THE RISKS ASSOCIATED WITH BARLEY PRODUCTION IN

NORTH DAKOTA

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ABSTRACT

The market for barley has shifted from a demand for exports and livestock feed, to a demand for human food and alcohol production. Due to the crop qualities required for malting in the alcohol industry, barley is perceived to be a more financially risky crop to grow in comparison to other crops. Monte Carlo simulation was used to estimate the distributions of net return to labor and management for barley, hard red spring wheat, corn, soybean, and canola in the primary, North Central, and transitional, Central, crop reporting districts of North Dakota. Stochastic efficiency with respect to a function was used to rank the distributions based on a farm manager's risk preferences. Results indicate that barley is not as risky to grow as farm managers perceive. However, soybeans were the dominant crop. Corn is dominant crop when a decision maker is risk neutral, but quickly diminishes as risk aversion increases.

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CHAPTER 1. INTRODUCTION

Malting companies and beer brewing companies face two difficulties. The first is that they must procure enough malting barley to meet production demands. The second is to ensure that the malting barley purchased meets specific quality standards. Malting barley is very quality sensitive because there are grading characteristics of barley that impact the quality and taste of the final product. Malting is the process by which fermentable sugars are utilized from cereal grains for alcohol production. During the malting process, grains are soaked in water and allowed to germinate. The grain is then dried and the germination process is halted. This creates new enzymes and prepares starches for conversion to sugar. Maintaining the quality standards of barley helps those involved in both the malting and brewing industries create a consistent supply of product that meets consumer demand for food and alcohol along with assuring there are no undesirable results throughout the brewing process. Recently there has been a change in the production of malting barley. Industry leaders in the malting barley field are concerned with a downward trend in barley acres.

In 1942 there were 16.96 million acres of barley harvested in North Dakota. In 1986 there were 11.87 million acres of barley harvested in North Dakota. By 2013 there were only 3 million acres of barley harvested in North Dakota (U.S. Department of Agriculture 2014). Figure 1.1 illustrates historic acres of barley harvested in the United States for the years 1866-2016.

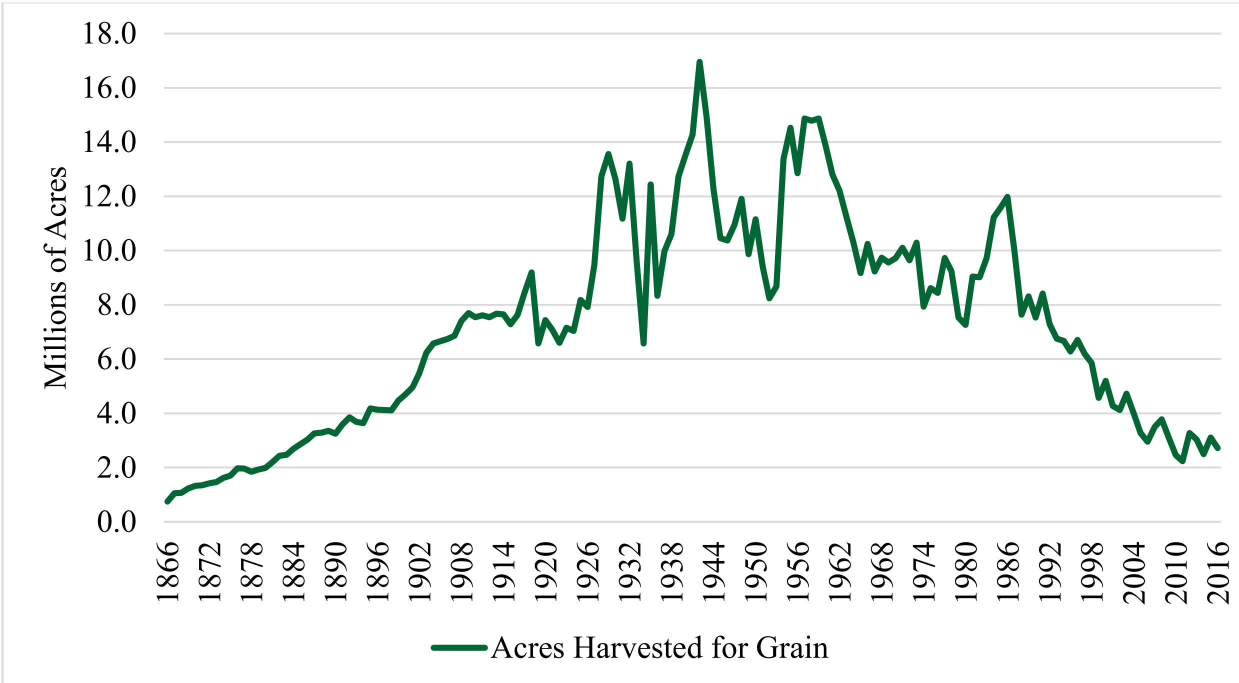

Figure 1.1. U.S. Historic Harvested Acres of Barley

In 1986 feed and residual use for barley in the United States was 319 million bushels compared to 59 million bushels in 2013. In 1986 barley use in the United States for food, alcohol, and industrial use was 157 million bushels compared to 149 million bushels by 2013. In 1986 U.S. barley export use was 19.71 million bushels compared to 8.85 million bushels in 2013 (U.S. Department of Agriculture 2016).

What these quantities illustrate is a shift in the driving market factors for barley. In previous years, feed and exports were the dominant use for barley. In Figure 1.2 it can be seen that in the most recent years, livestock feed and export use for barley has decreased substantially while use for food, alcohol, and industrial purposes has remained relatively consistent.

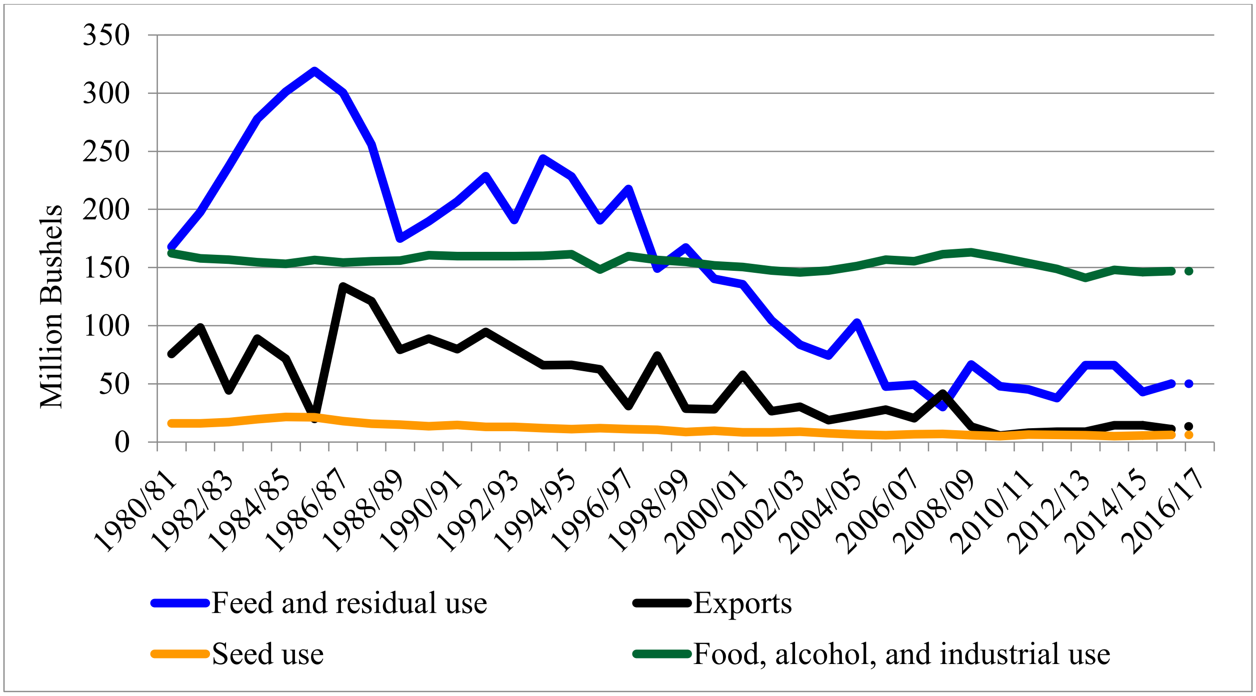

Figure 1.2. U.S. Barley Use in Millions of Bushels

Historical barley use for alcohol and food products has remained relatively consistent. However, feed use and exports have been decreasing. This has resulted in a shift in the driving factor in the market for barley. The food and alcohol sector has replaced livestock feed consumption and exports as the primary use for the U.S. barley market. The drop in acreage for malting barley is related to a perceived change in profitability due to increased prices of competing crops, quality price adjustments, and changing weather conditions.

North Dakota has historically been one of the top barley producers in the United States. In 2014, North Dakota was the number one barley producing state in the U.S. accounting for 32% of the overall acres harvested.

The common belief among farm managers is that there are several different types of increased risk when growing malting barley compared to other crops. Those risks are: the risk of not obtaining malting quality barley resulting in feed quality barley sold at a price discount to malting barley, and the risk of lower price due to limited marketing tools available.

There are many reasons why farm managers choose to grow or not to grow barley such as to spread the workload of harvested crops, cash flow purposes, or agronomic reasons. However, producing barley does incur risks. The first and probably most significant risk is not obtaining the required grade standards in order to receive the premium price for malting quality barley. Barley buyers are very specific about the quality of the product they are purchasing when compared to buyers of other crops. For example, if barley does not meet the base malting quality standards, it is then sold as feed barley at a significant price discount in addition to being sold in a much smaller market.

There is often a difference in the price of malting barley and the price of feed barley. The spread between the price of malting barley and the price of feed barley varies over time. The average price difference between malting and feed quality barley in January 2012 was $1.65 at Sun Prairie Grain in Minot ND. The difference in price between malting quality barley and feed quality barley was $0.57 in August of the same year. According to the North Dakota Barley Council, in order for barley to be accepted as malting quality, malting and brewing companies look for barley which possesses the following quality characteristics: no greater than 13.5% protein, no greater than 5% thin kernels, no less than 75% plump kernels, no greater than 13% moisture, no less than 48 pounds per bushel test weight, and no greater than two parts per million Deoxynivalenol or DON.

In recent years, high DON, commonly referred to as vomitoxin, has been one of the leading causes of rejection of malting quality barley. Excessive levels of DON are caused by barley that is infected with fusarium head blight (Gustafson et. al 2006). These excessive levels of DON result in an unwanted foaming effect during the brewing process and can cause an undesirable taste of the final product.

Another quality characteristic of barley that commonly leads to high rejection rates is protein. Protein levels are required in moderation to maintain a healthy yeast population during the brewing process. When high protein levels are present, in most cases above 13.5%, the amount of malt extract available is limited and foam stability is compromised (Personal Interview North Dakota Barley Council 2012).

An additional quality characteristic that can create significant problems for maltsters is barley sprout damage. Sprout damage is not a regular occurrence; however when present, it becomes a significant barrier to germination. Germination is essential to sprouting and producing malt.

In the past most malting companies would accept only the highest quality malting barley. However, due to the drop in acreage industry leaders have had to adjust their quality acceptance standards in order to get the quantity of malting barley needed to meet demand of the brewing industry. Quality standards are now more relaxed and consistent across companies than in previous years. An additional reason for the shift of the primary use for barley is the availability and ease of feeding corn to livestock. Corn is commonly grown by farm managers, is relatively cheap, and is a simple feed source for livestock. For these reasons, the malting industry is now the driving factor in the barley market. In addition, these are reasons why contracting has become an important practice for both industry leaders and farm managers. Barley does not have a futures market. This is important because it limits the tools available to manage price risk.

In North Dakota, farm managers in traditional barley producing regions are now transitioning to growing other crops such as corn and soybeans. One of the reasons farm managers are making this change is due to many of the quality issues associated with malting barley are not a concern for other crops like corn and soybeans (Knutson, Jonathon Agweek volume 27 number 3 august 22 2011). Another reason is once a farm manager has his or her barley rejected for malting quality, he or she becomes hesitant to risk the incident occurring again. Additionally, many farm managers in North Dakota believe they can grow other crops more profitably than barley. The historic barley acres harvested is illustrated in Figure 1.3.

Objective A

The primary objective of this research is to assess the comparative risks of producing barley, corn, hard red spring wheat (HRS), soybeans, and canola in a primary and transitional USDA NASS crop reporting district in North Dakota. In this project, the North Central NASS reporting district represents a primary barley production region. The Central NASS reporting district represents a transitional barley production region. This project estimates the variability in price, yield, and quality of barley, corn, HRS, soybeans, and canola for a typical farm manager in North Dakota. Risk is measured by estimating the distribution of net return to labor and management for each crop within each selected region. The revenue variability coincides with risks as they are perceived by a typical farm manager within these regions including the concept of risk preferences, where the farm manager (decision maker) weighs the expected revenue in comparison to the variability of net returns when making decisions about cropping alternatives.

Objective B

The second objective of this project is to rank the alternative distributions of net return to labor and management in order to compare these crops to one another according to a farm manager's attitude towards risk. This project will allow one to view possible quantified reasons why there has been a recent downward shift in barley acres and overall barley production in North Dakota.

The questions that are answered in this project are "What are the probability distributions of net return to labor and management for barley, hard red spring wheat, corn, soybeans and canola produced in North Dakota? How do the estimated probability distributions of net return to labor and management for these crops compare to each other? Can these distributions be ranked?"

Much of the current literature related to barley is focused on contract specifications, agronomic practices, and insurance coverage. This study adds to the current body of literature by using Monte Carlo simulation to estimate the variability of net returns to labor and management for five alternative crops produced in both a primary and transitional barley growing region in North Dakota. This model incorporates quality characteristics, and malting quality acceptance rates, with price discounts and premiums, combined with daily spot cash price, and yield variability for not only barley, but also for corn, HRS, soybeans, and canola. By doing this, one will be able to quantify the comparative risks associated with producing each of these crops relative to barley for a typical farm manager in a primary and transitional barley production region in North Dakota, rank the different crops according to farm manager's risk preferences, and integrate the concept of quality characteristics as they relate to risk modeling.

CHAPTER 2. LITERATURE REVIEW

Introduction

Chapter 2 reviews the body of literature relevant to risk for barley as related to price, yield, quality, contracting, and insurance. This chapter also reviews literature associated with stochastic efficiency analysis. The literature review describes methods of analyzing risk for a farm manager facing price, yield, and quality variability as a factor of net return to labor and management received by a typical farm manager in the Central and North Central production regions of North Dakota. It is important to note that much of the literature involving quality studies has been limited to hedonic modeling where the significance of various grading characteristics of a product are evaluated. In this project, Monte Carlo simulation is first used to estimate distributions of net return to labor and management for alternative crops in two different production regions of North Dakota. Stochastic efficiency with respect to a function (SERF) is the analysis method used in this project to rank the alternative crops within each region.

Prices and Volatility

Much literature has been dedicated to price and volatility modeling. Models such as the Black Schole's model (Black, F., & Scholes, M. 1973), require a set of options prices in order to estimate what is known as implied volatility. Barley does not have a futures market in the United States. This project relies on cash prices for variability. Thus a method had to be developed in order to estimate the volatility of the daily spot cash prices received by a typical farmer in the North Central and Central production regions of North Dakota.

In a study conducted by Wilson & Dahl (2011), contracting strategies for durum wheat were evaluated for three purposes. The first, was to obtain a survey of terms used in grower contracts, the second was to illustrate the issues of contracting associated with specialty grains in the upper Midwest, and the third was to develop a model to analyze alternative contracting strategies for durum wheat. In contrast to other crops, durum wheat does not have a futures market resulting in the high use of contracting. In this study, alternative pricing features are introduced. Option type contracts can be developed with premiums derived from the Black pricing model where it is applied to durum cash prices instead of a futures traded instrument. The authors introduce these alternative pricing methods and Monte Carlo simulation to analyze contracts in terms of risk and return to growers. Stochastic efficiency with respect to a function (SERF) was then used to rank these alternative contract methods. Results indicated that contracts reduce risk to growers and are preferred to no contracting. However results did vary based on growers risk aversion.

Another study exploring price volatility was conducted by Bessembinder & Senguin. (1993). In this study, the authors estimated the connection between market trading volume as it effects volatility. The authors used data of daily settlement prices from eight different agricultural, metal, currency, and financial futures markets between May 1982 and March 1990 to obtain a percentage change in settlement price across all open interest during these time frames. The daily volatilities were captured and then autocorrelated to both volume and open interest as a proxy for market depth. This study indicated that positive unexpected volume shocks have a greater effect on volatility than negative shocks. This study additionally adds that large open interest mitigates volatility.

