to insure a lower bound on yields of zero. A grid search is performed to find the optimal value of alpha and beta shape parameters that minimizes differences between the actual Risk Management Agency (RMA) base premium and empirical premium rates for 65% crop yield insurance coverage levels. Drawing 20,000 samples from this distribution for α values ranging from 0.5 to 10 in increments of 0.01 follows. These samples, demeaned by subtracting the mean, are added to the corresponding detrended yields. Subsequently, empirical premium rates are calculated at the 65% coverage level using the combined yields. This process is repeated for various α values, and the parameters yielding the empirical rate closest to the base premium rate are selected as the final values.

Stochastic Price Simulation

Monthly new crop harvest maturity futures prices spanning 2002 – 2022 from Barchart.com were used to simulate a dynamic monthly sequence of expected new crop futures price for 2023. The historical data are first transformed to natural logarithms, and autoregressive regression AR (1) models were estimated on historical monthly changes in new crop futures prices from March through the respective harvest months for corn (September), soybeans (September) and rice (October).

The simulation is based upon (1) the monthly average new crop futures prices for each commodity observed during February 2023 – the predetermined or deterministic component of the simulation – and (2) a sequence of monthly new crop futures price changes captured by our AR (1) regression models – the stochastic component of the simulation. Seven separate AR (1) regressions were estimated for each month in the sequence for corn and soybeans, while eight separate AR (1) regressions were estimated for each month in the sequence for rice. These AR (1) models capture seasonal trends in new crop futures prices and can be written as:

$$\widehat{\ln FP_m} = \beta_0 + \beta_1 * \ln FP_{m-1} + \mathcal{E}_m \tag{14}$$

where $\ln FP_t$ is the natural logarithm of the December new crop corn and November new crop soybeans and rice futures settlement prices observed in month m and ε is a normal distributed random error term.

Therefore, the discrete sequence of 2023 simulated monthly new crop futures prices can be written as:

$$\ln FP_{Feb\ 2023}, \widehat{\ln FP_1}, \widehat{\ln FP_2} \ldots\ldots\ldots\ldots \widehat{\ln FP_n} \qquad (15)$$

Where n = the 7th month for corn and soybeans or the 8th month for rice starting from March. This represents the sequence of the simulated new crop forecasts sampled each month prior to harvest and taken from equation (14). Each simulated forecast is generated by using the previous month's simulated forecast. For example, a single March simulated forecast is estimated from the equation $\widehat{\ln FP_1} = \beta_0 + \beta_1 * FP_{Feb\ 2023} + \mathcal{E}_m$, where $\mathcal{E}_m$ is a random drawing from the normally distributed error term in (14). Similarly, a single April simulated forecast, for the same price path sequence, is estimated from the equation $\widehat{\ln FP_2} = \beta_0 + \beta_1 * \widehat{\ln FP_1} + \mathcal{E}_m$, where again $\mathcal{E}_m$ is a random drawing from the normally distributed error term in (14). This approach allows us to generate a single random sequence of new crop futures prices across the pre-harvest to harvest 2023 months.

The 2023 expected harvest basis, B_e, is calculated as the mean of the yearly historical Stuttgart harvest basis over our sample period is given as:

$$B_e = (\textstyle\sum_{t=1}^{t} B_t)/t \qquad (16)$$

Harvest grain basis for the year t is calculated by using the equation:

$$B_t = \mathrm{Be} + \varepsilon \qquad (17)$$

Where ε is a truncated normal distribution based upon the historical demeaned yearly basis.

Elevators usually add some basis to the forward contract price to cover their costs and earn a profit. However, the expected basis can vary depending on several factors, such as the quality and location of the asset, transportation costs, storage costs, and supply and demand factors.

Therefore, to accurately reflect these factors in we use represent our elevator forward contracts offered each month from March through harvest as the monthly new crop futures forecast $\widehat{\ln FP_t}$ in equation (15) adjusted for the expected harvest basis B_e in equation (17).

The forward contract price FCP_m is calculated by adding up the expected basis with the monthly futures price as given in the equation,

$$FCP_m = \widehat{\ln FP_m} + B_e \qquad (18)$$

The Marketing Year Average (MYA) price is the average price farmers or producers receive for a particular commodity during a specified marketing year. The MYA price is calculated using historical futures prices to estimate the MYA price for the upcoming year. The process involves calculating the historic yearly mean of new crop futures price and fitting the demeaned difference between the yearly average new crop futures price and the yearly MYA price reported by USDA NASS. Then, simulated values are obtained from random draws from the demeaned error term, which we fit with a truncated normal distribution. The estimated MYA price for 2023 is estimated by adding these simulated values to the mean of the futures price sequence from equation (15).

The harvest cash price (HCP) for each commodity is calculated by adjusting the simulated new crop futures price observed during the harvest month using the simulated basis from equation (17). However, given rice has no observable historical harvest cash price or basis data, and given that eastern Arkansas is the delivery point for rice futures we assume a zero-harvest basis. In effect the new crop November rice futures price in October is assumed to represent the Stuttgart HCP for rice.

Exogenous Farm Program Parameters

The exogenous factors considered in the study include farm program parameters such as the ARC payment rate, Olympic Average (OA) prices, and OA yields. First, the OA yield and price are calculated using actual data from the last five years of NASS county yields and NASS MYA prices received, respectively. Next, the highest and lowest values are dropped, and the remaining three values are averaged to obtain the OA yield and price. Finally, these factors simulate the revenue distribution for all the crops.

CHAPTER VI

RESULTS

This section is divided into five subsections, each focusing on a different aspect of risk management in agriculture. The first subsection explores the farm-level yield and its characteristics, while the second subsection delves into the predicted futures price, forward contract price, and harvest price. The third subsection examines the insurance indemnities and insurance premiums under different levels of crop insurance, and the fourth subsection presents descriptive statistics of mean net return for different months under different forward contract levels and RP coverage levels. Finally, the fifth subsection discusses the optimal risk management strategy under EUT.

Characteristics of farm-level yield

Table 1 summarizes the key features of simulated farm yield for corn, soybeans, and rice in the Stuttgart farm. It includes the average yield, the standard deviation of yield, the shape parameter of the yield distribution (based on a beta distribution), and the lowest and highest yields observed for each crop. The average farm yield for corn, soybeans, and rice was 189.01bu/ac, 43.74bu/ac, and 66.66 cwt/ac, respectively.

Table 1 Characteristics of farm yield of different crops at Stuttgart, AR

	Corn	**Soybean**	**Rice**
Mean Yield	189.01	43.74	66.66
SD	84.36	23.05	27.69
Shape Parameters (α, β)	2.51,3.51	1.76,2.6	1,1.67
Min	0	0	25.61
Max	453.33	108.73	135.21

Note: The yield of Corn and Soybeans is expressed in bushels/acre, while the yield of rice is expressed in cwt/acres

Futures Price, Forward Contract Price, and Harvest Price

Table 2 displays the monthly means, standard deviations, and minimum and maximum prices for corn, soybean and rice futures and forward contracts. The table indicates that the mean futures prices for corn from March to September range from 5.96 (September) to 6.39 (June) US dollars per bushel, with standard deviations ranging from 0.20 to 1. The minimum and maximum futures prices vary between 3.46 in September to 5.33 in March and 6.75 to 10.41 US dollars per bushel, respectively. In contrast, the mean forward contract prices range from 5.78 to 6.16 US dollars per bushel, with standard deviations ranging from 0.2 to 1. The minimum and maximum forward contract prices for corn range from 3.23 to 5.10 and 6.52 to 10.18 US dollars per bushel, respectively.

Similarly, the mean futures prices for soybeans from March to September range from \$14.77 to \$15.52 per bushel, with standard deviations ranging from 0.63 to 2.01. The minimum and maximum futures prices vary between \$8.54 to \$12.77 and \$17.34 to \$23.40 per bushel, respectively. In contrast, the mean forward contract prices range from \$14.64 to \$15.39 per bushel, with standard deviations ranging from 0.63 to 2.01. The minimum and maximum forward contract prices for corn range from $8.41 to $12.64 and $17.21 to $23.27 per bushel, respectively.