In a study conducted by Garcia et al (2005), generalized autoregressive heteroskedasticity (GARCH) methods are used to forecast day-ahead electricity prices in California and Spain. These price forecasts are necessary to develop bidding strategies as well as hedging strategies against volatility in order to maximize profits. The Spanish data set consisted of hourly clearing prices from September 1, 1999 to November 30, 2000. The California data set consisted of hourly electricity prices from January 1, 2000 to December 31, 2000. Using GARCH methods, the forecast followed actual trend quite closely. Average errors for both California and Spain were very near 9% depending on the month being evaluated. GARCH outperformed autoregressive integrated moving average (ARIMA) models when volatility and price spikes were present. This study used hourly clearing prices in its data set which is an even deeper perspective on price data than is evaluated in this project. Additionally, GARCH was used in forecasting volatility. It can be argued that using exponentially weighted moving average (EWMA) is a more accurate method of forecasting volatility (Ding & Meade 2010). EWMA, is the method used in this project.

Price variability and volatility has been studied in depth by many. However, it is important to note that very few if any studies have attempted to use daily cash spot prices when forecasting data or attempting to put a distribution behind price variability and or volatility in cash markets. Most studies have focused on using futures prices to forecast volatility, have used the Black model, GARCH or any of the models in the autoregressive family, or implied volatility. Research has been quite limited in the area of forecasting a distribution of price volatility.

Yield and Variety Risk

Within the research conducted by J. Belasco et al. (2009) yield risks were specifically addressed as they relate to feeder cattle. A model was developed where the mean and variance of yield performance factors were linked to observable variables. Yield factors were defined as dry matter feed conversion, average daily gain, mortality, and animal health costs. Results indicated that factors such as entry weight, gender, placement season, and location have the greatest influence on the mean and variability of yield factors.

In a study conducted by Smith et al., (2012) the impact of agronomic practices on net return risk for malting barley produced in Canada was evaluated. The malt barley industry in Canada was faced with the issue of declining acreage and overall production. The declining acreage could be partially attributed to the farmer's ability to grow more profitable crops and reduced demand for feed barley due to declining livestock numbers.

Barley in Canada is produced for two purposes: feed for livestock, and malting barley which is grown for the malting and brewing industry. There are two different types of barley grown, two row, and six row cultivars. Each cultivar offers different quality characteristics, along with different yield characteristics (Shwarz, P. & Horsley, R. 2012). The Canadian malting barley market is primarily dominated by two row cultivars. Growers will produce malting barley seed varieties with the expectation of being selected by a malting company to receive a premium price. Barley not selected then goes into the feed market. Malting cultivars of barley can be used for feed however feed cultivars cannot be used for malting.

Results from this study indicated that the average simulated net revenue for production systems in a region was primarily dependent on barley yield. Within this study data was used from two field experiments between 2005 and 2008 at locations in Western Canada. A stochastic simulation model was used to generate revenue and evaluate the various production strategies in Western Canada. Simetar was the software program used for the simulation. These results concluded that mean net revenue was lowest in one region due to less than ideal growing conditions. The highest variability in this study was in a different region due to growing conditions. It was concluded that the variability in net revenue increased with increasing nitrogen application because both price and yield were more variable.

Another significant variable impacting net revenue was variety grown. The Crop Development Center (CDC) variety Copeland and the Agriculture & Agri-Food Canada (AC) variety Metcalf were the cultivars chosen for comparison. Net revenue had a tendency to be higher for CDC Copeland than AC Metcalf which reflects a higher yield and plumpness and lower protein for CDC Copeland. Higher seeding rates resulted in a limited yield advantage, higher seed cost, and a much lower probability of obtaining malting quality. The lowest variability in net revenue was obtained when no nitrogen was used or barley was grown for feed (Smith et al., 2012). From these studies it is apparent that crop production practices are a source of variability that results from a difference in production region in addition to simply just price and yield.

Quality Risk

One common method of analyzing qualities or characteristics in terms of a pricing model is the hedonic pricing model. In hedonic pricing models, individual characteristics of a given item, product, or object are evaluated to estimate their contribution to the final value.

In a study by Wilson (1984), hedonic modeling techniques were used to place a price on selected quality characteristics of malting barley particularly plumpness and protein. Results of this research indicated that a change may be occurring in the determination of malting barley prices. Further, that the feed barley sector is having a decreasing influence on the malting barley market.

In a study by Carew (2000), a hedonic price function evaluated the relationship of apple prices as a function of product and market quality. In this model, weekly prices of apples were used over 3 years. Characteristics or qualities included in this model were apple variety, grade, package size, fruit size, season of year, and method of storage. This study concluded that grade, cultivar, storage, and marketing season are the most significant variables influencing apple prices.

In a study conducted by Coatney et al. (1996), various physical characteristics, and seller-added characteristics were evaluated for statistical independencies in determining the overall price a buyer is willing to pay for a lot of feeder cattle. Data obtained from Superior Livestock Satellite Video Auction located in Brush Colorado was used to develop a probit model for each lot of cattle sold. Three-stage least squares regression was used in order to estimate the empirical model. This model concluded that the most prominent physical characteristics impacting price change was through the direct impact of frame score and weight of the cattle in the purchased lot. In addition, for seller-added characteristics and market factors, the most influential indirect impacts occurred via weight within the purchased lot.

In a study conducted by Nolan et al. (2014), quality attributes of Australian merino wool were evaluated in order to determine the monetary value for each quality characteristic. Data from the Australian Wool Exchange Ltd for 111,440 lots of wool sold during the 2008-2009 auction season was used to estimate five hedonic pricing models in order to determine the premiums and discounts associated with each of the wool characteristics in five different micron diameter categories. Results from this study indicated that fiber diameter had the greatest impact on price in all markets. In addition, brand contamination, and higher color contamination and vegetable matter were found to negatively influence price received.

Much of the research in the quality characteristic field has focused on other products such as wool, fruit, or meats where hedonic modeling is used to determine the significance of quality characteristics or grading standards as a factor of price received. Quality research in the barley field has focused on contract terms or insurance but has not focused on quality as a factor of net revenue received by a farm manager.

Impact of Insurance

Another study by Gustafson et al. (2006) addresses the significance of crop insurance as it relates to barley producers. This study primarily addresses the idea that barley is a risky crop to grow. It is argued that having a crop rejected for malting grade due to quality aspects is a risk along with the dangers of unfavorable weather conditions and volatile market prices. Federally subsidized crop insurance is one method that growers use to help address the associated production risks. Within this article, deficiencies involved with "coverage gaps" are discussed. The problems involved in coverage gaps include quality acceptance along with price and yield risks. In addition to these problems different maltsters and brewers have unique requirements and or specifications for the various quality aspects involved with malting barley production.

This study developed a model which measures risk in the production of malting barley along with how growers respond to the various types of crop insurance available. A stochastic simulation method of analysis was used to demonstrate the effects of each alternative insurance strategy. The distributions of net returns for each insurance strategy were then evaluated using the ranking methods of stochastic dominance with respect to a function (SDRF), and stochastic efficiency with respect to a function (SERF) methods.

SDRF indicated results as were expected for both irrigated and dryland crops. SDRF rankings for risk averse individuals suggested that more insurance was preferred to less and production with a contract being preferred to other alternatives. The highest return was associated with a 50% level of insurance coverage and a contract. Dry land production results were not as consistent for malting barley growers across all levels. The effect of premiums and federal subsidy levels increase the insurance premium prices paid by producers (Gustafson et al., 2006). This demonstrates the "coverage gap" in insurance for malting barley and just how important contracting and insurance is within the production sector of the malting barley industry.

Contracting

Another important part of malting barley and all crop production in North Dakota is the use of contracts. A contract is essentially a construct between parties that outlines mutually agreed upon rules of how the elements of allocation of value, risk, and decision rights are addressed in relationship to a transaction. According to Jang & Olson (2010), differences in communication and price discovery costs can be used to explain the transition between spot markets and contracts in agricultural food markets. These differences are more apparent for processors and or retailers whose product requires a unique or specific input characteristic (Jang & Olson 2010).

Time is a relatively unique aspect of crop contracting since it adds increased importance to each of the elements involved (Sykuta et al., 2003). According to the USDA, production marketing contracts account for 36 percent of the overall value of U.S. agricultural production and are another tool of risk management used by producers. Contracts can reduce income risks associated with variability in price and production yield (MacDonald et al., 2011).

Contracting is used extensively in all crops and more extensively for those that do not have a futures market such as barley. So it is important to note that quality clauses are a factor of price received within a contract.

Assessment of Risk

Determining risk entails defining risk, determining possible outcomes, assigning probabilities, and assessing alternatives using a decision maker's preferences towards risk. In order to compare a set of alternatives, the risk preferences of a decision maker must be determined. To understand the risk preferences of a decision maker, a utility function for the decision maker is needed. Determination of a utility function that is representative of a specific decision maker can be quite difficult. Other methods of efficiency analysis such as mean variance and stochastic dominance can be useful for ranking sets of alternatives. Various methods of efficiency analysis are addressed in the theory and methodology section of this document. Stochastic Efficiency with Respect to a Function (SERF) is a method of analysis commonly used in other research and is the method of efficiency analysis for ranking alternatives that will be used in this project.

In a study conducted by Grove et al., (2013), a model was developed to produce non-parametric cumulative distribution functions (CDF) for various marketing strategies. These methods, used by farmers in the southern regions of Africa, applied a ranking system which compared the various strategies. In this study, stochastic efficiency with respect to a function (SERF) was used to rank the various marketing strategy options available to grain farmers with the objective of determining the benefit of routine marketing strategies when compared to a baseline marketing strategy using spot cash markets. Price data was collected from the South African Futures Exchange from 2001-2011 in order to model the cumulative distribution functions for several different grains crops along with the strategies applied for the study. Using SERF to rank the CDF's of the various marketing strategies, this study was able to determine that there is a much higher probability of obtaining a lower income using baseline spot marketing strategies when compared to implementing strategies involving futures, options, and other derivative methods.

In a study conducted by Wilson, Shakya, Dahl (2015), a stochastic model was developed to analyze genetically modified traits in wheat using real options prices. The particular trait being drought tolerance. This study determines the value of drought tolerance at the farm level and uses both stochastic simulation and Stochastic Efficiency with Respect to a Function (SERF) to develop a risk premium, or expected value, of the trait to growers within selected USDA growing regions. This analysis then quantified the Certainty Equivalent for farmers in the growing regions for both wheat grown with and without the drought tolerance trait. Results from this study indicate that the value of this GM technology is in the money at each phase of development. Additionally, the value of the drought tolerant trait in wheat is greater than that of drought tolerant corn. Results indicate that the greatest value of this trait lies in the Prairie Gateway, and Northern Great Plains regions.

Current research in these fields has focused on areas where prices and yields demonstrate crop profitability and producer preferences. In addition many of these studies have used weekly, monthly, or annual price data rather than daily when estimating price variability and forecasting volatility. One contribution this project will add to the body of modern literature will be to introduce barley qualities as a source of revenue variability. In addition, daily spot cash price data points were used in order to estimate probability distributions of prices received versus using futures or weekly, monthly, or annual averages for prices offered. Within the United States there is no futures market for barley making its market prices unique to the other crops produced within Central and North Central regions of North Dakota.

CHAPTER 3. THEORY AND METHODOLOGY

Introduction

Risk

In order to assess risk, one must first understand what risk is. One common point of confusion is the difference between risk and uncertainty. "Events are uncertain when their outcome is not known with certainty. Uncertain events are important when their outcomes alter a decision maker's well-being. Situations that are defined as *risky* are those uncertain events whose outcomes alter the decision maker's well-being. According to Robison & Barry (1999). "This definition is broader than the popular concept of risk as involving possible loss or injury and implies that risky events form a subset of uncertain events".

When evaluating the concept of risk, one must understand that both probabilities and preferences for outcomes are held by any given decision maker. This attitude based concept of probabilities and preferences is known as the risk aversion held by the decision maker. Since different decision makers possess different risk preferences, it is often quite difficult to assign a specific risk aversion factor for any individual or well-defined group of decision makers. Risk aversion does not mean that a decision maker is unwilling to take risk. Rather, an individual must be compensated for taking risk in the form of a risk premium. The risk premium can be defined as the difference between the expected return of a risky alternative and the return on a riskless alternative that leaves the decision maker indifferent between the two alternatives (Robison & Barry 1999). Thus the risky investment must yield an expected return high enough to compensate the decision maker for taking the risk. The more risk averse the individual is, the higher the risk premium must be in order for the decision maker to prefer the risky alternative over the completely certain alternative (Robison & Barry 1999).

Efficiency Analysis

Mean Variance Analysis

Mean Variance (MV) is a method of analyzing the concept of choice as it relates to risky alternatives. The objective of MV is to assemble an efficient set of alternatives where expected return is maximized for a given preference of risk. The Mean Variance preference of a decision maker is often based on a Von-Neuman Morgenstern expected utility model. This is done in one of two ways. Either the decision maker's preferences are given by a quadratic utility function, or the distributions representing random alternatives are all from a family of normal distributions. "The definition of an efficient set within MV space corresponds to the commonly used normal distribution function assumption and is known as the MV efficient set. This set contains all distributions such that no additional available distribution possesses both a higher expected value and a lower variance" (Meyer 1979).

Subjective Expected Utility Hypothesis

One theory for defining risk aversion is the Subjective Expected Utility Hypothesis (SEU). According to the SEU (Schummann et al., 2004), a utility function for a decision maker that includes a risk measure is needed to assess risky alternatives. The SEU hypothesis also states that the utility of a risky alternative is the decision maker's expected utility for that given alternative (Hardaker et al., 2004a). The shape of this utility function is a reflection of an individual's attitudes towards risk. This theory is extremely important because it recognizes that an individual's risk preferences are consistent within the selected time frame but may change when a different time frame or scenario is selected. We cannot assume a single utility function is representative for all individuals. Other methods such as stochastic dominance and efficiency models have been developed that are not limited to only one utility function.

Let *U(x)* be a utility function for a decision maker whose decision will be *x* (net revenue). First we must assume that the risky alternatives to be compared have uncertain outcomes so the value of *x* will be stochastic. Assume *f1(x), f2(x), f3(x)…fn(x)* represent the probability density functions (PDF's) for the outcomes of *n* risky alternatives. The cumulative distribution functions (CDF's) are *F1(x), F2(x), F3(x)…Fn(x).* From the SEU hypothesis we get:

$$U(x) = EU(x) = \int U(x)f(x)dx = \int U(x)dF(x)$$

This tells us the utility of any given risky alternative is its expected value.

Quantifying Risk Aversion

Risk aversion is graphically represented by the shape or curvature of a decision maker's utility function. The second derivative can be applied such that three possible attitudes towards risk can be obtained. If the second derivative is equal to zero, the decision maker is said to be risk neutral. If the second derivative is less than zero, the decision maker is said to be risk averse and has a concave curvature of the utility function. If the second derivative is greater than zero, the decision maker has a preference for risk and possesses a convex curvature of the utility function. In this situation, a decision maker's utility function is defined as a positive linear transformation, thus that the utility function cannot be negative. The simplest form of a decision maker's risk aversion that is constant for a positive linear transformation of the utility function is the absolute risk aversion function:

$$r_a(w) = -U^2(w)/U^1(w)$$

Where U^2 and U^1 represent the second and first derivatives of the utility function respectively (Hardaker et al., 2007). This brings us to incorporating the absolute risk aversion coefficient $r_a(w)$ (ARAC). Theoretically the ARAC for a decision maker will decrease as wealth, w, increases. Thus as a decision maker's wealth increases, so does his or her preference towards risk.

A classification of degrees of risk aversion was proposed by Anderson and Dillon (1992) which is based on relative risk aversion with respect to wealth $r_r(w)$ (RRAC). This classification ranges from 0.5 to 4.0 where 0.5 represents a decision maker that is hardly risk averse at all and 4.0 represents a decision maker that is very risk averse.

In this project we do not consider utility and risk aversion in terms of wealth but rather in terms of transitory income where a positive or negative result has little if any effect on the probability distribution of subsequent years. Thus we use absolute risk aversion:

$$r_a(w) = r_r(w)/w$$

Anderson Dillon (1992) developed a scale of degrees of risk aversion based on a decision maker's RRAC:

$r_r(w) = 0$	risk neutral
$r_r(w) = 0.5$	hardly risk averse at all
$r_r(w) = 1.0$	somewhat risk averse
$r_r(w) = 2.0$	rather risk averse
$r_r(w) = 3.0$	very risk averse
$r_r(w) = 4.0$	extremely risk averse

A decision maker is located on this scale based on how much he or she is willing to risk for a 50% probability of a 20% increase in wealth compared to the amount of overall wealth possessed. When compared to existent literature, the implications of this scaling suggest that values of $r_r(w)$ greater than 1.0 may be more common than was previously believed (Hardaker 2004 book).

Stochastic Dominance

Stochastic dominance is a decision rule that provides partial ordering of risky alternatives within the efficient set for a decision maker whose preferences coincide with specified conditions about his or her utility functions. One interesting aspect of this method of ordering risky alternatives is that the fewer restrictions a person places on the utility function of an individual, the more generally applicable results will be. However, this is a trade-off. By using fewer restrictions, the criterion for ordering alternatives will become less powerful. Several versions or degrees of stochastic dominance can be used in order to rank risky alternative. First and second degree stochastic dominance will be discussed in this chapter.

First Degree and Second Degree Stochastic Dominance

Stochastic dominance is one of the most basic methods of efficiency criteria used to order risky alternatives. There are various degrees of stochastic dominance that are used to rank risky alternatives. First degree stochastic dominance (FSD) is the simplest and most universally applicable of efficiency criterion. FSD states that for a given level of risk, an individual prefers Alternative C_a to Alternative C_b for all levels of risk ($C_a > C_b$). With first degree stochastic dominance, the individual's risk aversion will lie between the bounds of positive and negative infinity. This can be viewed where a decision maker's attitude towards risk is $r_a(w)$ and lies within the bounds $-\infty < r_a(w) < +\infty$ (Hardaker et al., . 2004).

When neither alternative is dominant via FSD, Second Degree Stochastic Dominance (SSD) can be introduced. For SSD, it is assumed that an individual decision maker prefers more to less, however he or she is risk averse. Thus the decision maker's absolute risk aversion bounds are 0 and positive infinity: $0 < r_a(w) < +\infty$ (Hardaker et al., 2004). This acknowledges that a risk aversion parameter large enough to make a small difference of the lowest observation is very important. It has often been found that these two forms of analysis are not discriminatory enough to obtain an efficient set which is small enough to be considered manageable.

Stochastic Dominance with Respect to a Function (SDRF)

A method of efficiency analysis that utilizes tighter restrictions on an individual's absolute risk aversion is Stochastic Dominance with Respect to a Function (SDRF) introduced by Meyer (1977). With SDRF, the bounds for which an individual's risk aversion lies are reduced to $r_L(w) \leq r_a(w) \leq r_U(w)$. Ranking of risky alternatives is defined within the bounds for all decision making individuals whose absolute risk aversion function lies within those upper $r_U(w)$, and lower $r_L(w)$ bounds of a decision makers risk aversion function. Developing a utility function for the decision maker may be beneficial when determining risk aversion bounds. One downfall to this method is identifying the upper and lower bounds to place and rank the decision maker's utility function.

Stochastic Efficiency with Respect to a Function (SERF).

The analysis method for ranking risky alternatives used in this project is called stochastic efficiency with respect to a function (SERF). SERF is a more discriminating method of decision making analysis. SERF is different from other methods because it functions by identifying utility efficient alternatives rather than finding dominated alternatives. When SERF compares alternatives, it does so with all alternatives simultaneously rather than SDRF which will only compare two alternatives at a time. SERF has the potential to identify a smaller, more efficient set of alternatives than SDRF because it selects only utility efficient sets of alternatives. SERF orders risky alternatives using a certainty equivalent (CE). This is a measure of risk aversion as it varies throughout a defined range. The CE of a risky alternative represents the amount of compensation a decision maker must receive in order to be indifferent between a certain alternative and a risky alternative (Robison & Barry 1999).

In order to calculate the CE for a decision maker, Let *U(w)* represent a decision maker's utility function where *w* is wealth. It is assumed that the set of risky alternatives has uncertain outcomes, thus wealth is stochastic. Let $f_1(w), f_2(w),\ldots,f_n(w)$ represent the probability density functions and $F_1(w), F_2(w),\ldots,F_n(w)$ represent the cumulative distribution functions of a set of alternative decisions for a decision maker. From the SEU hypothesis we know that the utility of any risky alternative is its expected value. However, the shape of the decision maker's utility function is unknown and in turn the decision maker's risk aversion is unknown. A utility function must be chosen in order to assume a "best fit" for a decision maker. This is addressed where the decision maker's absolute risk aversion *r(w)* lies between its lower $r_L(w)$ and upper $r_U(w)$ bounds. The function for each risky alternative is:

$$U(w,r(w)) = \int U(w,r(w))dF(w) \approx \sum_{i=1}^{m} U(w_i,r(w))P(w_i), r_1(w \leq r(w) \leq r_2(w)$$

The second term represents the continuous case and is then converted to a discrete approximation in the third term where $P(w_i)$, is the probability for states *i* and there are *m* states for each alternative. The equation for each risky alternative states three things (Hardaker et al., 2004):

1. Select points on each CDF for a finite set of values *w*
2. Convert each of these values of *w* to its utility using the selected form of the utility function and the selected value of the risk aversion coefficient.
3. Multiply each finite utility by its associated probability to calculate a weighted average of the utilities of outcomes.

Equation 1 is a discrete function. Thus, the function for each risky alternative must then be evaluated at an adequate number of discrete points of $r(w)$.

The CE of a risky alternative represents the amount of compensation a decision maker must receive in order to be indifferent between a certain alternative and a risky alternative. The estimated CE is generally less than the expected monetary value (EMV) and greater than or equal to the minimum value. The EMV is the expected value of the probability distribution being analyzed. The difference between a CE and EMV is known as the risk premium. In order to calculate CE values, we must obtain the inverse of the utility function as follows:

$$CE(w,r(w))=U^{-1}(w,r(w))$$

As demonstrated by this equation, the value of the CE depends on the specified utility function. SERF determines a group of CE values for n alternatives within the risk aversion bounds $r(w)$. Only those alternatives with the highest value CE for a value within the range of $r(w)$ are considered utility efficient. All other alternatives are dominated in terms of SERF (Hardaker et al., 2004). Figure 4.1 shows the CE values being on the vertical axis with the risk aversion being on the horizontal within the bounds of $r_L(w)$ and $r_U(w)$ and determines alternatives 1 and 2 are the utility efficient set.

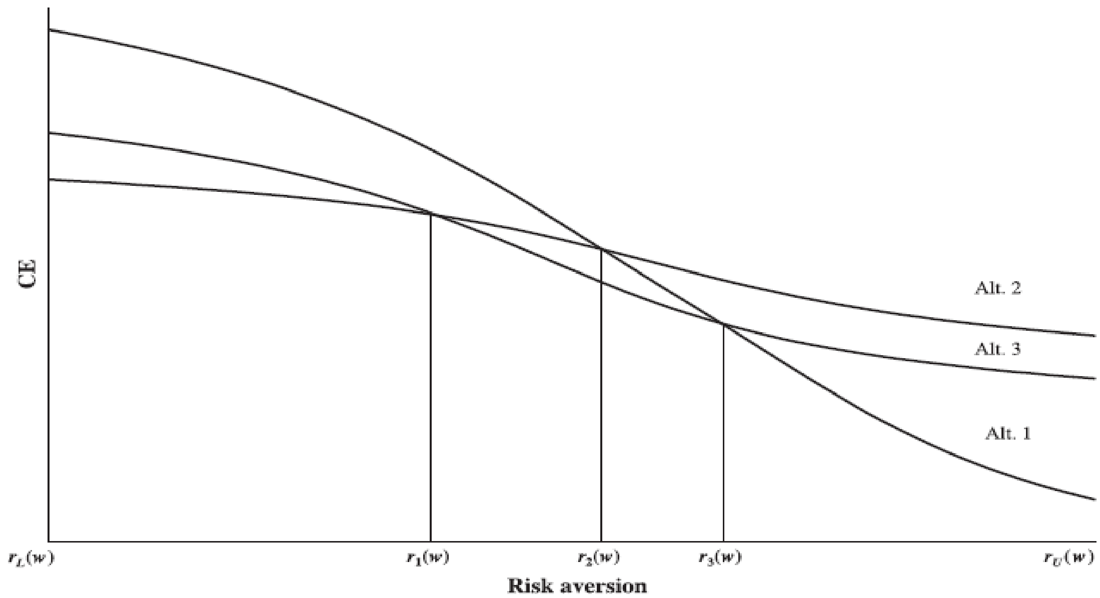

Figure 3.1. SERF results (Hardaker et al., 2004)

Alternative 1 is dominant through the risk aversion range of $r_L(w)$ to $r_2(w)$. Alternative 2 is dominant from $r_2(w)$ through $r_U(w)$. Since alternative 3 is dominated by some other alternative at all levels of risk aversion, it is not considered to be part of the utility efficient set as defined by SERF (Hardaker et al., 2004).

Benefits of SERF

The benefits of comparing alternatives using SERF rather than SDRF (Hardaker et al., 2004) are:

1. SERF can identify a smaller number of alternatives in an efficient set than SDRF over a given range of risk aversion.
2. SERF provides an ordinal ranking of alternatives between upper and lower risk aversion bounds customarily tested by SDRF.
3. SERF is a one step process similar to, but potentially more discriminating than running an SDRF analysis at all risk aversion levels within the stated bounds of $r_l(w)$ and $r_U(w)$.

The graphical presentation of SERF results facilitates the ordinal rankings for decision makers with different risk preferences.

4. SERF provides a cardinal measure of a decision maker's conviction for preferences among alternatives at each risk aversion level by interpreting the difference between CE's as risk premiums.
5. Unlike SDRF, SERF can be used to process data presented in different formats, not only data in the same fractal values as the distributions being compared.
6. SERF numerically evaluates CE values for alternatives over multiple years of *r(w)* and graphically displaying ordinal and cardinal rankings for many different groups of agents across a spectrum of risk aversion levels which can be as narrow or as wide as the situation warrants, that is risk preferring through risk neutral to strongly risk averse or moderately risk averse within a narrow range.

Methodology

Empirical Model

A farm manager faces the decision of which crop to grow. This decision comes with respect to the financial risk of growing each alternative crop, rotational production patterns, current weather trends, and current market trends. For this project, the primary focus is on the financial risks associated with price, yield, and quality.

Monte Carlo simulation will be used to estimate the distributions of net return to labor and management. SERF analysis will be used to rank each distribution as a risky alternative. A farm manager within the North Central and Central regions of North Dakota faces the decision about which crop to grow based on his or her willingness to face risk. Monte Carlo simulation is a mathematical technique that furnishes a decision maker with a range of possible outcomes and the probabilities that they will occur for any choice of action. This method of analysis works by substituting a probability distribution (range of values and their probabilities) for any factor that has uncertainty. Monte Carlo simulation then calculates the results over and over using a different set of random values from the probability distribution each time. Each evaluation of the model with a set of random drawings from the selected distributions is an iteration. A set of samples is obtained from each iteration representing the possible combination of values that could occur. These iterations are used to estimate distributions of output variables (Hardaker 2004 book). This project uses Monte Carlo simulation with 10,000 iterations to estimate the distributions of net return to labor and management for barley, HRS, corn, soybean, and canola produced in the North Central and Central regions of North Dakota. SERF analysis will then be used to rank each of these output distributions as an alternative within each region dependent upon a farm manager's attitude towards risk.

The previous section discussed the concepts surrounding efficiency analysis and SERF. This section will describe the empirical model, its various components, and the alternative net returns to labor and management for each crop produced in the two regions of North Dakota. As stated previously, risk can be defined as a situation with an unknown outcome but there is a potential for an adverse outcome. In order to measure risk, two different tools are used in this project: @Risk version 6.0 and Simetar 2008. @Risk was used to rank the fit of distributions to data and estimate the distributions of net returns to labor and management. Simetar 2008 was used in order to perform SERF methods to rank the distributions.

The empirical model answers two primary questions. 1. What are the distributions of net returns to labor and management for each of the designated crops grown in the Central and North

Central region of North Dakota? 2. How do these distributions rank against one another based on the different attitudes towards risk possessed by farm managers?

In order to determine the rank of each crop for a farm manager under his or her risk preferences, the model uses a set of inputs in an enterprise budget for each crop in Microsoft Excel. The input portion of the model provides the base work for estimating the distributions of net return to labor and management for each crop grown within each region. These inputs include expected values and distributions of daily spot cash price, trend line adjusted yield, and qualities specific to each crop. The model also includes a section for production costs as published in the NDSU Extension crop budgets. All direct production costs in this model are static other than a drying cost for corn. It is acknowledged that production costs are a source of variability for each crop being analyzed, however it is not the primary source of variability being studied in this project.

Distribution Fitting

For this project, the Akaike Information Criterion (AIC) was used to rank the alternative distributions to the data and determine the best fit for this model. AIC is the least restricting criterion as far as degrees of freedom are concerned when compared to other methods such as Bayesian Information Criterion (BIC) or Hannan-Quinn Information Criterion (HQIC). (Vose 2010). It is the default fitting criteria for @Risk.

Specification of Stochastic Variables

Many of the data requirements for stochastic models are similar to those of deterministic models. Generally, additional data are needed in stochastic models in order to represent uncertainty. The stochastic variables price, yield, and quality are specified and defined here for each crop alternative.

Barley

The primary distributions that were fit are unique to each crop. The stochastic variables for barley are: malting quality vs. feed quality acceptance, trend line adjusted yield, contracted malting quality price volatility, malting barley price, and malting barley price/feed price spread.

HRS

The primary variables for which distributions were for HRS are de-trended yield, market price, protein premium, protein discount, falling number, and test weight.

Corn

The variables used to produce distributions for corn were yield, price, test weight, and moisture. Test weight and moisture were quality variables obtained from expert sources. Additionally, a variable for drying cost was added for corn since drying cost and kernel shrink can become a factor on years where corn must be harvested with higher moisture.

Soybean

The variables used to produce distributions for soybeans were yield, price, test weight, and moisture. Test weight and moisture were quality variables obtained from expert sources.

Canola

The variables used to produce distributions for canola were yield, price, and green count. Moisture was acknowledged as a quality standard but was not included as a discounting quality variable. Buyers of canola typically do not accept canola with moisture content greater than 11.5%. Therefore growers of canola neither harvest nor attempt to market canola with moisture content beyond the cut off standard. The variability estimated from green count was also obtained from an expert source. This is due to the dynamic nature of weather events resulting in years where green count in canola is a significant issue.

Truncation

After the distribution fitting operation was completed for the input variables above, distributions were estimated for each designated output cell in an excel spreadsheet. These distributions may possess values on both the positive and negative sloping regions which may be extreme or even continue infinitely. This can result in distributions that have tails with values that can become quite unrealistic or are unobtainable. For example, the distribution for net return to labor and management for corn could potentially show a tail representing that there is a chance of receiving over $800 per acre for net return to labor and management. In order to eliminate these types of "tails" and extreme unrealistic values taken from random draws of a probability distribution, truncation is used. Truncation limits the upper and or lower bounds of the probability distribution of input variables. For these reasons the draws from the input distribution for this project must be truncated. Thus, draws in this project only occur within the defined range. This prevents the extreme values from appearing within the simulation.

Price Variability and Volatility

There is a difference between price variability and volatility. Price volatility is the statistical measure of dispersion of the price received. Price volatility is the standard deviation of the percent change in price over a selected period of time.

Implied Volatility (IV), is a method of introducing the measure of variability into models which has many benefits and useful attributes. However, it is not without impractical disadvantages as well. IV methods such as the Black Schole's model assume normality of the distribution of percentage change in price to estimate volatility over a specified period of time (Black F., Scholes M. 1973) (Belasco et al., 2009). These models are based entirely on the expectations of a particular option pricing model and assume a constant volatility. If the option model used is not correctly specified, the model could potentially lead to inaccurate forecasts (Longerstaey, J. & Spencer, M. 1996). Another reason IV methods are at a disadvantage in this study is that they require directly observable options prices of all crops.

This project is designed to assess the risks of barley. Barley does not have a futures market in the United States and thus does not possess a set of observable options. For this reason another method was adapted to capture the variability in the daily spot cash prices that are used.

One distinction that must be made is that just because a given cash price is offered by a buyer, does not mean it is accepted by a seller. For this project, we represent price variability using price received by the farm manager. Due to the privacy and difficulty of sampling the overall price received by a farm manager, it is difficult to estimate the variability about the price received. Previous literature has led to the acceptance that the volatility of price received can be represented by a lognormal distribution (Black F., & Scholes M. 1973). Malting barley is heavily contracted by producers. Contracted price also has an effect on the distribution of price received by the producer. Volatility was also estimated for contracted price and was included in the model. By utilizing these factors, price variability is captured as it relates to a typical farmer within the Central and North Central growing regions of North Dakota.

An agricultural producer faces market risk from two different sources: cash prices, and futures prices. Crops such as corn, soybeans, HRS, and canola are distinct from barley in that they are traded on both a cash market and a futures market. The variability in the cash market is not necessarily the same as that of the futures market. This results in the difference between futures and cash prices known as basis. In this project, historical spot cash prices are used in order to estimate price volatility. By using cash prices, a farm manager's exposure to basis is implied.