The highest mean price of $17.44 per hundredweight for rice is observed in September, and the lowest of $16.77 per hundredweight in March. The highest level of volatility with a standard deviation of $2.39 per hundredweight is observed in September. The broadest range of prices is observed in October, with a minimum of $9.28 and a maximum of $31.20 per hundredweight, indicating that rice prices in October can fluctuate wildly. The forward contract prices are identical to the futures prices because there was no harvest basis involved for calculating the monthly forward contract price.

The table suggests that the average price of corn and soybean futures and forward contracts tends to be highest in June and lowest in September.

Table 2 Simulated Monthly Futures and Forward Contract Price

	Futures Price				Forward contract Price			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Corn								
March	6.02	0.2	5.33	6.75	5.78	0.2	5.1	6.52
April	6.25	0.39	5.11	7.7	6.01	0.39	4.87	7.47
May	6.3	0.44	4.94	7.81	6.06	0.44	4.7	7.57
June	6.39	0.46	5	7.95	6.16	0.46	4.76	7.71
July	6.09	0.85	3.49	9.71	5.85	0.85	3.25	9.47
August	6.02	0.95	3.49	10.41	5.79	0.95	3.26	10.18
September	5.96	1	3.46	9.94	5.73	1	3.23	9.71
Soybean								
March	14.92	0.63	12.77	17.34	14.79	0.63	12.64	17.21
April	15.15	0.84	12.41	18.88	15.02	0.84	12.28	18.75
May	15.19	1	11.87	19.77	15.06	1	11.74	19.64
June	15.52	1.29	11.78	20.86	15.39	1.29	11.65	20.73
July	15.24	1.67	10.04	22.69	15.11	1.67	9.91	22.56
August	14.98	1.86	9.54	24.23	14.86	1.86	9.41	24.1
September	14.77	2.01	8.54	23.4	14.64	2.01	8.41	23.27
Rice								
March	16.77	0.82	14.03	19.96	16.77	0.82	14.03	19.96
April	17.28	1.2	12.94	21.84	17.28	1.2	12.94	21.84
May	17.3	1.4	12.94	22.4	17.3	1.4	12.94	22.4
June	16.97	1.5	12.27	22.84	16.97	1.5	12.27	22.84
July	16.85	1.89	11.04	25.84	16.85	1.89	11.04	25.84
August	16.95	2.09	10.75	27.9	16.95	2.09	10.75	27.9
September	17.44	2.39	10.98	30.8	17.44	2.39	10.98	30.8
October	17	2.47	9.28	31.2	17	2.47	9.28	31.2

Note: The prices are listed in US dollars per bushel for Corn and Soybean and US dollars per hundredweight for rice

Table 3 presents the harvest prices of corn, soybean, and rice. The mean prices are $5.63 per bushel for corn, $11.20 per bushel for soybean, and $17 per hundredweight for rice. The standard deviation values indicate that soybean has the highest price variability at $2.8 per bushel, followed by rice at $2.47 per hundredweight and corn at $1.05 per bushel. The minimum price for corn is $2.96 per bushel, $9.35 per bushel for soybean, and $9.28 per hundredweight for rice. The maximum price for corn is $9.20 per bushel, $22.84 per bushel for soybean, and $31.2 per hundredweight for rice.

Table 3 Harvest Cash Price of Corn, Soybean, and Rice

	Corn	**Soybean**	**Rice**
Mean Price	5.67	14.630	17
SD	1.05	2.06	2.47
Min	2.96	9.35	9.28
Max	9.20	22.84	31.2

Note: The harvest prices of corn and soybeans are listed in US dollars per bushel.
The harvest prices of rice are listed in US dollars per hundredweight.

Insurance Indemnities and Insurance Premiums Under Different Levels of Crop Insurance

Tables 4 show mean insurance indemnities and premium per acre at all eight RP coverage level for corn, soybean and rice respectively. Table 4 shows that the crop insurance policy with an 85 percent RP (Return Protection) provides the highest average net indemnity.

As the coverage level increases, the mean insurance indemnity also increases, indicating that the insured party would receive a higher payout in the event of a loss or damage. However, the mean insurance premium increases as the coverage level increases, meaning that the cost of obtaining coverage increases.

Table 4 Insurance Indemnities and Premiums for Different Crops at Different Coverage Levels

	Insurance Indemnities				Insurance Premium			
Coverage Level	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Corn								
50%	36.83	103.14	0	809.76	11.07	1.26	8.8	18.07
55%	39.28	110.57	0	895.64	13.19	2.35	6.65	22.99
60%	65.12	147.74	0	981.52	16.42	1.87	13.06	26.81
65%	83.15	171.81	0	1067.41	21.49	2.45	17.09	35.08
70%	103.98	196.76	0	1153.29	24.94	2.85	19.84	40.72
75%	127.51	222.42	0	1239.17	30.42	3.47	24.2	49.67
80%	153.86	248.5	0	1325.05	38.67	4.41	30.76	63.14
85%	183.08	274.77	0	1410.93	51.41	5.86	40.9	83.94
Soybean								
50%	64.72	113.63	0	535.07	4.56	0.34	3.45	5.81
55%	82.04	131.34	0	597.32	6.11	0.45	4.63	7.79
60%	101.62	149.24	0	659.58	7.6	0.56	5.75	9.68
65%	123.54	167.06	0	721.83	10.83	0.8	8.19	13.79
70%	147.69	184.65	0	784.09	13.51	0.85	10.73	16.75
75%	173.91	201.94	0	846.34	18.47	1.17	14.67	22.9
80%	202.08	218.87	0	908.6	26.5	1.95	20.06	33.75
85%	232.28	234.93	0	970.85	38.81	2.86	29.38	49.44
Rice								
50%	27.61	65.69	0	394.8	3.54	0.2	2.93	4.24
55%	43.59	89.21	0	470.06	4.51	0.25	3.73	5.4
60%	63.39	114.18	0	545.32	5.41	0.3	4.48	6.48
65%	86.57	140.22	0	620.58	7.17	0.4	5.93	8.58
70%	113.11	166.82	0	695.84	8.28	0.46	6.86	9.92
75%	142.95	193.54	0	771.1	10.95	0.61	9.06	13.11
80%	176.03	220.06	0	846.36	14.83	0.83	12.27	17.76
85%	212.1	246.19	0	923.3	19.83	1.11	16.42	23.75

Note: The insurance indemnities and premiums are listed in US dollars per acres

Descriptive Statistics of Mean Net Return for Different Months Under Different Forward Contract Levels

Tables 5 through 9 present the mean net returns per acre for corn, soybeans, and rice with respect to each pre-harvest forward contracting month, and given different levels of forward contracting (0%, 25%, 50%, 75% and 100%), and excluding any payments from crop revenue insurance or government support plans. The mean net revenue for all crops varies by month, with the highest mean net revenue observed in June for corn and soybean, and in September for rice. Our results clearly show a net return premium to forward contracting corn and soybeans in the summer. Interestingly, a similar forward contracting summer premium does not exist for rice, with the highest net returns earned by forward contracting in September.

There is a considerable probability of making a loss for all three crops under different scenarios. It can be seen from table 5 through 9 that increasing the level of forward contracting results in a decrease in the probability of making a loss for all three commodities. For example, for corn, the probability of making a loss decreases from 35.31% when no forward contracting is done to 26.92% when 100% forward contracting is done. Similarly, for soybeans, the probability of making a loss decreases from 52.61% to 26.92%, and for rice, it decreases from 48.91% to 46.35%. However, with respect to the likelihood of suffering large losses in extreme conditions, our 1% tail risk values show that there is a nonlinear effect of forward contracting greater percentages of expected production. Irrespective of commodity, as forward contracting levels initially increase from 0% through 25% there is moderate decrease in extreme losses at the 1% tail risk level. However, at levels of 50% through 100% forward contracting extreme losses at the 1% tail risk level increase quite dramatically. This is consistent with the notion that in cases where yields are low and harvest cash prices are higher relative to forward contract prices the penalty for non-delivery has a significantly negative impact on net returns.