Previous literature has shown several methods of analysis that can be used to forecast volatility. Common methods include Generalized Autoregressive Conditional Heteroskedasticity (GARCH), Stochastic Volatility (SV), or Exponentially Weighted Moving Average (EWMA). There has been very little difference in forecasting accuracy found between such methods. However, if the overall objective is to achieve accuracy in forecasting volatility, EWMA is considered to have greater accuracy than GARCH or SV models (Ding J., & Meade N. 2010). The method used in this study to quantify price volatility is EWMA. Some would argue that this is an improvement over traditional methods that rely on fixed weights such as the equally weighted moving average (Guldimann et. al 1995). EWMA works by applying the greatest amount of weight to most recent observations and slowly a decaying weight to older, past observations for volatility estimation. This has two key advantages over equally weighted moving average methods. The first is that the most recent observations carry the most weight compared to those that occurred further in the past that carry less weight, and the second is the effect of a "shock", or drastic change in observations, will decline as the weight of the observation declines over time (Guldimann et. al 1995). The decay factor or parameter used is λ, where ($0< \lambda <1$). λ, determines the relative weight that is applied to the observations throughout the data set. In this project, 0.94 was used as the decay value of λ.

Contracting

Contracting is an exceptionally important marketing tool for the average price received by a farm manager. Barley is heavily contracted by farm managers to lock in a price since barley does not have a U.S. futures market. According to the North Dakota Barley Council, about 70% of all malting barley produced in North Dakota is produced under some sort of a contract with a company. These contracts are held by combination of local elevators, private malting companies, and brewing companies such as Anheuser Busch. For this project private data of contracted prices was collected directly from the contracts between growers and Anheuser Busch. This data was used to create a distribution of contract prices and connect them to the price received by a farm manager. This accounts for the variability about the prices which growers contract. The distribution for contracted price in the project was assumed to be lognormal to represent price received. The expected value of this distribution was obtained directly from the contracted price data from Anheuser Busch. The standard deviation of the percentage change in price (volatility) was used for the standard deviation of this lognormal distribution. As previously stated the acceptance rate used for malting quality barley is 60% which holds true for barley gown with a contract. The other 40% of contracted barley produced is then marketed as feed. In this project 70% of barley grown is under contract. The other 30% is sold in open market. Additionally, an act of god clause was assumed in the contracts. This means that if the contracted yield is not met due to unforeseeable circumstances, the obtained yield is simply marketed under contract price.

Insurance

Crop insurance is a tool used by farm managers to protect against several different factors that could lead to unprofitability or losses. Many different types of crop insurance exist such as multi-peril insurance, hail insurance, and revenue protection insurance. According to the North Dakota Barley Council, nearly all crops including barley are grown with insurance and the most commonly used is revenue protection insurance with the 75% coverage level. For this project, revenue protection insurance with a 75% coverage level was applied to all crops within each region.

Crop revenue protection insurance and its application to this project will now be explained. First, the base price for the crop is determined. To do this, all crops in this project use the higher of two prices which are the projected price or the harvest price. The higher of the projected price or the harvest price is then multiplied by the Actual Production History (APH) yield and the coverage level chosen (in this case 75%). This price is called the revenue guarantee where: revenue guarantee = (higher of projected price or harvest price * APH)(0.75). A farm manager's actual revenue is then calculated by multiplying the actual harvested yield by the harvest price. If the actual revenue is less than the revenue guarantee, than the farm manager receives an indemnity payment. The indemnity payment is equal to the difference between the revenue guarantee and the actual revenue.

The projected and harvest prices are calculated differently for each crop and also may vary by state. Projected and harvest prices for crops such as corn, soybeans, and HRS which have a corresponding futures market. However, the projected price and harvest price for crops that do not have a futures market are generally calculated using another highly correlated futures market and an adjustment factor as determined by the USDA Risk Management Agency (RMA). One example of this is other than barley durum wheat. The prices for durum wheat in North Dakota are calculated using HRS prices from the Minneapolis Grain Exchange (MGE) along with an adjustment factor determined by RMA. For barley, the price used for insurance coverage is the higher of either the projected or harvest price using corn futures prices as they are traded on the CME Group market multiplied by an adjustment factor determined by RMA. The projected price for barley is calculated using average December futures corn price during the month of February and multiplying it by the adjustment factor.

To establish this adjustment factor for all states other than Alaska, a 10 year average of yearly data is used. Two series of prices are used to estimate the relative values of barley and corn. The first is the NASS marketing year average price for feed barley. The other is the CBOT September corn contract price. The September corn prices from August 1st through August 31st during each year are then averaged. For each year, the ratio between the feed barley price and CBOT corn price is calculated and the most recent 10 years of ratios are averaged. The result is the adjustment factor (U.S. Department of Agriculture RMA 2013). The method of calculating the projected price for each crop is illustrated in Table 3.1. The method for calculating the harvest price for each crop is illustrated in Table 3.2.

Table 3.1

Projected Price Calculations

Crop	Month avg. Calculated	Futures Month and Crop Used	Location	Adj. Factor
Barley	February	Sept corn	CME	Yes
HRS	February	Sept HRS	MGE	No
Corn	February	Dec corn	CME	No
Soybeans	February	Nov Soybeans	CME	No
Canola	February	Nov canola	ICE	No

Table 3.2

Harvest Price Calculations

Crop	Month avg. Calculated	Futures Month and Crop Used	Location	Adj. Factor
Barley	August	Sept Corn	CME	Yes
HRS	August	Sept HRS	MGE	No
Corn	August	Dec Corn	CME	No
Soybeans	October	Nov Soybeans	CME	No
Canola	September	Nov canola	ICE	No

Net Return to Labor and Management

The estimated distributions for the variable outputs price, yield, and quality were combined to obtain the distribution of market revenue for each crop. In addition, production costs were added to obtain the overall cost of production for each crop. The difference between the distribution of market revenue and cost of production is obtained to estimate a distribution of net return to labor and management for each crop in each region. In this model, barley has a 60% probability of being accepted for malting quality and a 40% probability of being rejected for malting quality and being placed into the livestock feed quality category, two different profit functions are used. The first function is specifically for barley. The second is for all other crops.

Profit Function

The profit function used in this project is a *cost-revenue-profit function.* The definition of this type of function is:

Profit = Revenue – Cost or $P(x) = R(x) – C(x)$

In this case, the profit or loss is net return to labor and management. Net return to labor and management is defined as the distribution of monetary value a farm manager receives after both direct and variable costs are subtracted from the revenue generated by each crop due to the revenue variables of price received, yield, and quality. Federal farm program benefits are not included in the model as they do not have a direct effect on the decision of a farm manager to grow or not grow a given crop.

The profit function for net return to labor and management for barley is:

$RLM_i = CY_i(CP_m \text{ or } SP_f) + SY_i(SP_m \text{ or } SP_f) + I_i - VC_i - L - M_i$

The profit function for net return to labor and management for all other crops is:

$RLM_i = ([SP_i \pm Q_{ij}]\ Y_i) + I_i - VC_i - L - M_i$

Where: RLM_i = Net return to labor and management for crop $_i$

SP_i = Spot cash price for crop $_i$

SP_f = Malting price minus discount for feed quality

SP_m = Spot cash price for malting barley

CP_m = Contracted barley price

Q_{ij} = Quality attribute $_j$ for adjusted crop $_i$

CY_i = Contract yield for crop $_i$

SY_i = Spot yield for crop $_i$

VC_i = Variable costs for crop $_i$

L = Constant land cost for all crops

I_i = Insurance indemnity (if any) for crop $_i$

M_i = Machinery costs for crop $_i$

SERF

Negative Exponential Utility Function

The utility function used in this project for ranking risky alternatives is the negative exponential utility function (Lien, G., Hardaker, J.B., & Flaten, O. 2007). The negative exponential utility function was used due to the fact that annual income can be either positive or negative. In addition, income is generally viewed as small when compared to relative wealth. Thus it can be assumed that a constant absolute risk aversion (CARA) utility function is useful (Richardson 2010). According to Richardson, "The easiest CARA function to use is the negative exponential utility function". The most important point is to specify the absolute risk aversion coefficient (ARAC) using the formula:

$r_a = r_r / w$

"Where *w* is wealth or net worth of the decision maker" (Richardson 2010).

Absolute Risk Aversion Coefficient

In order to rank distributions, the software program Simetar was used. The simulation output data of 10,000 iterations was used and transferred to Simetar. When the SERF function is used, absolute risk aversion coefficients (ARAC) based on a negative exponential utility function was chosen. Within the utility function, an upper parameter was defined being the Maximum Risk Aversion Coefficient, and a lower parameter designated as the Minimum Risk Aversion Coefficient (RAC). For this project a minimum ARAC of 0.0 was chosen. 0.0 was chosen as a minimum since anything below 0.0 would be considered risk preferring. A maximum ARAC of 0.04 was chosen representing a decision maker or farm manager who is extremely risk averse.

CHAPTER 4. DATA

Introduction

Price, yield, and quality variability are the key sources of risk addressed in this project. A combination of primary and secondary data sources were used in order to collect the data necessary. Barley is a crop that does not have a futures market in the United States. This required that spot cash price data be used for all crops being analyzed in this project. Cash price data had to be obtained from primary sources. Daily average price data from specific elevator locations within the North Central and Central production regions in North Dakota. Some of these locations did not have all of the necessary crops, or possessed incomplete data.

In addition, some quality data such as DON (parts per million deoxynivalenol) in barley and HRS, or green count (green seeds that cause an undesirable green coloring in oil) in canola was limited to a small time frame or not available at all. Some crops only have two or three quality characteristics to be analyzed where others have several. Quality characteristics such as moisture and test weight in corn are important but this data is generally not publicly accessible or is kept private between the producer selling his or her crop and the buyer of that crop. Yield data also had its own set of drawbacks. In some crops, such as canola, only a limited number of years were available. Data was collected from both primary and secondary sources and used to estimate distributions for these variables. The distributions of variables were then used as inputs in the model to estimate the distribution of net return to labor and management for each crop within the primary North Central and transitional Central regions of North Dakota.

Growing Region

For this project it was decided that using two different geographical growing regions would be useful for comparison. Historical planted acreage was evaluated to select a primary or traditional barley growing region, and a transitional barley growing region within North Dakota. The transitional growing region is a region where barley is not generally viewed as a primary crop to grow but could be if it were competitive with other crops. It was established that the North Central USDA NASS crop reporting district should be used as the primary growing region, and the Central USDA NASS crop reporting district should be used to represent the transitional growing region. These are the regions for which data for price, yield, qualities, and cost of production were acquired. Figure 4.1 shows the USDA NASS reporting regions for North Dakota and the counties included within each region.

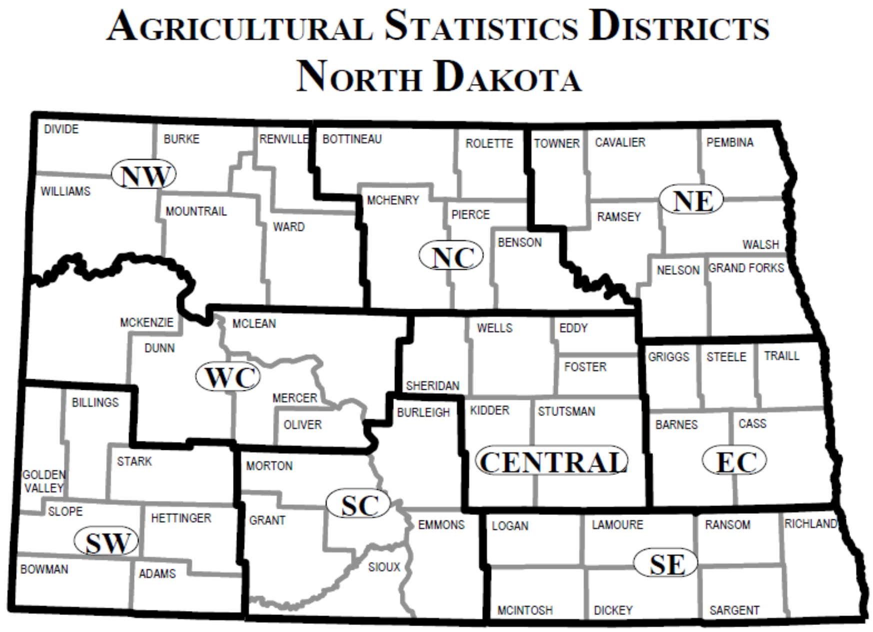

Figure 4.1. North Dakota Agricultural Statistics Districts

Figure 4.1 illustrates the USDA NASS Agricultural Statistics Reporting Districts in North Dakota. The two reporting districts from which data was gathered are the North Central and Central districts.

Yield

Yield is a very important determinant of the overall revenue received by a crop producer. Producers seek to obtain the yield that will generate the greatest return to their labor, and management practices.

In order to create a probability distribution for yield for each alternative crop, county average yield data was collected from USDA-NASS. County yield data was available from 1949 to 2012 for barley, corn, soybean, and HRS. Yield data for canola has a unique profile as NASS data was only available from 1999 forward. This will be addressed in detail further in this document.

Yield data is unique compared to other types of data. This type of data typically possesses a progressively increasing mean over time. As time has gone by there have been changes in technology such as new seed varieties, improved inputs, and better overall management practices which have allowed for an increase in the yield potential of all cropping alternatives. The yield data for each crop was adjusted for trend in order to compensate for the technology changes over time.

De-trending is used to adjust for this changing yield over time. A weighted least squares regression was run on the USDA NASS county level yield data where $Y=\beta o + \beta 1*T + \varepsilon$, and harvested acres were used as the weighting matrix for the yield of barley, corn, HRS, soybean, and canola for the counties in the North Central and Central production regions of North Dakota. The error factor (residual factor) from this process was used to represent the deviation from the trend line yield and used as the measure of yield variability. The predicted yield is subtracted from the actual yield in order to calculate the residuals.

Non Parametric Levene's Test

Canola yield data was only available for years 1999 through 2012. This brought to attention that data consistency had to be addressed in order to avoid introducing additional error into the model. It was decided that a Non-Parametric Levene's Test should be run in order to determine the equality of variability for all crops in each county. This would then answer the question: "Can the county average data be combined for each crop in each region?" The summary statistics from this test are illustrated in Table 4.1. All crops in both regions possess a P-value that is greater than the critical value of 0.10. This leads to the conclusion that the yield data collected from each county can indeed be combined into one pool to represent a complete region. As a result, yield data for all crops used in this project was pooled to represent each of the North Central and Central regions in North Dakota.

Table 4.1

Non-Parametric Levene's Test Results for NC and C Region

Crop	Central Region		North Central Region	
	F Value	P Value	F Value	P Value
Barley	0.25	0.939	0.26	0.9003
Canola	0.74	0.5982	0.81	0.5244
Corn	1.7	0.1338	0.38	0.8231
Soybeans	0.45	0.8098	0.46	0.7661
Wheat	0.42	0.8361	0.18	0.9493

The next step was estimating probability distributions of the yield residuals for each crop in both of the North Central and Central regions. Those distributions were then added to the forecasted trend line yield in order to obtain the predicted yield distribution used in the model. The summary statistics for the distributions for the residuals of each crop can be viewed in Table 4.2 for the North Central region and Table 4.3 for the Central region.

North Central Region Yield Residual Distributions

Table 4.1 illustrates the distributions of trend line yield residuals for each of the crops used in this project for the North Central region of North Dakota. There are several different fitting criterion for fitting distributions. For this project Akaike Information Criterion (AIC) was used. AIC is a method that can be used to select one fitted type of distribution over another, or model selection (Palisade Corporation 2013). Using the AIC criterion, the error factor or residuals from a de-trending regression analysis for barley grown in the North Central region of North Dakota has a logistic distribution with a minimum value of -30.039 bu. per acre, a maximum value of 30.038 bu. per acre, and a standard deviation of 7.067 bu. per acre. The yield distribution of HRS produced in this region was a Weibull distribution with a minimum value of -15.592 bu. per acre, a maximum value of 15.199 bu. per acre, and a standard deviation of 5.169 bu. per acre. The yield distribution of corn produced in this region was a Logistic distribution with a minimum value of -58.98 bu. per acre, a maximum value of 59.48 bu. per acre, and a standard deviation of 13.92 bu. per acre. The yield distribution for soybeans produced in this region was a Logistic with a minimum value of -12.465 bu. per acre, a maximum value of 12.468 bu. per acre, and a standard deviation of 4.263 bu. per acre. The yield distribution for canola produced in this region was a Triangular with a minimum value of -354.88 lbs. per acre, a maximum value of 355 lbs. per acre, and a standard deviation of 163.26 lbs. per acre.