Table 5 Mean Net Revenue for Different Months at 0% Forward Contract with No Insurance and Government Support Plans

Months	Mean	SD	Min	Max	1%	5%	10%	Probability of loss
Corn								
March	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
April	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
May	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
June	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
July	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
August	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
September	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
Soybean								
March	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
April	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
May	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
June	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
July	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
August	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
September	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
Rice								
March	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
April	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
May	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
June	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
July	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
August	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
September	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
October	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%

Note: Mean net revenue is in $/acre and the mean of simulated net revenue is drawn from 5000 iteration in @RISK

Table 6. Mean Net Revenue for Different Months at 25% Forward Contract with no Insurance and Government Support Plans

Months	Mean	SD	Min	Max	1% Tail risk	5%	10%	Probability of loss
Corn								
March	291.91	596.48	-1045.27	2537.49	-778.89	-583.47	-441.93	34.44%
April	307.42	598.09	-1016.07	2594.03	-754.94	-564.81	-433.93	33.76%
May	310.67	598.65	-1011.04	2614.07	-755.22	-561.29	-431.66	33.37%
June	316.47	598.76	-1004.24	2621.94	-749.28	-556.00	-426.52	33.15%
July	298.00	608.05	-938.72	2663.94	-778.37	-587.92	-451.40	34.54%
August	294.76	611.49	-962.99	2709.58	-778.08	-598.75	-449.38	34.71%
September	288.83	613.85	-954.35	2684.05	-786.20	-600.34	-452.70	35.29%
Soybean								
March	14.46	344.30	-692.92	1294.31	-573.96	-489.46	-419.59	51.73%
April	17.81	344.69	-687.54	1300.97	-569.27	-489.17	-417.71	51.27%
May	18.47	345.12	-690.76	1309.46	-571.58	-488.48	-415.44	51.19%
June	23.41	346.20	-655.92	1317.49	-566.08	-481.22	-414.59	51.08%
July	19.18	347.86	-645.48	1306.18	-569.07	-487.89	-419.26	51.44%
August	15.42	349.01	-633.03	1320.59	-574.01	-490.98	-425.05	51.90%
September	12.28	349.85	-625.40	1351.66	-578.86	-493.48	-430.23	52.11%
Rice								
March	85.02	486.69	-656.98	1958.77	-611.36	-558.03	-500.39	49.24%
April	95.31	487.93	-673.40	1960.02	-606.31	-548.18	-492.70	48.57%
May	95.70	488.99	-688.26	1998.99	-613.30	-549.21	-491.79	48.34%
June	89.18	489.79	-692.79	2031.72	-621.44	-556.23	-498.03	48.86%
July	86.69	493.12	-718.40	2057.95	-632.19	-563.09	-504.79	49.18%
August	88.62	494.52	-731.58	2076.98	-634.90	-565.83	-503.22	48.99%
September	98.54	496.87	-740.40	2145.34	-631.29	-556.47	-494.37	48.22%
October	89.64	497.71	-740.03	2125.09	-642.58	-564.07	-500.37	48.98%

Note: Mean net revenue is in $/acre and the mean of simulated net revenue is drawn from 5000 iteration in @RISK

Table 7 Mean Net Revenue for Different Months at 50% Forward Contract With no Insurance and Government Support Plans

Months	**Mean**	**SD**	**Min**	**Max**	**1% Tail risk**	**5%**	**10%**	**Probability of loss**
Corn								
March	293.99	581.45	-1075.44	2587.57	-785.51	-589.64	-434.25	34.36%
April	325.01	585.06	-1054.81	2601.65	-762.30	-553.99	-404.92	32.25%
May	331.51	586.45	-1058.05	2618.56	-759.12	-552.09	-406.42	31.83%
June	343.10	586.71	-1045.88	2630.71	-748.21	-540.52	-395.60	31.22%
July	306.26	600.60	-1021.31	2818.90	-768.29	-573.26	-436.37	34.22%
August	299.83	607.22	-945.55	2872.75	-784.22	-583.49	-451.06	34.80%
September	288.19	610.27	-930.26	2878.97	-790.47	-602.24	-462.68	35.31%
Soybean								
March	18.59	344.13	-760.50	1168.25	-588.96	-485.82	-415.45	51.19%
April	25.25	344.80	-746.73	1171.10	-578.40	-480.98	-409.81	50.63%
May	26.57	345.71	-736.36	1196.72	-574.65	-480.82	-408.36	50.30%
June	36.46	347.89	-699.04	1241.14	-563.86	-471.03	-403.71	49.62%
July	28.01	351.11	-702.31	1274.26	-567.52	-480.17	-410.97	50.80%
August	20.50	353.22	-665.95	1305.19	-574.80	-489.25	-419.24	51.84%
September	14.26	355.04	-615.28	1295.62	-580.06	-491.54	-425.12	52.55%
Rice								
March	80.46	480.47	-710.12	1652.00	-622.01	-560.26	-500.90	49.49%
April	101.00	483.66	-715.67	1696.14	-611.87	-544.65	-479.48	48.19%
May	101.85	485.11	-700.78	1726.64	-611.37	-542.54	-483.30	47.91%
June	88.78	486.53	-700.32	1738.98	-626.71	-559.34	-493.36	48.85%
July	83.70	490.36	-740.07	1806.70	-636.57	-567.94	-505.53	49.06%
August	87.76	493.69	-742.41	1884.85	-641.86	-565.59	-504.96	49.08%
September	107.62	498.13	-732.89	1916.89	-633.08	-549.28	-486.41	47.62%
October	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%

Note: Mean net revenue is in $/acre and the mean of simulated net revenue is drawn from 5000 iteration in @RISK

Table 8 Mean Net Revenue for Different Months at 75% Forward Contract without Insurance and Government Support Plans

Months	**Mean**	**SD**	**Min**	**Max**	**1%**	**5%**	**10%**	**Probability of loss**
Corn								
March	297.37	577.07	-1371.40	2401.36	-818.11	-576.23	-431.92	33.00%
April	343.91	580.57	-1283.80	2501.30	-768.64	-525.96	-388.91	30.46%
May	353.67	581.77	-1268.71	2589.29	-745.40	-517.60	-382.29	30.00%
June	371.05	582.13	-1248.29	2611.77	-729.43	-501.61	-363.26	29.09%
July	315.65	602.22	-1075.53	2705.98	-767.61	-570.87	-432.56	32.95%
August	305.92	609.66	-1028.16	2760.62	-785.31	-591.94	-447.08	33.72%
September	288.12	614.73	-959.03	2684.05	-790.80	-603.84	-455.25	35.32%
Soybean								
March	19.40	340.14	-904.49	1209.20	-620.97	-489.31	-411.15	50.85%
April	29.44	340.95	-888.35	1229.18	-611.11	-478.85	-399.52	49.96%
May	31.43	341.72	-898.03	1254.62	-600.03	-476.72	-395.58	49.59%
June	46.24	344.04	-793.50	1278.73	-573.81	-460.81	-385.47	48.35%
July	33.57	347.01	-751.68	1244.80	-574.81	-477.24	-404.63	49.84%
August	22.28	348.95	-701.10	1279.94	-582.04	-487.56	-418.61	51.05%
September	12.87	349.82	-631.14	1358.37	-579.78	-491.84	-428.77	51.96%
Rice								
March	75.79	477.55	-881.66	1626.11	-679.31	-575.66	-502.56	49.41%
April	106.65	479.60	-870.26	1629.87	-646.27	-550.04	-477.19	47.24%
May	107.81	481.61	-821.32	1746.79	-648.50	-547.10	-470.65	47.16%
June	88.25	482.73	-819.14	1844.97	-658.98	-564.56	-494.54	48.68%
July	80.78	489.22	-772.89	1923.67	-660.34	-576.93	-504.21	49.26%
August	86.59	491.73	-750.25	1980.75	-648.86	-570.29	-502.88	48.89%
September	116.33	497.76	-741.14	2185.84	-629.10	-547.68	-478.93	47.08%
October	89.64	497.71	-740.03	2125.09	-642.58	-564.07	-500.37	48.98%

Note: Mean net revenue is in $/acre and the mean of simulated net revenue is drawn from 5000 iteration in @RISK

Table 9 Mean Net Revenue for Different Months at 100% Forward Contract without Insurance and Government Support Plans