Table 4.2

North Central Summary Statistics for Yield Residuals

Crop	Units	Min	Max	Std	Skewness	Kurtosis	Distribution
Barley	bu./acre	-30.039	30.038	7.067	-0.0097	3.7252	Logistic
HRS	bu./acre	-15.592	15.199	5.169	-0.2566	2.7854	Weibull
Corn	bu./acre	-58.980	59.480	13.920	0.0002	3.8460	Logistic
Soybean	bu./acre	-12.465	12.468	4.263	0.0092	3.0527	Logistic
Canola	lbs./acre	-354.88	355.000	163.060	0.0124	2.2942	Triangular

Central Region Yield Residual Distributions

Table 4.3 reports the summary statistics of the trend line yield residuals for the crops in this study produced in the Central region of North Dakota. The yield distribution for barley was an Extreme Minimum Value (ExtValueMin) with a minimum value of -33.461 bu. per acre, a maximum value of 19.876 bu. per acre, and a standard deviation of 8.682 bu. per acre. The yield distribution of HRS for this region was a Weibull with a minimum value of -17.888 bu. per acre, a maximum value of 17.436 bu. per acre, and a standard deviation of 5.856 bu. per acre. The yield distribution of corn for this region was a Laplace with a minimum value of -70.03 bu. per acre, a maximum value of 68.99 bu. per acre, and a standard deviation of 15.12 bu. per acre. The distribution of soybeans for this region was a Triangular with a minimum value of -12.478 bu. per acre a maximum value of 12.483 bu. per acre, and a standard deviation of 5.3 bu. per acre. The yield distribution of canola for this region was a Triangular with a minimum value of -429.78 lbs. per acre, a maximum value of 430.00 lbs. per acre, and a standard deviation of 187.98 lbs. per acre.

Table 4.3

Central Summary Statistics for Yield Residuals

Crop	Units	Min	Max	Std	Skewness	Kurtosis	Distribution
Barley	bu./acre	-33.461	19.876	8.682	-0.8223	3.6906	ExtValueMin
HRS	bu./acre	-17.888	17.436	5.856	-0.2326	2.7828	Weibull
Corn	bu./acre	-70.030	68.990	15.120	-0.0026	5.0433	Laplace
Soybean	bu./acre	-12.478	12.483	5.300	-0.0165	2.3872	Triangular
Canola	lbs./acre	-429.78	430.000	187.980	-0.0456	2.3572	Triangular

Price

One important difference between this project and previous studies is the use of daily spot cash price data within specific regions of North Dakota. Other studies (Manfredo et al., 1999) have used data such as futures prices or average yearly, monthly or weekly cash prices. Unlike the other crops being evaluated in this project, malting barley does not have a futures market available in the United States. The Intercontinental Commodity Exchange (ICE) does offer a feed barley futures market located in Winnipeg, Manitoba Canada. Within this market, trading volumes are somewhat low and the contracts being traded represent feed barley only. For these reasons daily spot cash prices for all crops were utilized in order to adequately model price data at the farm level. It is much easier not only to obtain, but also to use monthly or annual average cash prices to estimate probability distributions that represent price volatility. Monthly or weekly price data for certain locations can be obtained through USDA NASS. Using daily price data has the advantage of introducing a much more dynamic method of modeling the variability of prices despite data being much more difficult to obtain. In order to obtain daily spot cash price data, prices from specific locations had to be acquired. This introduces another drawback in that records of local spot cash prices offered often have missing points in the data series or are only available for a certain range of years. These missing data points can range from a single day in the time series, to as long as several consecutive months.

Price data used for this project was obtained using DTN and Cash Grain Bids through the Bloomberg and Profit X platforms. Daily cash price data for the marketing years of 2010, 2011, 2012, and 2013 was collected in order to accurately capture the most current trends in price variability and volatility for each crop. Since barley is the most limiting in terms of cash prices, locations with the most complete data set for malting barley and feed grade barley were the first criteria for selection. Next, locations with the most complete data sets for each additional crop were evaluated in order to find the best fitting locations possible.

Data from BTR Farmer's Co-op in Leeds ND, combined with Equity Co-op in Sheyenne ND were the locations selected for the North Central region. A combination of Equity Co-op in Sheyenne ND, Lake Region Co-op in Devil's Lake, and Fessenden Co-op Association Elevator were used for the Central region. These specific locations were selected because they were the most complete within the geographical region in addition to being similar enough to cooperatively assemble a complete data set.

Each of the selected elevators is not without missing data of its own for each crop; however, the locations were the most feasible to fill these data gaps and provide an accurate model using average daily spot cash prices. The first choice for filling data gaps was using the futures market and cash price data points before and after the data gap in order to determine the typical local basis within the time period of the missing data. Next, the basis was averaged and subtracted from the current futures price. This uses a close, realistic basis and an accurate futures price to provide an estimate of the cash price. This method is not without its disadvantages; however, it does eliminate the problem with estimating price volatility that exists when data is not continuous.

After the data gaps were filled and continuous price data was created for both the North Central and Central regions, some additional factors in modeling were bought to attention. The first issue to be addressed is that just because a price is offered in a location does not mean that it is the price received by a typical farm manager. The second is how is the price volatility addressed when creating a distribution of prices received?

Previous literature has indicated that the distribution of a price received can be estimated using a log normal distribution (Black, F., & Scholes, M. 1973). There are two pieces required to estimate a lognormal distribution. These are an expected value, and a standard deviation. . The distribution of volatility is used in place of the standard deviation. Volatility is the standard deviation in percent change of price over a period of time.

Volatility of prices must be modeled using historical cash data since barley does not possess a futures market in the United States. In addition to cash prices received by a producer, contracting is a marketing tool heavily used among producers. This adds another portion of variability to the distribution of price received by a farm manager. For barley, volatility in both the cash price received, and the contracted price was modeled. Contract price data was obtained from Anheuser Busch daily bid sheets.

Forecasting volatility is a difficult and controversial issue among researchers. Using models such as Implied Volatility would introduce a greater amount of error into the model if such techniques could even be used. This is because implied volatility is a static measure. For this project, a probability distribution of volatilities is used. Since barley does not have a futures market, a method of using historical data had to be used to model volatility. It can be argued that

Exponentially Weighted Moving Average (EWMA) is one of the most accurate methods of forecasting volatility when using historical data (Ding, J., & Meade, N. 2010). EWMA is the method of forecasting volatility used in this model. Tables 4.4 and 4.5 illustrate the summary statistics of the distributions of volatility estimated for each crop in each region using EWMA.

Central Region Volatility Distributions

Using AIC fitting criterion, volatility distributions were fit to each crop within each region. In the Central production region, the volatility distribution for malting barley was a Weibull with a minimum value of 0.0388, a maximum value of 0.7652, a mean of 0.1825, and a standard deviation of 0.0980. Contracted barley had a Gamma distribution with a minimum value of 0.0450, a maximum of 0.6447, a mean of 0.1781, and a standard deviation of 0.1181. HRS had a Beta General distribution with a minimum of 0.1727, a maximum of 0.4695, a mean of 0.3024, and a standard deviation of 0.0609. Corn had a Weibull distribution with a minimum value of 0.1711, a maximum of 0.8310, a mean of 0.3663, and a standard deviation of 0.0937. Soybeans had a Log Logistic distribution with a minimum value of 0.1361, a maximum value of 0.8691, a mean of 0.2750, and a standard deviation of 0.1066. Canola had a Lognormal distribution with a minimum value of 0.1173, a maximum value of 0.9536, a mean of 0.2825, and a standard deviation of 0.1104. Note that many of the maximum volatility values in the distribution fitting became unrealistically high. This was due to the fact that several distributions possessed a domain with a maximum of positive infinity. After the fitting process the distributions were truncated to allow draws only up to the maximum volatility value supplied by EWMA and a minimum of 0.0. The maximum values for the Central region were: 0.60 for barley, 0.64 for HRS, 0.67 for corn, 0.87 for soybeans, and 0.85 for canola.

Table 4.4

Central Summary Statistics of Price Volatility Distributions

Crop	Distribution	Min	Max	Mean	Standard Deviation
Malting Barley	Weibull	0.0388	0.7652	0.1825	0.0980
Contracted Barley	Gamma	0.0450	0.6447	0.1781	0.1181
HRS	Beta General	0.1727	0.4695	0.3024	0.0609
Corn	Weibull	0.1711	0.8310	0.3663	0.0937
Soybean	Log Logistic	0.1361	0.8691	0.2750	0.1066
Canola	Lognormal	0.1173	0.9536	0.2825	0.1104

North Central Region Volatility Distributions

Malting barley in the North Central production region had a Weibull volatility distribution with a minimum value of 0.0450, a maximum of 0.6446, a mean of 0.1781, and a standard deviation of 0.1181. Contracted barley had a Gamma distribution with a minimum value of 0.0450, a maximum of 0.6443, a mean of 0.1781, and a standard deviation of 0.1181. HRS had a Beta General distribution with a minimum of 0.1726, a maximum of 0.4696, a mean of 0.3024, and a standard deviation of 0.0609. Corn had a Pearson 5 distribution with a minimum value of 0.1723, a maximum of 0.8310, a mean of 0.3663, and a standard deviation of 0.0937. Soybeans had a Weibull distribution with a minimum value of 1.6269, a maximum value of 6.7366, a mean of 2.9984, and a standard deviation of 0.7575. Canola had a Gamma distribution with minimum of 0.1177, a maximum of 0.9514, a mean of 0.2825, and a standard deviation of 0.1104. The truncated minimum volatility value was 0.0, and the maximum values for the North Central region were: 0.60 for barley, 0.47 for HRS, 0.76 for corn, 0.87 for soybeans, and 0.56 for canola.

Table 4.5

North Central Summary Statistics of Price Volatility Distributions

Crop	Distribution	Min	Max	Mean	Standard Deviation
Malting Barley Contracted	Weibull	0.0450	0.6446	0.1781	0.1181
Barley	Gamma Beta	0.0450	0.6443	0.1781	0.1181
HRS	General	0.1726	0.4696	0.3024	0.0609
Corn	Pearson 5	0.1723	0.8310	0.3663	0.0937
Soybean	Weibull	1.6269	6.7366	2.9984	0.7575
Canola	Lognormal	0.1177	0.9514	0.2825	0.1104

Quality

Quality data was obtained for barley and HRS from the crop quality surveys sponsored by the North Dakota Wheat Commission, North Dakota Barley Council, and from studies analyzed by North Dakota State University.

Crop quality aspects were an important part of this study to provide an accurate measure of the variability of net return to labor and management. Qualities such as protein, moisture, and test weight have the impact of introducing a discounted or in some cases, even a premium price received for a given crop.

Using the expert opinions of Steve Edwardson (executive administrator North Dakota Barley Council), Guy Christensen (oil seed merchandiser for Archer Daniels Midland), Keith Finney (Clifford Merchandising Group), Paul Coppin (general manager at Reynolds United Co-op), and David Fiebiger (manager at Finley Farmer's Elevator) each quality and its standard was determined for each crop in the project along with any additional special issues that might be involved with their production and marketability.

Barley Quality

Typically, when a farm manager brings his or her barley to market, it must meet the specifications for malting quality; otherwise the barley is marketed as feed. The quality attributes for barley are: percent plump, percent thin, test weight, percent moisture, percent protein, and parts per million deoxynivalenol (DON or vomatoxin). The quality standards for malting barley are no less than 75% plump kernels, no greater than 5% thin kernels, no less than 48 lbs. per bushel test weight, no more than 13% moisture, no more than 13.5% protein, and no more than 2 parts per million DON. If any one of these quality standards is not met, barley may be rejected for malting quality and must then be marketed as livestock feed.

Deoxynivalinol (DON)

DON, commonly known as vomitoxin, is a mycotoxin that results from the disease fusarium head blight. This disease has an impact on cereal crops such as barley, HRS, durum, and rye. When this disease is present in barley it causes an undesirable foaming effect during the brewing process. For barley the standard that malting companies use to determine if barley is adequate for malting quality or should be rejected and used as feed quality is typically 2 parts per million (ppm). For final food products such as flour, bran, or germ, DON levels in HRS must be no greater than 1ppm.

During the data gathering process barley quality surveys sponsored by the North Dakota Barley Council were evaluated to determine if they were a viable data source for barley quality. Upon further review of the data, the sample size for each of the individual quality characteristics for barley was very small in the most recent years; there were not enough responses to these surveys to create a representative data set for the qualities associated with barley production. A new method had to be utilized in order to introduce the variability of barley quality into the model. According to Steve Edwardson of the North Dakota Barley Council, "Expert opinion would be a much more reliable data source than the use of an unbalanced data set which would introduce a greater quantity of error into the model".

Through a personal interview with the North Dakota Barley Council it was determined that an estimated 60% of barley produced is accepted for malt use and 40% was rejected. These rates vary from year to year but this is what is believed to be a good long term representation. Thus for use in the model, 60% of barley produced in the specified regions of North Dakota is placed into the price pool for malting quality, and 40% was placed into the price pool for feed quality.

Hard Red Spring Wheat Quality

The quality standards used for hard red spring wheat (HRS) include: a base protein level of 14%, a minimum falling number of 300, and a minimum test weight of 58lbs. per bushel. The raw quality data for HRS was obtained from the North Dakota Wheat Commission wheat quality survey. DON and moisture tests are not included in these quality surveys, and were not included in this project. HRS is quality sensitive, but is not perceived to be as sensitive as barley. It receives a price premium for having a high protein level along with a discount when protein levels are below the standard. Price premiums and discounts for HRS protein were obtained from Sun Prairie Grain in Minot, ND for the years 1989 through 2013. Quality data for spring wheat was obtained from the spring wheat quality reports (NDSU North Dakota Wheat Commission).

In addition to the wheat quality data, the quality standard parameters were obtained from the North Dakota Wheat Commission quality survey. The spread between protein premiums and discounts was tested for statistical significance. Results from an F-test indicated that protein the spread difference between protein premiums and discounts is indeed statistically significant. This makes it important to acknowledge the distribution of protein spreads for HRS in the model. This study uses wheat samples that received a protein premium and those that received a protein discount. The Spearman's rank order correlation method was used in order to correlate the protein spreads to the distribution of protein for HRS. According to the correlation matrices, the correlation between the protein premium and market price is -0.8845. The correlation between the protein discount and market price is -0.2356.

Corn and Soybean Quality

The qualities used for corn and soybeans include: test weight and moisture. Data for these qualities is not readily available and thus was obtained using expert opinion from personal interviews with the following experts: Paul Coppin (general manager of Reynolds United Cooperative Elevator), Keith Finney (Clifford Merchandising Group), and David Fiebiger (general manager of Finely Farmers Grain and Elevator). Triangular distributions were then estimated to represent the variability in corn and soybean quality.

Canola Quality

The two most important quality attributes for canola are green count and moisture. Data for green count is not readily accessible. Expert sources were utilized in order to estimate the variability for green count. During an interview with Guy Christensen (ADM grain merchandiser in Enderlin ND 08/27/2013) it was determined that green count is problematic 1 out of every 10 years. Discounts for high green count tend to be more severe during years when it is a problem when compared to years green count is not a problem. During the years when green count is a problem, it was determined that it has an effect on 10% of the overall bushels harvested. Discrete distributions were used in this model to include the 10% of years where green count is a problem. In addition to discrete distributions, expert opinion was used to create triangular distributions for both the North Central and Central region. Within both regions, the minimum value was \$0.045, the most likely value was \$0.340, and the maximum value was \$0.650 (all canola price values are expressed in cents per hundred weight). During a second interview with Mr. Christensen (10/24/2014), it was added that moisture in canola is an additional major restricting quality factor. Sufficient equipment is not readily available to dry wet canola due to the small size of the seed. Buyers will not accept canola over the 11.5% maximum moisture level. Due to this restriction, farm managers will not harvest canola that is known to have a higher moisture content.

Farm Program

The farm program has been a dynamic and changing factor of farm income in past years. In the most recent years, the farm program has not had an impact on a farm manager's decision to produce alternative crops. Farm program payments are an important form of income on the whole farm level, but in recent years they have been de-coupled from a farm manager's planting decisions. Other factors such as a farm manager's rotational pattern and current market trends outweigh the additional income generated by growing an alternative crop. Farm program payments were not included in this project.

CHAPTER 5. RESULTS

Introduction

Probability distributions of net return to labor and management were estimated for barley, corn, hard red spring wheat (HRS), soybeans, and canola grown in a primary (North Central), and a transitional (Central) growing region of North Dakota during the 2012-2013 growing season. Net return to labor and management is what a farm manager receives after cost of production is subtracted from the gross revenue received from growing a particular crop. Probability distributions for the stochastic variables of price received, trend adjusted yield, and crop quality were estimated based on a combination of historical data and expert sources. Monte Carlo simulation was used to conduct 10,000 iterations to estimate the distributions for net return to labor and management. Next, stochastic efficiency with respect to a function (SERF) analysis was used to rank the estimated probability distributions of net return to labor and management for each crop within each region according to a farm manager's assumed risk preferences as they apply to producing a given crop within that region of North Dakota.

The results of this model along with their implications are presented in this chapter, which is divided into two sections. The first section describes the results of the distributions of net return to labor and management for each crop in each region and the second illustrates the results of the SERF ranking.