Months	Mean	SD	Min	Max	1% Tail risk	5%	10%	Probability of loss
Corn								
March	299.49	575.50	-1534.46	2333.29	-866.70	-581.13	-430.87	32.88%
April	361.55	579.19	-1417.67	2466.55	-804.84	-520.37	-376.20	29.25%
May	374.56	580.43	-1397.54	2583.87	-776.24	-504.61	-362.97	28.76%
June	397.73	580.92	-1370.31	2613.84	-749.43	-481.57	-338.38	27.19%
July	323.87	602.19	-1179.41	2754.25	-770.04	-572.49	-425.50	32.34%
August	310.89	610.16	-1076.81	2786.15	-780.58	-589.63	-444.67	33.43%
September	287.17	615.56	-961.37	2684.05	-793.11	-606.13	-457.57	35.38%
Soybean								
March	21.87	341.67	-1010.28	1166.64	-654.06	-496.58	-412.32	50.19%
April	35.26	342.47	-988.75	1193.28	-636.61	-480.16	-401.99	48.88%
May	37.91	343.17	-1001.66	1227.21	-625.27	-473.82	-393.76	48.79%
June	57.66	345.60	-862.29	1259.35	-593.95	-453.57	-375.67	46.77%
July	40.77	348.19	-806.53	1214.11	-581.69	-472.67	-398.75	48.80%
August	25.71	349.78	-735.14	1259.61	-585.80	-487.53	-416.29	50.73%
September	13.17	349.83	-634.01	1361.73	-580.56	-493.37	-429.16	52.03%
Rice								
March	71.17	479.68	-1058.12	1521.20	-755.10	-600.22	-515.11	49.19%
April	112.32	481.25	-1042.92	1595.43	-694.12	-564.53	-471.39	46.39%
May	113.87	483.12	-976.04	1682.40	-699.87	-561.32	-469.18	46.29%
June	87.79	483.73	-943.86	1751.60	-704.66	-578.97	-493.53	48.11%
July	77.82	489.95	-854.65	1856.52	-698.90	-586.76	-507.15	49.29%
August	85.57	492.16	-805.69	1932.64	-671.58	-578.97	-504.58	48.98%
September	125.23	499.49	-757.61	2206.09	-641.94	-545.23	-471.92	46.50%
October	89.64	497.71	-740.03	2125.09	-642.58	-564.07	-500.37	48.98%

Note: Mean net revenue is in $/acre and the mean of simulated net revenue is drawn from 5000 iteration in @RISK

Descriptive Statistics mean net return for different levels of forward contracting and different RP coverage levels on Mean net return of Corn, Rice, and Soybean

Figure 9-11 shows the descriptive statistics of mean net return for corn, soybeans and rice respectively for different RP coverage levels. Table 10 showcases the mean net revenue for corn, soybean under different scenarios involving various combinations of ARC and RP insurance coverage, as well as the different level of forward contracting (FC) provided. The highest average mean net return for all crops (corn, soybean and rice) was observed with 100% forward contracting and 85% RP coverage level. With respect to rice we similarly present results for different scenarios of RP and FC and PLC. Since 2023 faced a relatively high price environment ARC and PLC coverage plays little to no role in impacting mean net revenues. In general, mean net revenue for all three commodities tends to increase as the level of insurance coverage (RP) and the percentage of FC increase. This is because higher levels of insurance coverage reduce the risks associated with agricultural production, leading to higher mean net revenues for the producers.

For corn, the mean net revenue increases with the level of FC and RP coverage. Without ARC and RP, the mean net revenue is $288.39 /acre for 0% FC and increases to $397.73 /acre for 100% FC. Adding RP further increases the mean net revenue at each level of FC, with the highest mean net revenue observed at $527.52 /acre for the combination of ARC and 85% RP at 100% FC.

In the case of soybeans, the addition of RP coverage increases mean net revenue, with a more pronounced effect when combined with ARC. An increase in mean net revenue is associated with higher RP coverage levels. The highest mean net revenue observed at $253.32 /acre for the combination of ARC and 85% RP at 100% FC.

For rice, similar to corn, the mean net revenue demonstrates an increasing trend with higher levels of FC and RP coverage. The mean net revenue starts at $89.93/acre for 0% FC without RP and PLC. The highest mean net revenue is observed at $318.45 /acre with PLC and 85% RP coverage at 100% FC.

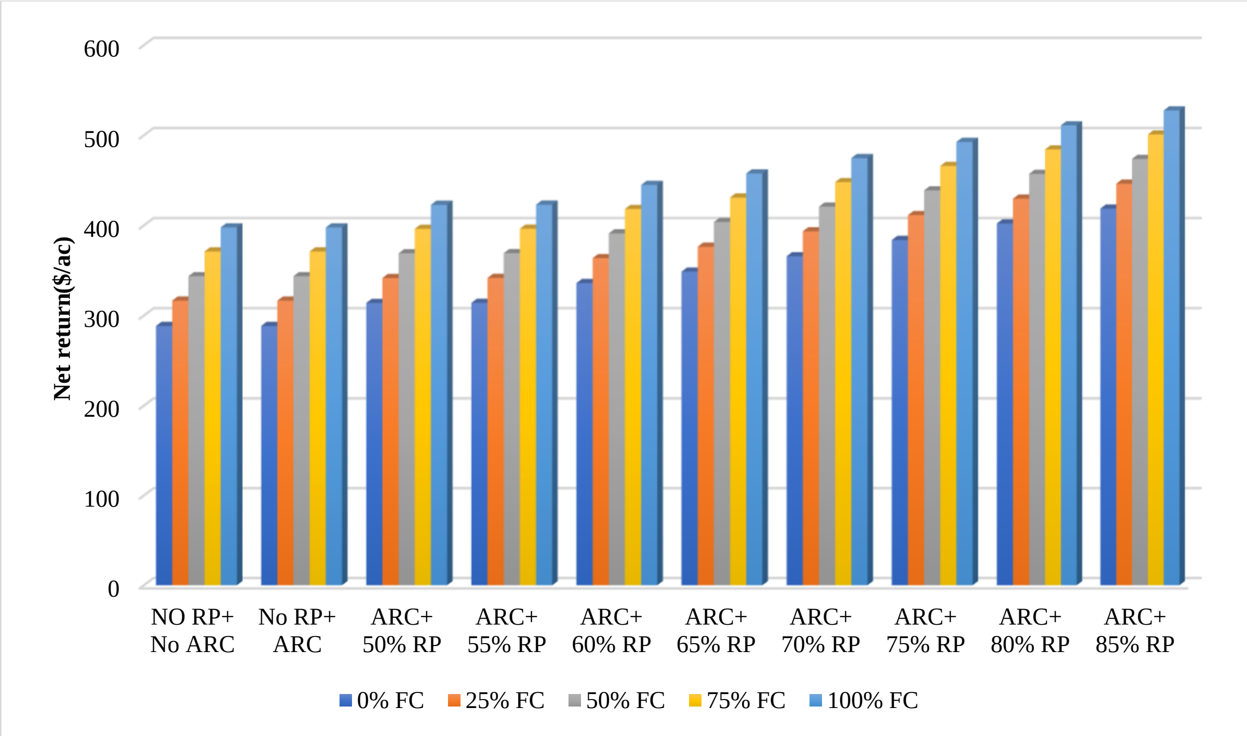


Figure 9 Mean net return of corn on June for different levels of forward contracting at different RP coverage levels

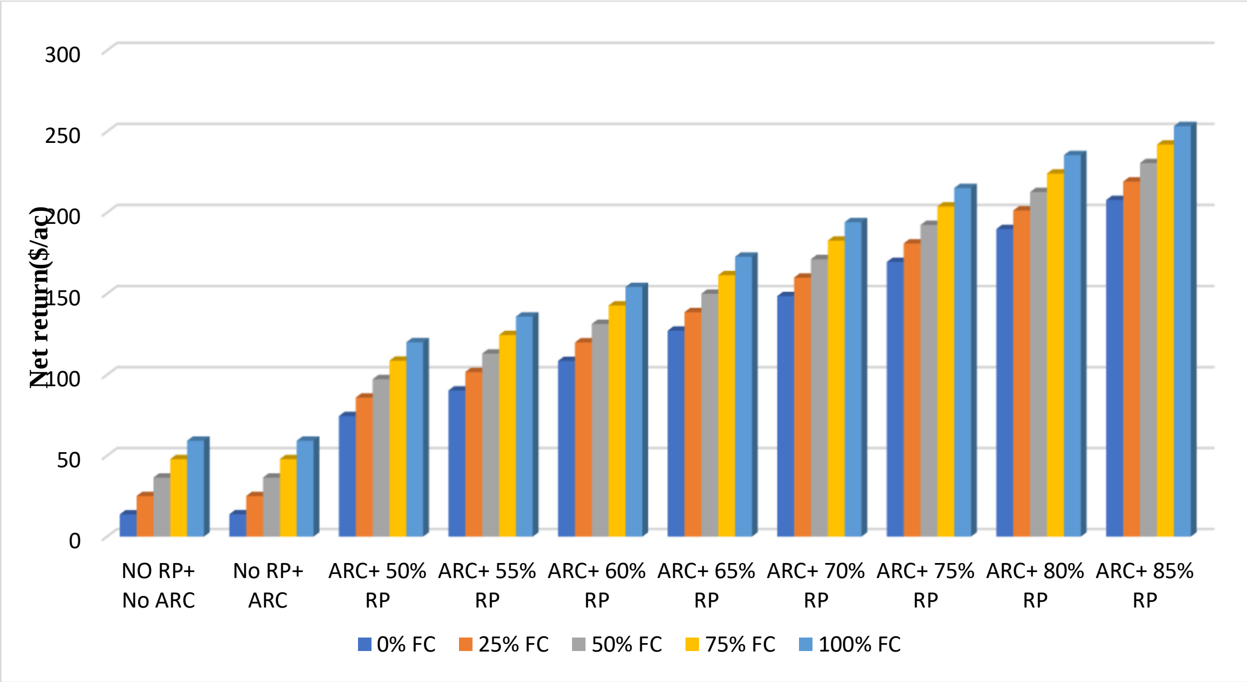


Figure 10 Mean net return of soybeans on June for different levels of forward contracting at different RP coverage level

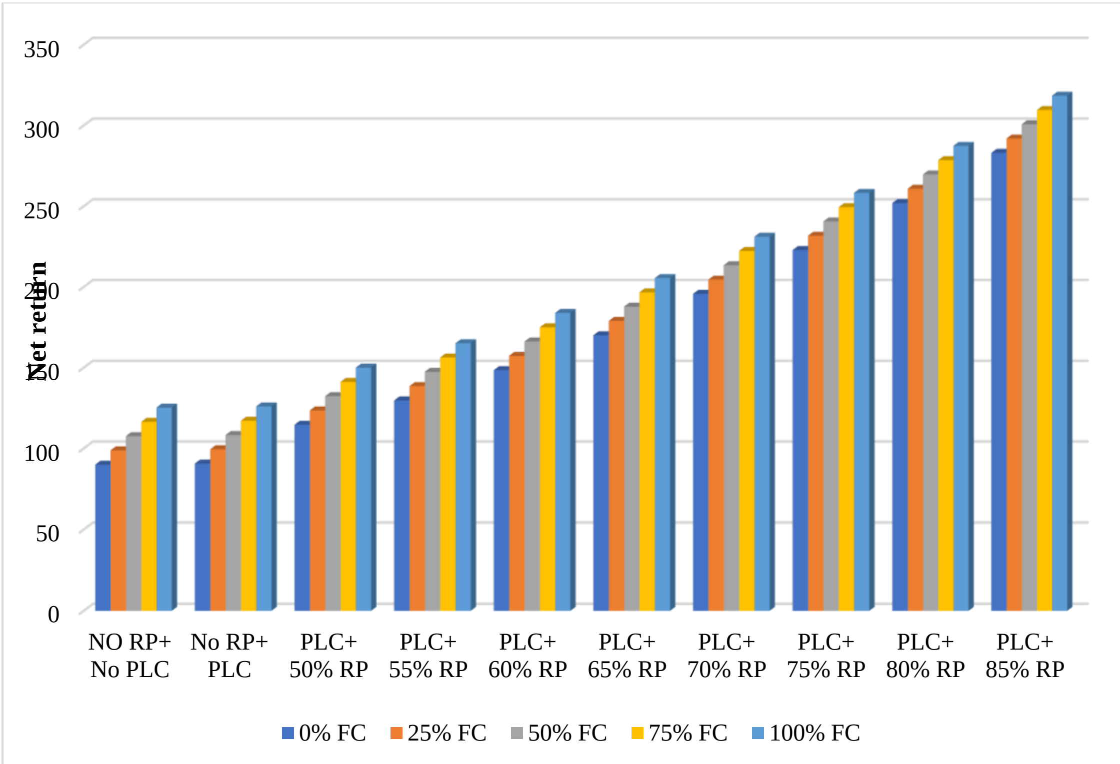


Figure 11 Mean net return of rice on September for different level of forward contracting and different RP coverage level

Table 10 Mean net revenue for corn, soybean, and rice under different level of forward contracting (FC) with various combinations of Revenue Protection (RP) insurance coverage and ARC

	NO RP+ No ARC	**No RP+ ARC**	**ARC+ 50% RP**	**ARC+ 55% RP**	**ARC+ 60% RP**	**ARC+ 65% RP**	**ARC+ 70% RP**	**ARC+ 75% RP**	**ARC+ 80% RP**	**ARC+ 85% RP**
Corn (June)										
0% FC	288.39	288.39	313.94	314.06	336.01	348.67	365.73	383.76	402.06	418.63
25% FC	316.47	316.47	341.57	341.68	363.63	376.30	393.35	411.38	429.68	446.25
50% FC	343.56	343.56	369.03	369.14	391.09	403.76	420.81	438.84	457.14	473.71
75% FC	371.05	371.05	396.15	396.27	418.22	430.88	447.94	465.97	484.27	500.84
100% FC	397.73	397.73	422.84	422.96	444.91	457.57	474.62	492.65	510.96	527.52
Soybean (June)										
0% FC	13.67	13.77	74.46	90.29	108.53	127.19	148.49	169.56	189.87	207.75
25% FC	25.06	25.06	85.86	101.68	119.92	138.58	159.88	180.95	201.26	219.14
50% FC	36.46	36.46	97.25	113.07	131.31	149.97	171.27	192.35	212.65	230.54
75% FC	47.85	47.85	108.64	124.46	142.71	161.37	182.67	203.74	224.05	241.93
100% FC	59.24	59.24	120.04	135.86	154.10	172.76	194.06	215.13	235.44	253.32

Rice (September)	**NO RP+ No PLC**	**No RP+ PLC**	**PLC+ 50% RP**	**PLC+ 55% RP**	**PLC+ 60% RP**	**PLC+ 65% RP**	**PLC+ 70% RP**	**PLC+ 75% RP**	**PLC+ 80% RP**	**PLC+ 85% RP**
0% FC	89.93	90.61	114.66	129.76	148.50	170.10	195.73	222.85	251.97	283.06
25% FC	98.77	99.46	123.51	138.60	157.35	178.95	204.57	231.70	260.81	291.90
50% FC	107.62	108.31	132.36	147.45	166.20	187.79	213.42	240.55	269.66	300.75
75% FC	116.47	117.15	141.21	156.30	175.04	196.64	222.27	249.40	278.51	309.60
100% FC	125.32	126.00	150.05	165.15	183.89	205.49	231.12	258.24	287.35	318.45

Note: Mean net revenue is in $/acre and the mean of simulated net revenue is drawn from 5000 iteration in @RISK

Revenue Risk During High Mean Net Revenue Months

Revenue risks faced by producers during high mean net revenue months with and without forward contracting (100%FC) and RP (85% coverage level) are presented in Figure 12-14. Figure 12-14 demonstrates that for corn, the 1% tail risk increases by $36.71 /acre with 100% FC, while 100% FC with 85% RP reduces the risk by $740.66 per acres. Similarly, for soybean, the 1% tail risk rises by $25 per acre with 100% FC without crop insurance, but it reduces by $578.82/ acre with 100% FC and 85% RP. Furthermore, for rice, the 1% tail risk decreases by $3.64 /acre with 100% FC and decreases by $559.36 / acre with 100% FC and 85% RP.