Distribution Results

North Central Region

Table 5.1 shows the summary statistics of the probability distributions of net return to labor and management for each crop (barley, HRS, corn, soybeans, and canola) in the North Central region of North Dakota. The minimum value of net return to labor and management for barley was -$82.50 per acre, the maximum return was $425.16 per acre, the mean was $117.00 per acre, and the standard deviation was $54.33 per acre.

HRS shows a minimum net return to labor and management value of -$137.22 per acre, a maximum value of $618.71 per acre, a mean of $101.32 per acre, and a standard deviation of $98.62 per acre.

Corn for the North Central Region of North Dakota produced a distribution with a minimum net return to labor and management of -$201.10 per acre, a maximum of 557.88 per acre, a mean of $151.99 per acre, and a standard deviation of $133.43 per acre.

The distribution of net return to labor and management for soybean generated a minimum of -$165.01 per acre, a maximum of $435.03 per acre, a mean of $107.24 per acre, and a standard deviation of $88.47 per acre.

The distribution of net return to labor and management for canola indicated a minimum value of -$140.17 per hundred lbs. (cwt), a maximum of $621.75 per cwt, a mean of $96.47 per cwt, and a standard deviation of $101.03 per cwt.

The results for all crops analyzed in the North Central region of North Dakota can be viewed in Figure 5.1 in the form of cumulative distribution functions (CDF). From these results we can see that corn has the greatest mean net return to labor and management. It also possesses the greatest standard deviation. Soybeans had the second greatest mean and its standard deviation is the second lowest. Barley and soybeans were quite similar in terms of standard deviation. However, barley is the lowest with a much lower mean as well. Barley possesses the distribution with the least amount of variability of crops analyzed in this region.

Coefficient of Variation

In Table 5.1 and Table 5.2, the coefficient of variation (CV) is also illustrated. The CV is the standard deviation divided by the mean. This gives a unitless measure of variability about the mean. The CVs for the North Central Region are illustrated in Table 5.1. From these values we can see that barley has the lowest CV followed by soybeans. This means that the standard deviation of net return to labor and management is lowest in comparison to the mean. Canola and corn have the highest CV and further the greatest amount of variability in net return to labor and management.

Table 5.1

North Central Net Return to Labor and Management Summary Statistics

Crop	Units	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis	CV
Barley	$ / acre	-$82.50	$425.16	$117.00	$54.33	0.1756	3.4504	0.4643
HRS	$ / acre	-$137.22	$618.71	$101.32	$98.62	0.9441	4.8275	0.9733
Corn	$ / acre	-$201.10	$557.88	$151.99	$133.43	0.1364	2.5338	0.8779
Soybeans	$ / acre	-$165.01	$435.03	$107.24	$88.47	0.2661	2.8990	0.8250
Canola	$ / acre	-$140.17	$621.75	$96.47	$101.03	0.7953	4.2544	1.0472

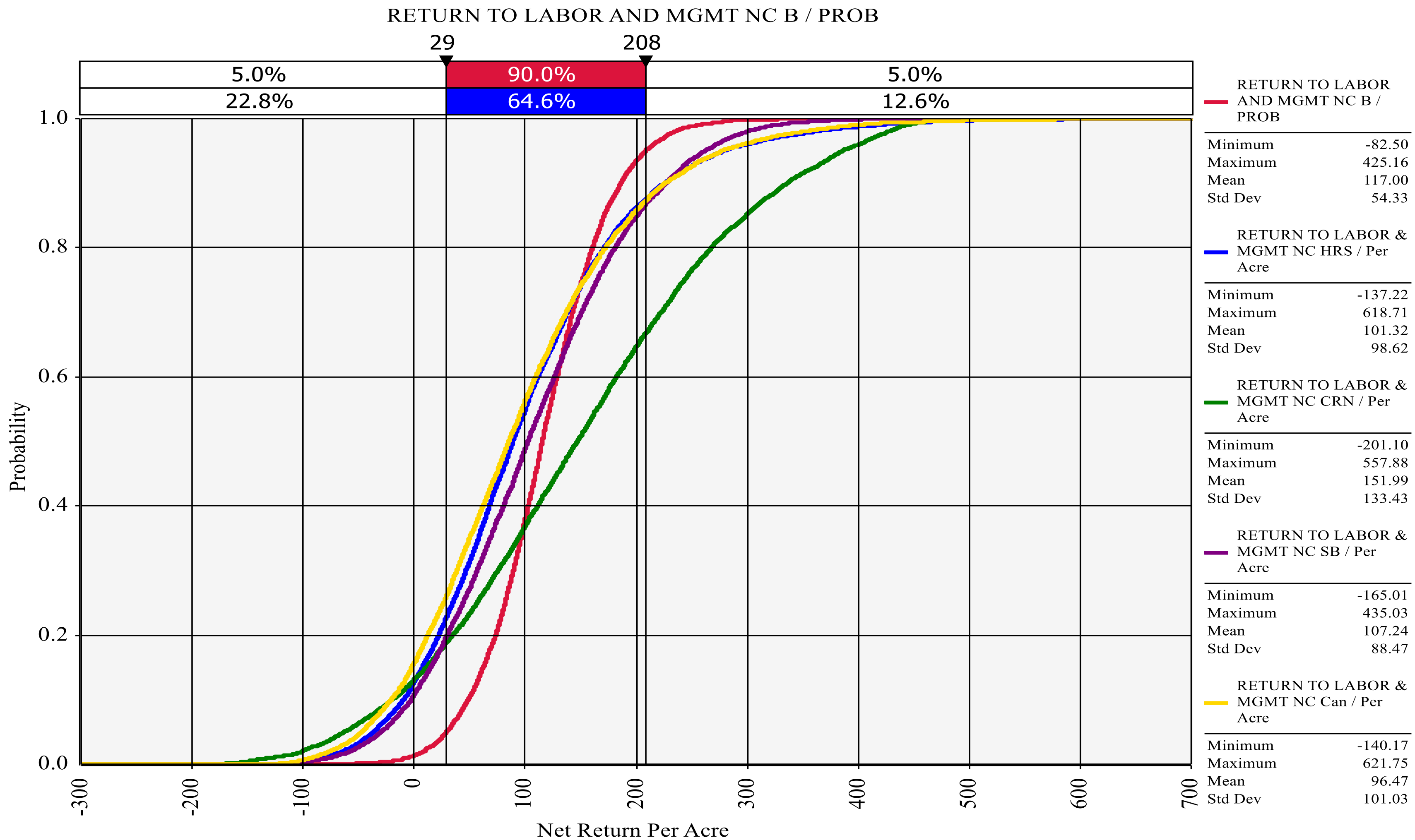

Figure 5.1. North Central Crop CDF Comparison of Net Return to Labor and Management

Central Region

Table 5.2 provides a statistical description of the probability distributions of net returns to labor and management for the Central production region of North Dakota. The results for the central region can be viewed in Figure 5.2 in CDF form.

The probability distribution for barley shows that a producer within this region can expect a minimum net return of -$182.17 per acre, maximum of $335.44 per acre, a mean of $96.63 per acre, and a standard deviation of $58.67 per acre.

The distributions for HRS estimated a minimum net return to labor and management of -$210.85 per acre, a maximum of $691.41 per acre, a mean of $52.19 per acre, and a standard deviation of $99.06 per acre.

The distributions for corn estimated a minimum net return to labor and management of -$337.72 per acre, a maximum of $595.11 per acre, a mean of $96.71 per acre, and a standard deviation of $166.08 per acre.

The probability distribution of soybeans for the Central producing region of North Dakota shows a minimum net return to labor and management of -$126.84 per acre, a maximum of $425.65 per acre, a mean of $148.99 per acre, and a standard deviation of $90.57 per acre.

Finally, the simulation run on canola provided a minimum net return to labor and management of -$169.96 per acre, a maximum of $580.34 per acre, a mean of $43.16 per acre, and a standard deviation of $103.02 per acre. The results of the distributions of net returns to labor and management for each crop analyzed in the Central production region of North Dakota can be viewed in Figure 5.2 in the form of CDF's. The CDF for Soybeans possessed the greatest mean and the second smallest standard deviation. Barley had the third greatest mean and the smallest standard deviation making it the least variable of all crops analyzed in this region. Corn had the second greatest mean, but also had the greatest standard deviation. The standard deviation in the case of corn produced within the Central region of North Dakota was greater than any other by a substantial amount when compared to the North Central region. Canola has the lowest mean value but has a standard deviation second only to that of corn.

Coefficient of Variation

The CV for each crop grown in the Central Region is illustrated in Table 5.2. From these statistics it can be seen that the variability of net return to labor and management for each crop is relatively higher in the Central production region than in the North Central Region. Barley still possesses the lowest CV of all crops followed closely by soybeans. Canola and corn have the highest CV and further the greatest variability in net return to labor and management.

Table 5.2

Central North Dakota Probability Distributions of Net Return to Labor and Management

Crop	Units	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis	CV
Barley	$ / acre	-$182.17	$335.44	$96.63	$58.67	-0.1204	3.2031	0.6071
HRS	$ / acre	-$210.85	$691.41	$52.19	$99.06	0.5056	3.7436	1.8980
Corn	$ / acre	-$337.72	$595.11	$96.71	$166.08	0.1939	2.4979	1.7173
Soybeans	$ / acre	-$126.84	$425.65	$148.99	$90.57	-0.0398	2.7273	0.6079
Canola	$ / acre	-$169.96	$580.34	$43.16	$103.02	0.9114	4.3497	2.3869

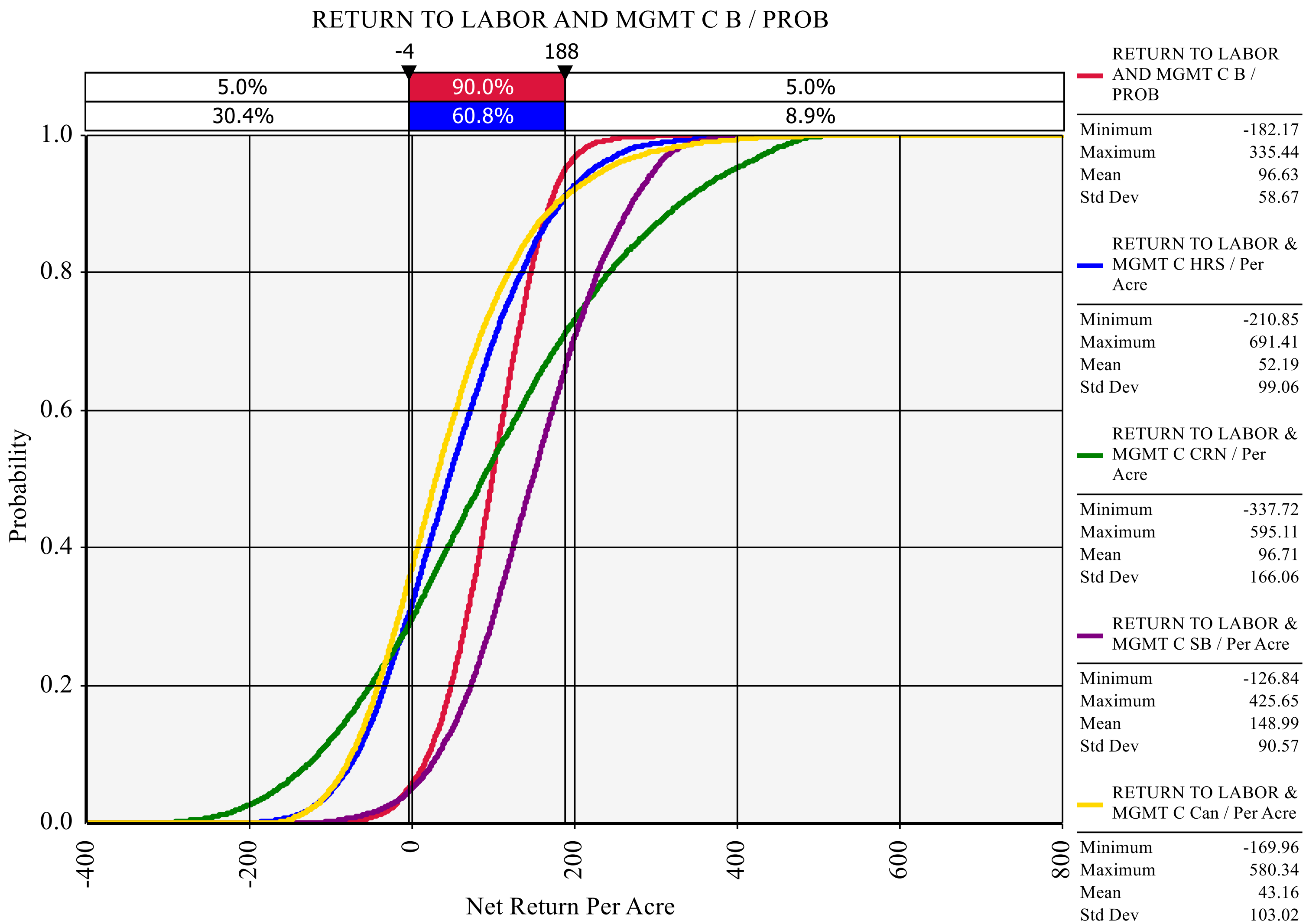

Figure 5.2. Central Region CDF Crop Comparison of Net Return to Labor and Management