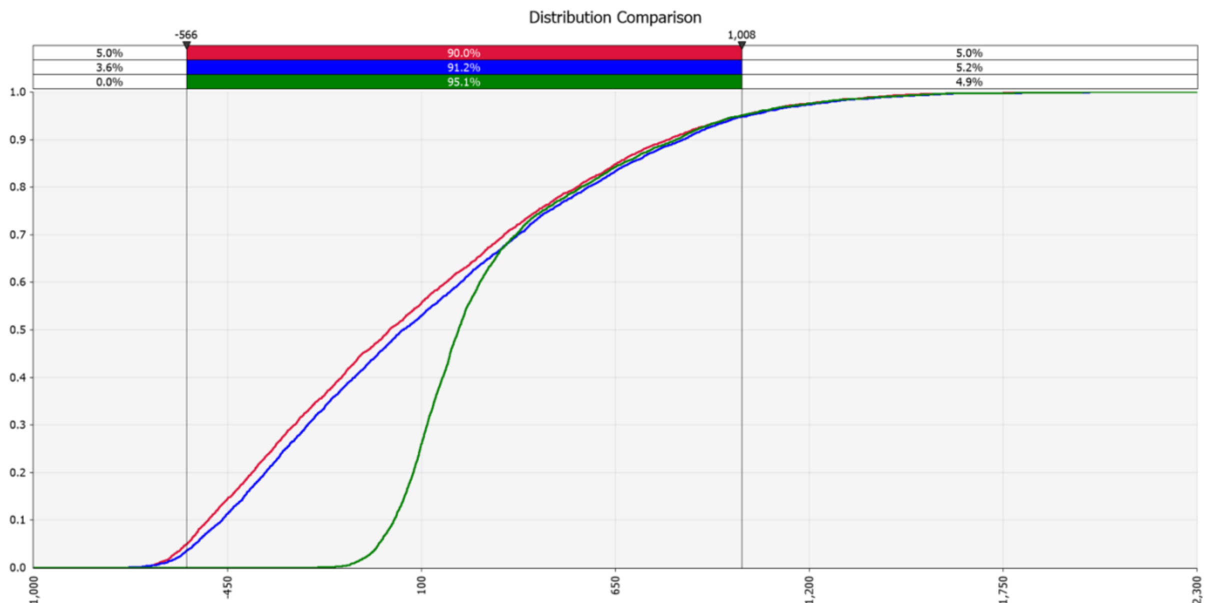


Figure 12 CDF of 0% FC with no insurance (red), 100% FC with no insurance (blue) and 100% FC with 85% RP (green) for rice

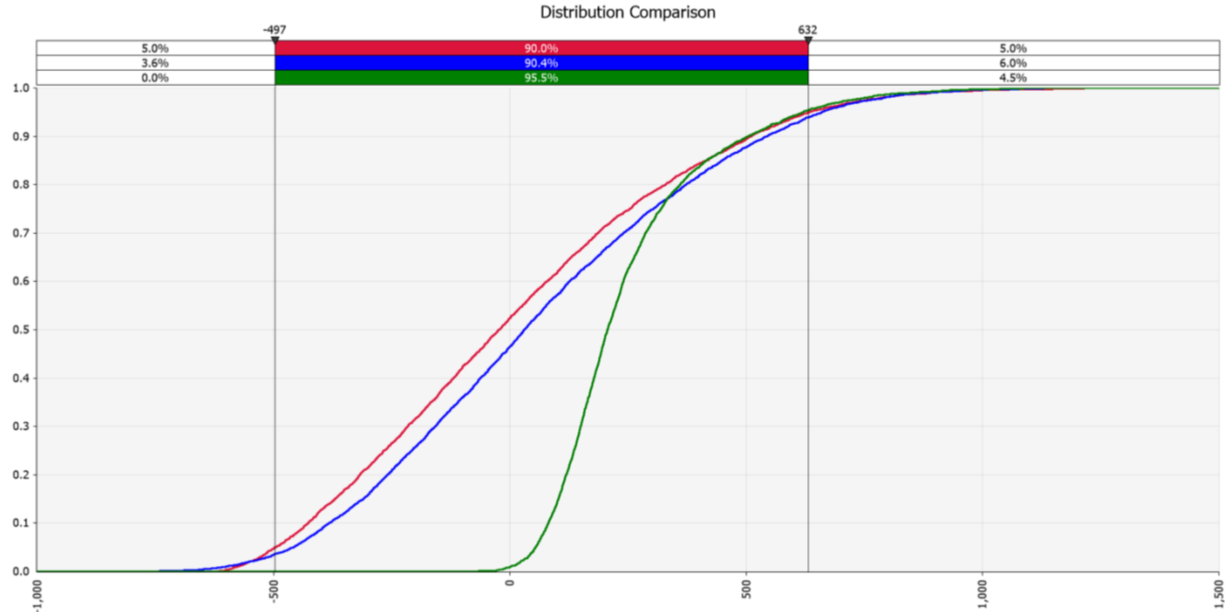


Figure 13. CDF of 0% FC with no insurance (red), 100% FC with no insurance (blue) and 100% FC with 85% RP (green) for soybean

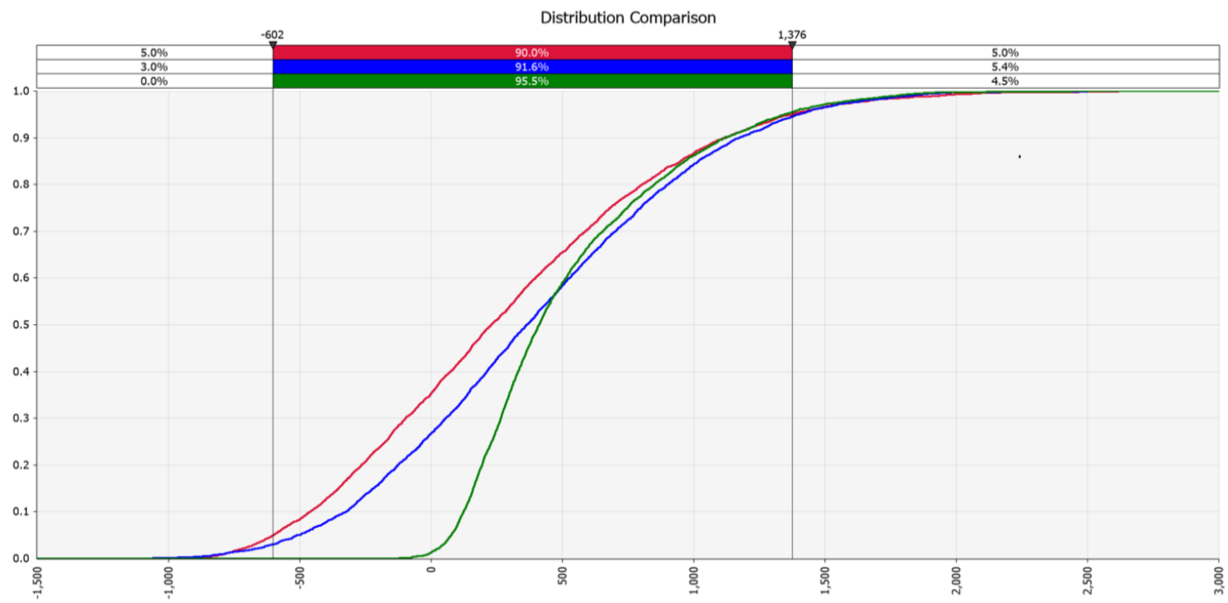


Figure 14. CDF of 0% FC with no insurance (red), 100% FC with no insurance (blue) and 100% FC with 85% RP (green) for corn

Risk Aversion Under CE

Figure 15, 16, and 17 present the estimated certainty equivalents (CE) for corn, soybeans, and rice, respectively, under different scenarios and absolute risk aversion coefficients (ARACs). Based on the results presented in figure 15 through 17, it is recommended that farmers who are not very risk-averse use a strategy of 100% forward contracting with 85% RP coverage level for all crops. However, very risk-averse farmers may prefer to use a strategy of 25% forward contracting for corn, rice and soybean when crop insurance is not available. This indicates that very risk averse farmers prioritize risk reduction over maximizing profits, where higher levels of risk are associated with more aggressive forward contracting (100%) versus (25%) due to greater non-production/delivery risk. This is consistent with our 1% tail risk net returns presented in tables 5 through 9. Although crop revenues insurance cannot eliminate all net returns risk, insuring at the 85% level while forward contracting 100% of expected production always yields higher CEs in comparison to either simply selling in the harvest cash market without insurance or forward contracting; or forward contracting at low (25%) levels without insurance; or forward contracting at high (100%) levels and without insurance.

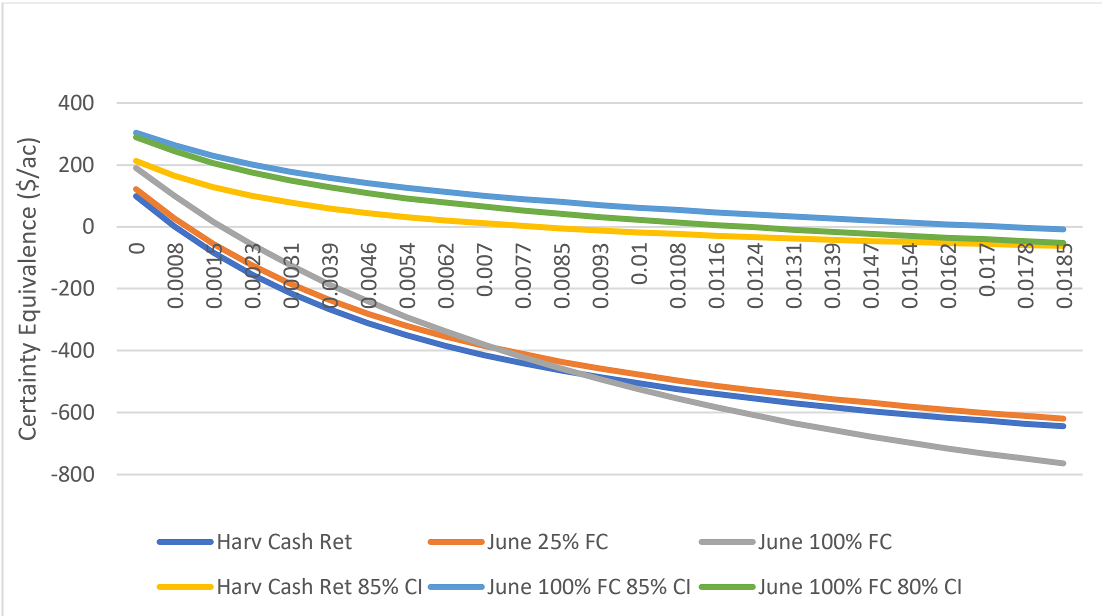


Figure 15 CE under a negative Exponential Utility Function for Corn

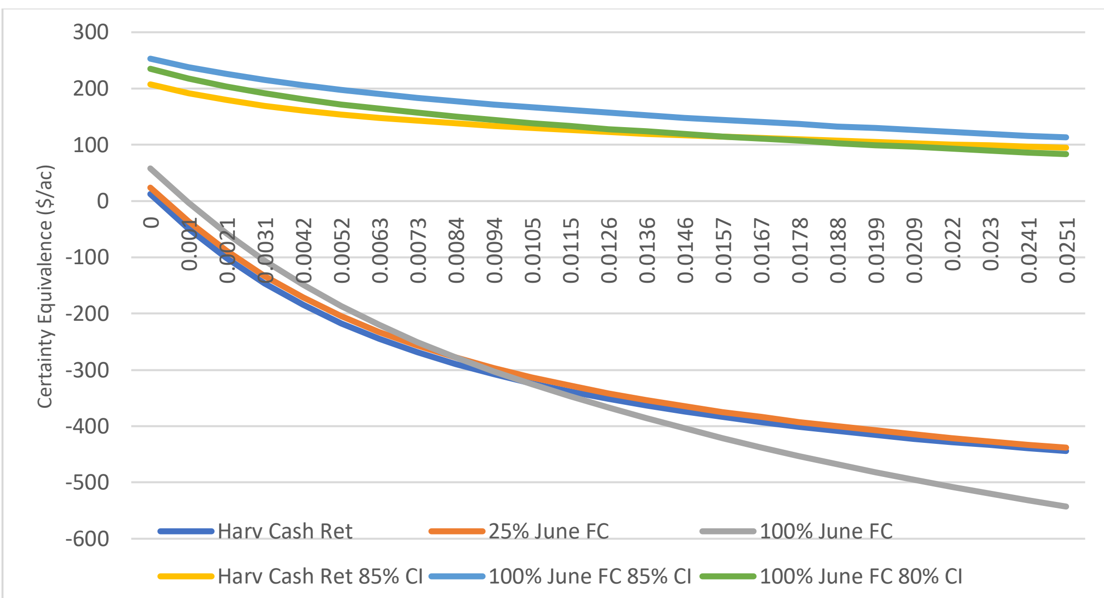


Figure 16 CE under a negative Exponential Utility Function for Soybean

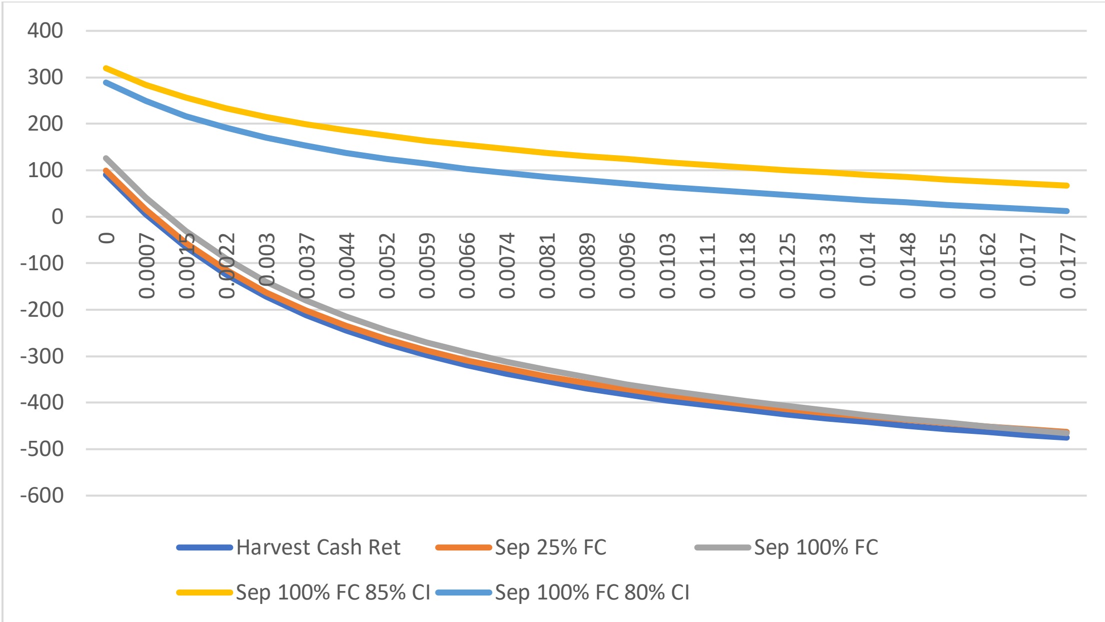


Figure 17 CE under a negative Exponential Utility Function for Rice

CHAPTER VIII

CONCLUSIONS

The agricultural sector faces significant challenges due to the inherent risks associated with production, market, and financial factors. Forward contracting and crop return insurance are essential risk management tools that can help farmers navigate these challenges and maintain financial stability. As the price of agricultural commodities follows seasonality and tends to have higher prices during summer, producers can catch that price to increase their return by forward contracting during summer. However, with a higher level of the forward contract, the production risk increases due to a high chance of non-delivery. This problem can be mitigated with RP crop insurance. This study aims to assess the risk and return at different time and level of forward contracting coupled with the various RP coverage level.