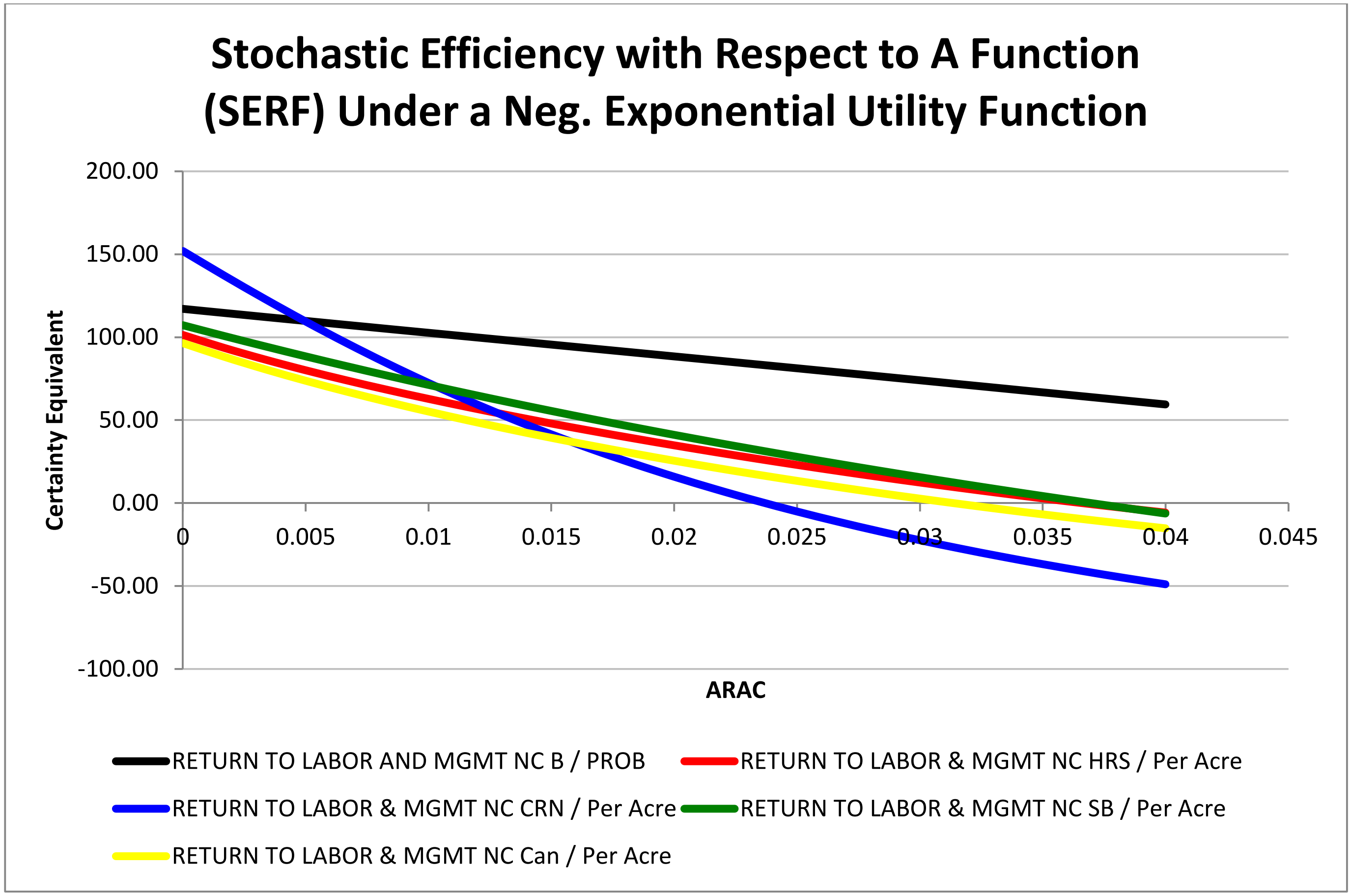

Figure 5.3. North Central Region SERF Results

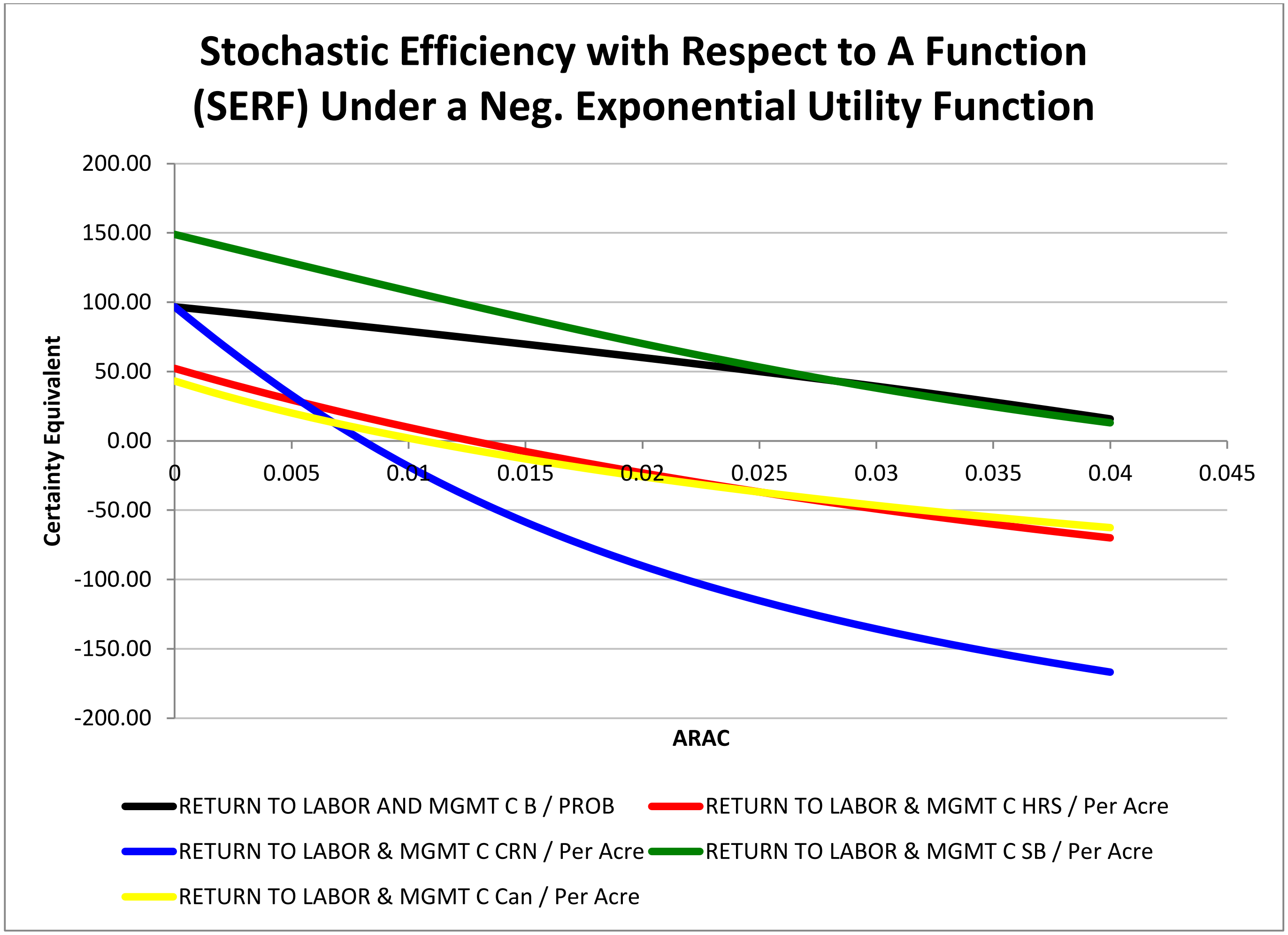

Figure 5.4. Central Region SERF Results

SERF

One difference that can be easily viewed when comparing the SERF results in figures 5.3 and 5.4 is the difference in variability between the two regions. The SERF results from the North Central production region indicate that the crop alternatives have a greater similarity to one another than those in the Central production region. This might suggest that the overall variability in net return to labor and management for producing alternative crops is greater in the Central region than in the North Central region. In the Central region, soybean is consistently the dominant crop alternative across all levels of risk aversion. In comparison, in the North Central region, corn begins as the dominant alternative and quickly tapers off. Soybeans then become the dominant crop across all other levels of risk aversion. When a farm manager moves from an ARAC of .005 to 0.015, corn will have moved from the preferred alternative to the second lowest ranked alternative crop to grow. It appears to be consistent across both regions that as a farm manager becomes more risk averse, for example from an ARAC of 0.005 to 0.025, barley becomes a preferred alternative. What this tells us is corn is a dominant crop if an individual is risk neutral, but quickly becomes dominated by other crops with even a small amount of increased risk aversion.

Certainty Equivalents

Tables 5.3 and 5.4 display the certainty equivalents for all crops in comparison to barley. The ARACs used for comparison across all crops in both regions are 0.0, 0.015, and 0.03, although the overall range of the empirical model was 0.0 through 0.04. Zero represents a farm manager that is risk neutral, 0.015 represents a farm manager that is between somewhat risk neutral and risk averse, and 0.03 represents a farm manager that is very risk averse. To understand what these certainty equivalents mean, a certainty equivalent of a risky alternative represents the amount of compensation a decision maker must receive in order to be indifferent between a certain alternative and a risky alternative (Robison & Barry 1999). In this case, The CE's are the monetary value per acre that it would take to make a farm manager at a given level of absolute risk aversion to be indifferent between or consider growing a crop other than barley. For example, in order for a very risk averse farm manager in the primary North Central production region to consider growing corn instead of barley, it would take an additional income of $34.82 per acre. As a generalization, it appears that the CE's are more extreme in the transitional Central region than the primary North Central region. Additionally, CE's in the Central region also appear to have a greater range of variability by crop when compared to the North Central region. This helps to illustrate the difference in production regions.

Table 5.3

North Central Certainty Equivalents in Dollars Per Acre

HRS		Corn		Soybean		Canola	
ARAC	CE	ARAC	CE	ARAC	CE	ARAC	CE
0.0	-15.67	0.0	35.00	0.0	-9.75	0.0	-20.52
0.015	-47.51	0.015	-54.05	0.015	-39.89	0.015	-56.05
0.03	-61.58	0.03	-96.40	0.03	-59.74	0.03	-71.19

Table 5.4

Central Certainty Equivalents in Dollars Per Acre

HRS		Corn		Soybean		Canola	
ARAC	CE	ARAC	CE	ARAC	CE	ARAC	CE
0.0	-45.14	0.0	-7.62	0.0	49.47	0.0	-44.90
0.015	-79.25	0.015	-135.42	0.015	15.72	0.015	-78.47
0.03	-95.51	0.03	-180.19	0.03	-8.58	0.03	-85.58

CHAPTER 6. SUMMARY AND CONCLUSIONS

Problem

Both the malting and brewing industries face the requirement of procuring enough malting quality barley in order to produce a consistent final product. The malting and brewing industry is very specific with quality standards in order to guarantee a consistent final product. There are a variety of characteristics or qualities that have very specific standards which must be met in order for barley to make malting grade.

North Dakota is one of the leading producers of barley in the United States. If a grower does not produce barley that meets malting quality standards, his or her barley is then marketed as livestock feed at a substantially lower price than malting barley.

In recent years, there has been a change in the driving factors in the barley market. In the past, exports and feed usage have been the primary use for barley. In more recent years, the use of barley for feed and exports has declined while use for food and alcohol has remained relatively constant. This has resulted in a shift of the primary driving market factor for barley from feed and export use, to food, alcohol, and industrial use. These factors have resulted in a recent downward trend in barley acres harvested in North Dakota. This is a concerning fact for those involved in the malting and brewing industry.

Farm managers in North Dakota are asking the question "Why should I attempt to grow malting barley when I can grow crops that are far less quality sensitive such as corn, soybeans, HRS, or canola?" In addition to this quality sensitivity, there is not a futures market for barley in the United States like there is with other crops such as corn and soybeans. There are fewer marketing tools available for specialty crops such as barley which can make marketing more difficult than other standard crops that can be hedged using tools such as futures and options.

Objectives

The first objective of this project is to estimate the probability distributions of net return to labor and management for barley, corn, hard red spring wheat, soybean, and canola produced in the primary, North Central, and transitional, Central, production regions of North Dakota. The second objective is to rank these distributions using stochastic efficiency with respect to a function (SERF).

Procedures

This project used Monte Carlo simulation to estimate probability distributions of net return to labor and management for the five crops: barley, hard red spring wheat (HRS), corn, soybeans, and canola for both the primary, North Central, and transitional, Central, production regions of North Dakota. For this project, net return to labor and management is defined as the monetary value a producer receives after gross revenue is adjusted for price received, yield, quality premium and discount adjustments, and cost of production. Cost of production includes variable direct costs such as fertilizer, fuel, seed, etc. as well as fixed direct costs such as machinery and land. After these distributions were estimated, SERF was used to rank the distributions based on a producer's perceived attitude toward risk.

SERF

Stochastic efficiency with respect to a function (SERF) was the analysis tool used to rank the distributions of net return to labor and management for each crop. SERF uses utility efficient alternatives for a range of risk preferences. In order to rank utility efficient alternatives SERF uses certainty equivalents (CE) as a measure of risk aversion over a defined range (Hardaker 2004). SERF can compare and rank multiple alternatives simultaneously in a simple spreadsheet and can be displayed graphically in a manner that is easily understood.

In order to rank alternatives, SERF must assume a utility function and identify a farm manager's attitude towards risk. The utility function used in this project was a negative exponential utility function. Alternatives are ranked based on an farm manager's risk aversion coefficient. A numerical schedule of risk aversion in terms of relative risk aversion coefficient was introduced by Anderson & Dillon (1992). The scaling of this schedule was adjusted in order to properly represent risk aversion in the model for this project for a farmer within the North Central and Central regions of North Dakota. The scale that was introduced by Anderson & Dillon (1992), is representative of a relative risk aversion coefficient (RRAC). A RRAC accounts for a decision maker's wealth. This project used an absolute risk aversion coefficient (ARAC) since the farm manager's wealth in this situation is represented by the mean of the net return to labor and management for each crop. The value invested in the production of each crop is measured in hundreds of dollars and thus the risk aversion scale was divided by 100. The adjusted ARAC schedule can be viewed as follows:

$r_a(w) =$	0.0	Risk Neutral
$r_a(w) =$	0.005	Hardly risk averse at all
$r_a(w) =$	0.01	Somewhat risk neutral
$r_a(w) =$	0.02	Rather risk averse
$r_a(w) =$	0.03	Very risk averse
$r_a(w) =$	0.04	Extremely risk averse

Review of results

Base Case

The base case for the model for each crop within the North Central and Central regions of ND includes the variables for price received, de-trended yield, and crop quality. Direct costs associated with production were incorporated as static values rather than variables. Production costs are a source of variability in crop production but they were not the primary focus of this study. The combination of these variables was used to estimate a probability distribution of net return to labor and management for barley, HRS, corn, soybeans, and canola produced in the Central and North Central regions of North Dakota. SERF was the analysis tool used to rank these distributions by using a negative exponential utility function. Table 6.1 illustrates the results of the SERF analysis for the North Central production region. Table 6.2 illustrates the results of SERF analysis for the Central production region.

According to the results, for a farm manger with a risk a version of 0.015 in the North Central region, the best choice is to grow soybeans, followed by barley. For a farm manager with an ARAC of 0.015 in the Central region, the best choice would also be to grow soybeans followed by barley. This leads us to the conclusion that barley isn't as risky a crop as many farm managers believe. Barley may have the potential to be as equally profitable and less risky than other crops produced in the Central and North Central production regions of North Dakota.

North Central SERF

Table 6.1 summarizes the SERF rankings as they progress through various ARAC values. According to these results, the rankings for a farm manager at the points of risk neutral, slightly risk verse, and very risk averse are illustrated below:

Table 6.1

NC SERF Rank of Each Crop Based on Absolute Risk Aversion Coefficient (ARAC)

Rank	ARAC = 0	Rank	ARAC = 0.015	Rank	ARAC = 0.03
1.	Corn	1.	Barley	1.	Barley
2.	Barley	2.	Soybean	2	Soybean
3.	Soybean	3.	HRS	3.	HRS
4.	HRS	4.	Corn	4.	Canola
5.	Canola	5.	Canola	5.	Corn

A farm manager with an ARAC of 0.0, being risk neutral, would prefer to grow corn over all other crops. A farm manager with an ARAC of 0.03, being very risk averse would prefer growing barley over all other crops. The more risk averse the farm manager becomes the more appealing barley and soybeans become as an alternative crop to produce. Additionally, the more risk averse a farm manager becomes, the less appealing corn, HRS, and canola are.

Central SERF

In Table 6.2 we can see the SERF rankings as they would be for an individual at each points along the ARAC scale in the Central production region of North Dakota. According to these results the rankings for a farm manager that is risk neutral, slightly risk averse, and very risk averse are illustrated below:

Table 6.2

C SERF Rank of Each Crop Based on Absolute Risk Aversion Coefficient (ARAC)

Rank	ARAC = 0	Rank	ARAC = 0.015	Rank	ARAC = 0.03
1.	Soybean	1.	Soybean	1.	Barley
2.	Barley	2.	Barley	2.	Soybean
3.	HRS	3.	Canola	3.	Canola
4.	Canola	4.	HRS	4.	HRS
5.	Corn	5.	Corn	5.	Corn

In the Central production region, soybean is consistently the best alternative crop to produce by a farm manager until they become very risk averse. Barley is very close and is the next best alternative as a decision maker becomes more risk averse. Corn, HRS, and canola are the riskiest alternative crops to produce in the Central region.

When comparing figures 5.1 and 5.2, it can be seen that the return to labor and management curve for corn changes much more drastically and approaches a negative risk profile much more quickly in the Central than in the North Central production region. For example, in the Central region corn is already ranked 5th at the risk aversion level of 0.01 and continues this ranking. In the North Central region, corn changes from a ranking of 2 to 4 when risk aversion changes from 0.01 to 0.015. The risk profiles for barley, HRS, soybeans and canola were generally similar in both regions. The crops grown in the Central production region tended to have a slightly steeper and negative slope overall than that of the North Central region. This makes it appear that production of crops within the Central region is riskier when compared to the North Central region. After being ranked using SERF, the net return to labor and management of barley had a risk profile that was quite different from the other crops evaluated for each production region.

Coefficient of Variation

The coefficients of variation for both regions are illustrated in Table 5.1 and Table 5.2. Overall, the coefficients of variation in the Central production region tended to have a greater value than those in the North Central region. This indicates a greater level of variability in net return to labor and management in the Central region when compared to the North Central region.

Expectations and Outcome

Both malting and brewing companies in the barley industry have been concerned with a downtrend in barley acres in North Dakota. There is a general belief among farm managers that barley is a risky crop to grow due to tight quality specifications for malting grade and limited feed marketability if malting quality is not obtained. Farm managers believe they can grow crops such as corn, soybeans, or canola more profitably than barley without the concerns associated with quality specifications in addition to the limited tools available for marketing.

When research for this project began the hypothesis was "The distribution of net return to labor and management for barley will rank lower than that of corn, soybeans, HRS, and canola due to its greater quality sensitivity and more limited marketability". "Barley will rank higher in the primary North Central production region than in the transitional Central production region".

In addition to this, another hypothesis existed in that soybeans would rank the highest overall, especially among those individuals whose risk aversion fell into a category of higher weight.

The alternative to this hypothesis was that barley would be a crop which is competitive with corn, HRS, soybeans, and canola in both production regions. Further, the risks associated with price and yield variability of growing corn, HRS, soybeans, and canola would outweigh the quality risks associated with growing barley.

Results indicated that the distribution of net return to labor and management for barley ranked relatively highly in comparison to other crops in both regions especially when an individual is more risk averse. It appears that the quality sensitivity of barley is not enough to outweigh the risk involved with yield and price variability associated with other crops. In addition soybeans ranked very highly in both regions and across all levels of risk aversion. Evidence does not support the initial expectation that barley would be a more risky crop to produce, due to its quality sensitivity, than other alternative crops typically grown in the North Central and Central regions of North Dakota. It was expected that soybeans would rank quite highly as an alternative crop among farm managers. This expectation was met.