The findings emphasize the efficacy of adopting a strategy integrating 100% forward contracting with 85% RP coverage, particularly during June for corn and soybean and September for rice. This approach has proven optimal for risk-neutral to moderately risk-averse producers, leading to increased mean net revenue and high CE. Our results may in part be driven by the fact that commodity prices in 2023 are at relatively high levels with the likelihood of harvest prices being higher than forward contract prices also relatively low. In addition, we assumed that farm yields are uncorrelated with harvest cash prices and forward contract prices. If instead farm yields are negatively correlated with prices, aggressively forward contracting high percentages of expected production could add to overall net return risk. This is an interesting avenue of further research.

The risk factors faced by producers during high mean net revenue months with and without forward contracting (100%FC) and revenue protection (RP) (85% coverage level) vary across different crops. The results showed that for corn, soybean, and rice, using 100% FC in conjunction with 85% RP can help reduce the 1% tail risk, which may be beneficial for producers looking to manage their revenue risks.

In this study, the impact of government payment plans such as the PLC and ARC was not found to have a significant effect on the overall results, primarily due to the simulation yielding high MYA prices. The high MYA prices resulted in minimal or no PLC/ARC payments, thus reducing their relevance in this risk management strategy analysis.

Investigating the impact of forward contracting at low yield and high-futures price during harvest would be a valuable extension of our research. This could help to provide insights into the potential benefits or drawbacks of using forward contracting as a risk management tool in situations where crop yields are lower than expected or where market prices are unfavorable. Additionally, exploring the basis risk of rice on its optimal level of forward contracting would also be a worthwhile extension of our research.

REFERENCES

Abbott, P. C., Hurt, C., & Tyner, W. E. (2008). What is driving food prices? (No. 741-2016-51224).

Agricultural Improvement Act of 2018 (Pub. L. 115-334)

Anderson, John D., Ardian Harri, and Keith H. Coble. "Techniques for multivariate simulation from mixed marginal distributions with application to whole-farm return simulation." *Journal of Agricultural and Resource Economics* (2009): 53-67.

Angadjivand, S. (2018). US Farm Commodity Support: An Overview of Selected Programs. *Congressional Research Service*. Retrieved April 23, 2019.

Barham, E. H. B., Robinson, J. R., Richardson, J. W., & Rister, M. E. (2011). Mitigating cotton return risk through irrigation, insurance, and hedging. *Journal of Agricultural and Applied Economics*, *43*(4), 529-540.

Biram, Hunter, "Mitigating price and yield risk using return protection and agriculture risk coverage" (2019). Theses and Dissertations. 3121. https://scholarsjunction.msstate.edu/td/3121

Biram, H. D., Coble, K. H., Harri, A., Park, E., & Tack, J. (2022). Mitigating price and yield risk using return protection and agriculture risk coverage. *Journal of Agricultural and Applied Economics*, 54(2), 319-333.

Burns, C. B., & Macdonald, J. M. (2018). America's Diverse Family Farms (No. 281176). United States Department of Agriculture, Economic Research Service.

Coble, K. H., Heifner, R. G., & Zuniga, M. (2000). Implications of crop yield and return insurance for producer hedging. *Journal of Agricultural and Resource Economics*, 432-452.

Du, X., Feng, H., & Hennessy, D. A. (2017). The rationality of choices in subsidized crop insurance markets. *American Journal of Agricultural Economics*, 99(3), 732-756.

Farm Service Agency. (2019). *Arkansas ARC/PLC Program*. Washington DC: United States Department of Agriculture.

Glauber, J. W. (2013). The growth of the federal crop insurance program, 1990—2011. *American Journal of Agricultural Economics*, 95(2), 482-488.

Goodwin, B. K., & Ker, A. P. (2002). Modeling price and yield risk. *A comprehensive assessment of the role of risk in US agriculture*, 289-323.

Hardaker, J. B., Lien, G., Anderson, J. R., & Huirne, R. B. (2015). *Coping with risk in agriculture: Applied decision analysis*. CABI.

Hardaker, J. B., Richardson, J. W., Lien, G., & Schumann, K. D. (2004). Stochastic efficiency analysis with risk aversion bounds: a simplified approach. *Australian Journal of Agricultural and Resource Economics*, *48*(2), 253-270.

Hardke, J. (2019). *Rice Production in Arkansas*. Retrieved from University of Arkansas Cooperative Extension Service: https://www.uaex.edu/farm-ranch/crops-commercial - horticulture/rice

Jacobs, K., Li, Z., & Hayes, D. (2016). Forward Contracting by Iowa Corn Producers: Connecting Hedging with Price Movements. *Agricultural Policy Review Fall*.

Li, Z., Hayes, D. J., & Jacobs, K. L. (2018). The weather premium in the US corn market. *Journal of Futures Markets*, *38*(3), 359-372.

Lubben, B. D. (2015). *The Economics of ARC vs. PLC*. Retrieved from University of Nebraska-Lincoln Institute of Agriculture and Natural Resources: https://agecon.unl.edu/cornhusker-economics/2015/economics-of-arc-vs.-pl

MacDonald, J. M., Perry, J., Ahearn, M. C., Banker, D., Chambers, W., Dimitri, C., & Southard, L. W. (2004). Contracts, markets, and prices: Organizing the production and use of agricultural commodities. *USDA-ERS Agricultural Economic Report*, (837).

Maples, W. E., Giri, A. K., Coble, K. H., & Subedi, D. (2022). Impact of government programs on producer demand for hedging. *Applied Economic Perspectives and Policy*, 44(3), 1126-1138.

Mishra, A. K., & Perry, J. E. (1999). Forward contracting of inputs: A farm-level analysis.

Mitchell, J. L. (2021). *Trends in Arkansas Cattle Markets: Feeder Cattle Prices Seasonality, 2011-2020.* Cooperative Extension Service, University of Arkansas.

Maples, W. E., Giri, A. K., Coble, K. H., & Subedi, D. (2022). Impact of government programs on producer demand for hedging. *Applied Economic Perspectives and Policy*.

National Agricultural Statistics Service. (2019). *2012 Census Volume 1, Chapter 1: US. National Level Data*. Retrieved from USDA NASS: https://www.nass.usda.gov/Publications/AgCensus/2012/Full_Report/Volume_1,_Chapter_1_US

National Agricultural Statistics Service. (2019). *2018 State Agriculture Overview: Arkansas.* Retrieved from USDA: NASS: https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=ARKANSAS

Nelson, C. H., & Preckel, P. V. (1989). The conditional beta distribution as a stochastic production function. *American Journal of Agricultural Economics*, 71(2), 370-378.

Phoon, K. K., Quek, S. T., & Huang, H. (2004). Simulation of non-Gaussian processes using fractile correlation. *Probabilistic Engineering Mechanics*, 19(4), 287-292.

Schnepf, R. (2017). *Farm Saftey-Net Payments Under the 2014 Farm Bill: Comparison by Program Crop*. Retrieved from Congressional Research Service: https://fas.org/sgp/crs/misc/R44914.pd

Schnepf, R. D., & Resources, Science, and Industry Division. (2005, December). *Price determination in agricultural commodity markets: a primer*. Congressional Research Service, Library of Congress.

United States Department of Agriculture. (2018). *FY 2017 Budget Summary*. Washington DC: United States Department of Agriculture.

USDA, R. (2012). *Summary of business reports and data*. US Department of Agriculture, Risk Management Agency. https://www. rma. usda.gov/data/sob.html.

Velandia, M., Rejesus, R. M., Knight, T. O., & Sherrick, B. J. (2009). Factors affecting farmers' utilization of agricultural risk management tools include crop insurance, forward contracting, and spreading sales. *Journal of Agricultural and Applied Economics*, *41*(1), 107-123.

Walters, C. G., & Preston, R. (2013). *Return Risk, Crop Insurance, and Forward Contracting* (No. 324-2016-11932).

Wang, H., Adusumilli, N., Gentry, D., & Fultz, L. (2020). Economic and stochastic efficiency analysis of alternative cover crop systems in Louisiana. *Experimental Agriculture*, *56*(5), 651-661.