After reviewing the results and SERF rankings of barley, when compared to other crops, it appears that barley, although more quality sensitive other alternative crops, is not as risky a crop to grow as it is perceived by producers. Barley could potentially be just as profitable as other alternative crops and is less risky than it is perceived by some producers. Soybeans were the most consistently and highly ranked across all levels of risk aversion. Barley was the next most consistent ranking highly among soybeans especially as a farm manager becomes more risk averse. HRS was very consistently ranked in the middle across all levels of risk aversion. Corn was a highly ranking alternative when a farm manager has a low risk aversion, but swiftly becomes a lower ranking alternative when the risk aversion for a farm manager increases. Canola consistently ranks in the bottom tier of the ordered alternatives across all levels of risk aversion.

Implications

Soybeans are the dominant crop when a farm manager has any measure of risk aversion. If a farmer is risk neutral, corn is the dominant category thus implying that the potential gains from growing corn outweigh the potential losses. Farm managers should not be afraid to grow barley especially if he or she is risk averse. Barley is a competitive crop as a farm manager's risk aversion increases despite the common belief that being rejected for malting quality is risky. Based on this research, it appears that the relative variability in price and yield outweigh the risks that are added with obtaining malting quality barley.

Contributions, Limitations, and Further Research

This project contributes to the literature by modeling the comparative risks of growing barley and ranking it as an alternative among other cropping alternatives using SERF analysis. The results were obtained from ranking the estimated distributions of return to labor and management for barley, HRS, corn, soybean, and canola produced in the North Central and Central production regions of North Dakota. The distributions of net return to labor and management for each crop within each region were obtained by using price, yield, and quality as stochastic variables with underlying distributions and deducting static production costs. Each alternative within each region was simulated with 10,000 iterations. The resulting distributions of net return to labor and management were then ranked using SERF. NDSU Extension crop budgets were used as the base for all alternative crops and their cost of production. This allows for ease in use for other alternative crops.

The common perception among farm managers in North Dakota is that barley is a risky crop to produce due to the increased quality concerns that are not associated with other crops. They believe that the risk of not obtaining malting quality is a greater risk than the quality, price, and yield risks associated with producing other crops. The alternative crops used for the comparative risk analysis in this project were barley, corn, HRS, soybeans, and canola. In conclusion, a farm manager in the primary North Central or the transitional Central production regions in North Dakota should consider growing barley especially if he or she is a risk averse individual. The results from this project indicated that the price and yield risk of other cropping alternatives carried much more weight than the quality risks associated with barley production.

There are multiple areas opened for further research based on this study. To begin, this is the first study to introduce barley qualities into the concept of crop production in addition to spot cash prices from individual regional sources in order to produce a distribution of prices and their variabilities rather than using implied volatility.

In this study, barley, HRS, corn, soybeans and canola were compared in the Central and North Central growing regions of North Dakota. This form of research could be done with any quality sensitive crop and any other region. Other crops that could be evaluated are edible beans, non-genetically modified (GMO) soybeans, or sunflowers.

It was difficult to create continuous price data sets for volatility estimation. Since daily spot cash prices were used in this project, there was not even one location possessing a complete data set for all crops. Other methods had to be sought to come up with an estimation of basis, and in turn an estimation of the cash price for the missing data points. Several geographically similar locations were also used in filling these gaps. It would be beneficial to use complete data sets rather than a combination of locations and estimations to fill missing data. This would reduce potential error when capturing price variability.

Another concept that has been controversial during this project is the use of daily spot cash price data. It could be argued that when a farm manager is making the decision to plant crops, it is an annual decision he or she makes based on individual crop rotation plans, market conditions, technology changes, required input costs, livestock feed requirements, and any one of several other factors. So why not use price data that estimates an annual average of volatility rather than a forecast based on daily volatilities? In this project daily spot cash prices were used to estimate the distributions of price variability and volatility. It can be argued that by using daily data, more of the underlying variability in price movement can be captured.

Yield

This study combined both irrigated and dry land yield statistics for both the North Central and Central regions of North Dakota. This leaves a broad spectrum of specific data open for both dry land and irrigated crop production in other regions. Additionally, county average yield data was used to estimate yield distributions. If one could access farm level yield data, distributions could be estimated on a more accurate level.

Quality

One area this project vastly opens up in quality research. Quality data was obtained where it was available, but many aspects of this project relied on expert sources to develop triangular distributions for quality characteristics of certain crops. There were not enough responses to barley crop quality surveys in order to create a viable data set. In addition, data for moisture and test weight in crops such as corn and soybeans in kept private between the buyer and seller. Developing more complete data sets would aid in better estimating the distributions of each individual quality characteristic for each crop in each region. Possible data sources would be USDA RMA data, or directly from private elevator sources.

Contracting

Contracting is a risk management tool heavily used by farm managers for all crops. In this project a contract clause was used for barley only. The price data was obtained directly from private data obtained from Anheuser Busch. This type of data was not obtained for the other crops being analyzed. An improvement to this model would be to add a contracting clause to all crops being evaluated.

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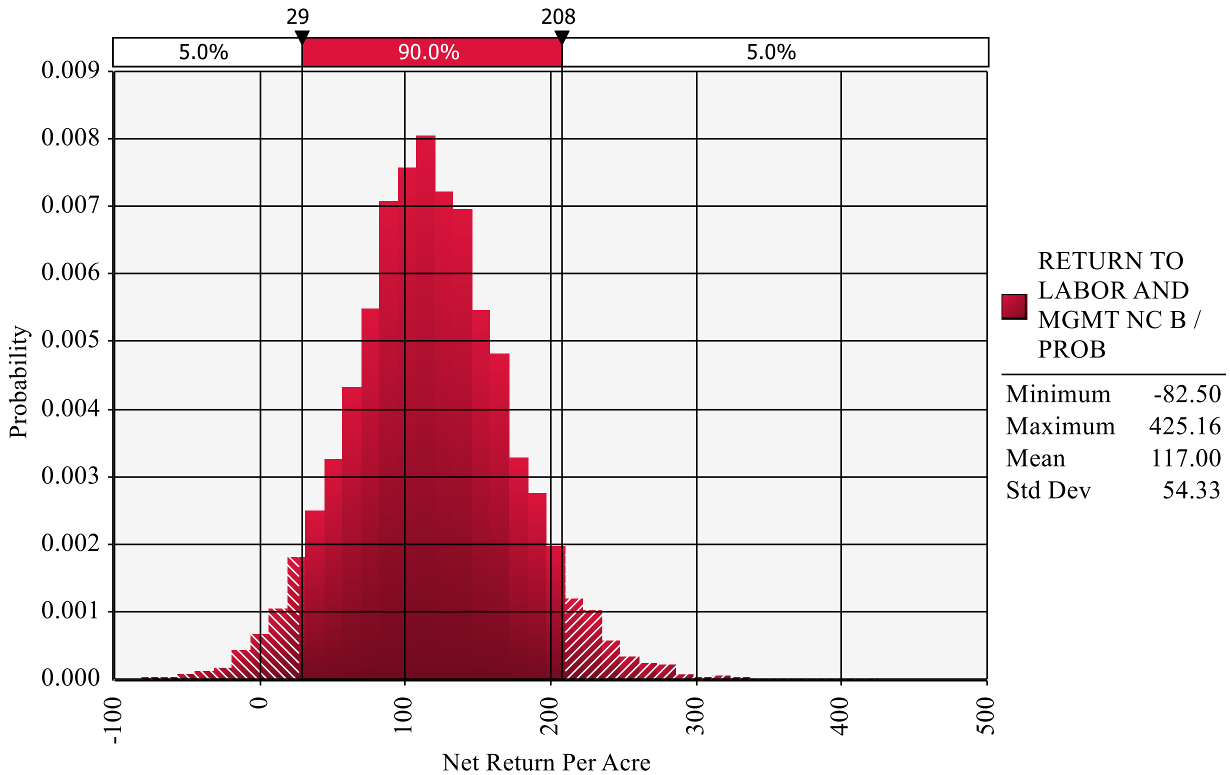
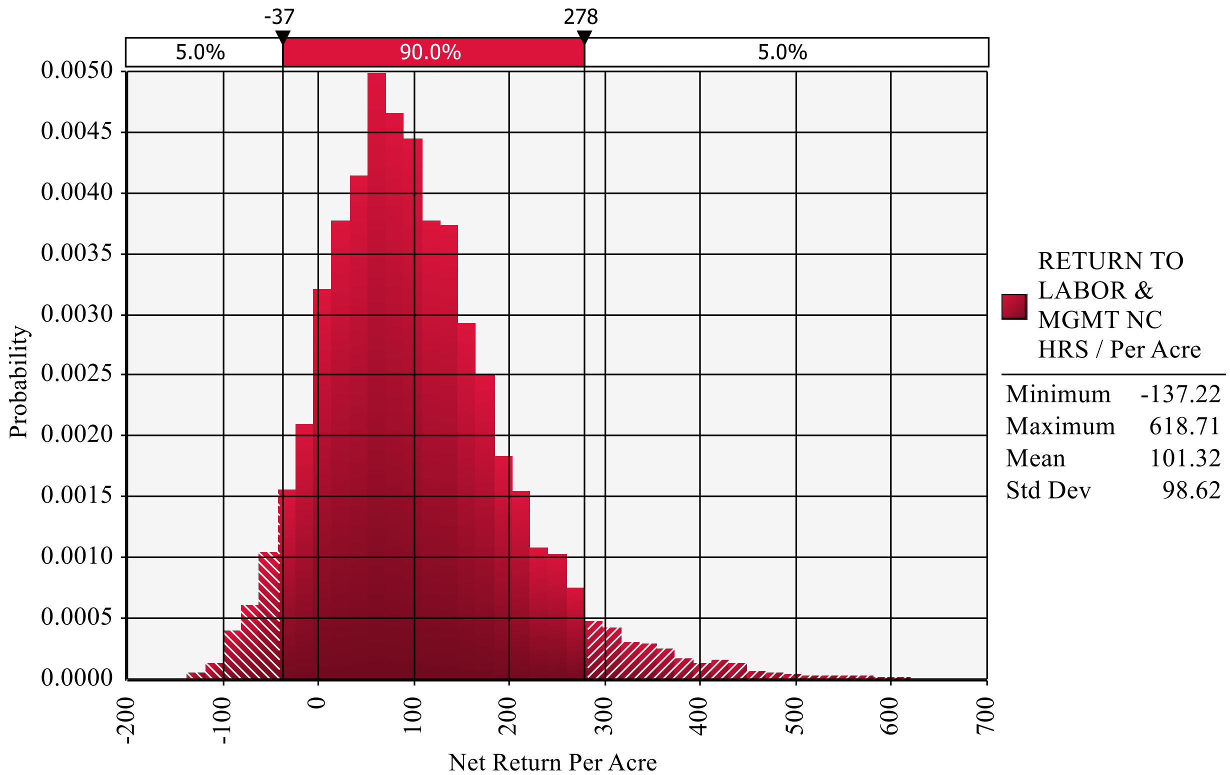
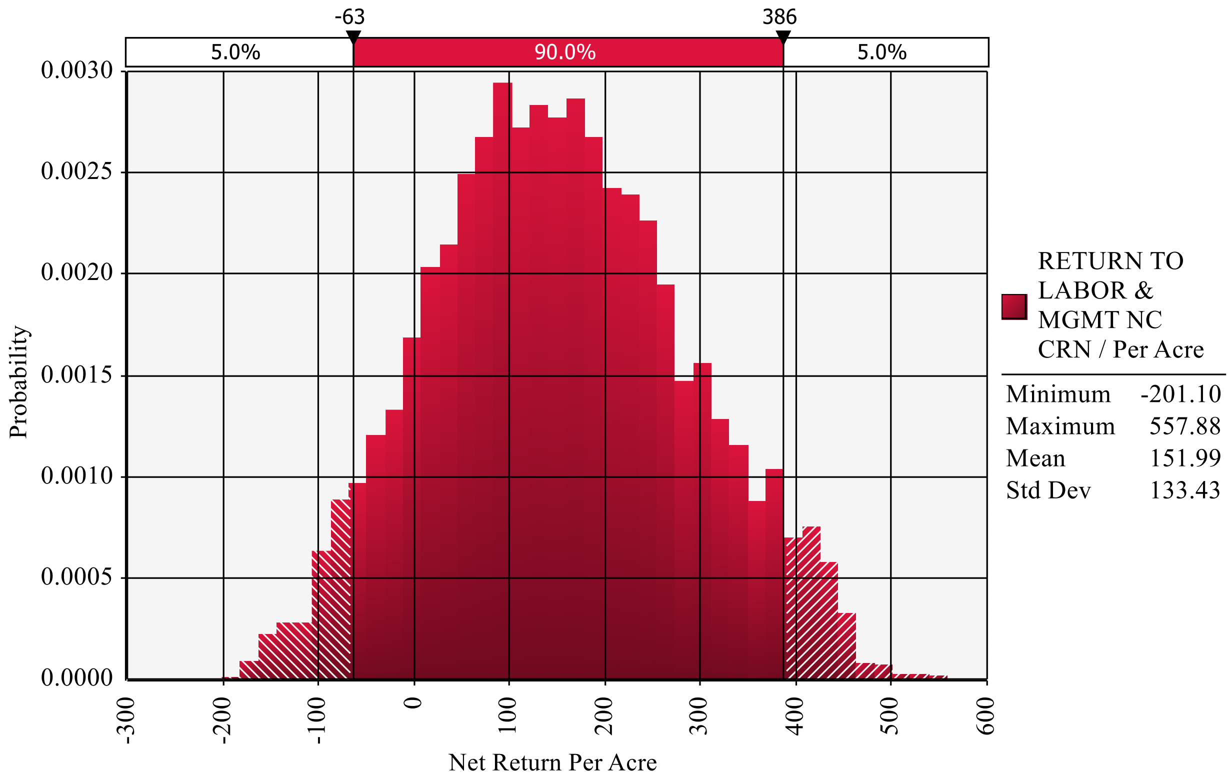
APPENDIX A. NORTH CENTRAL BARLEY



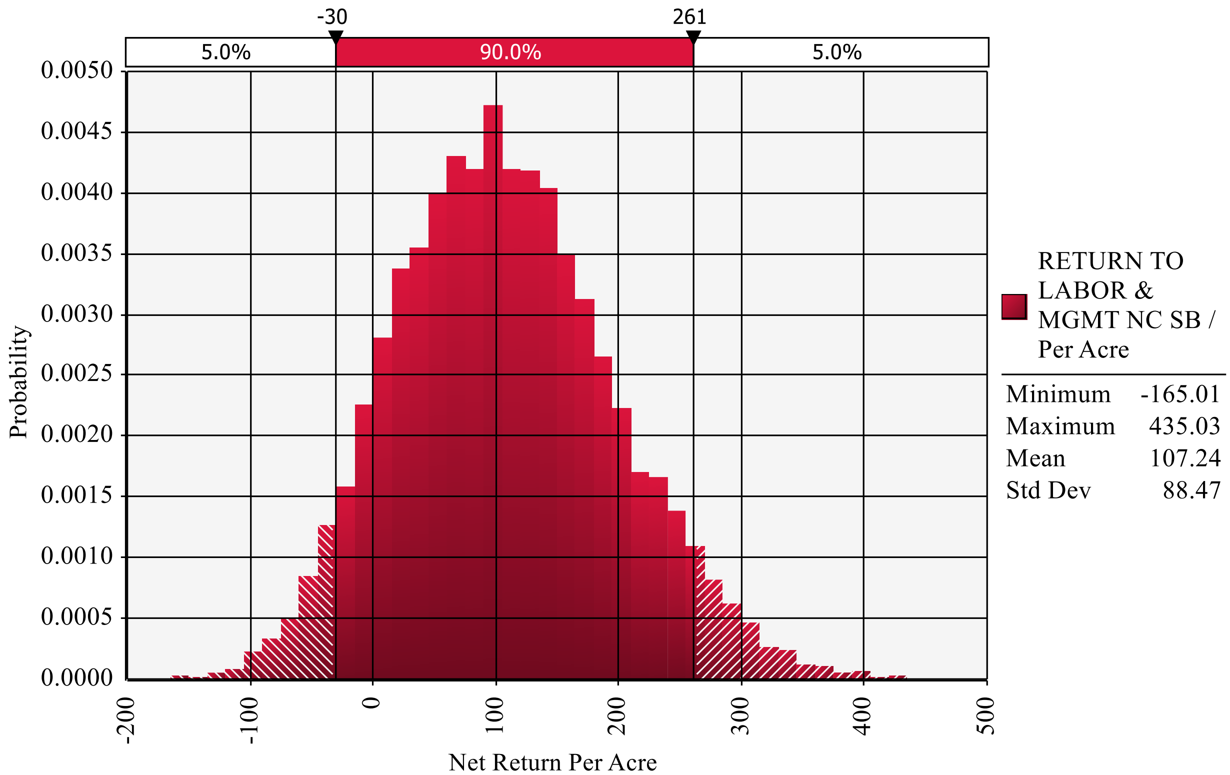
APPENDIX B. NORTH CENTRAL HARD RED SPRING WHEAT



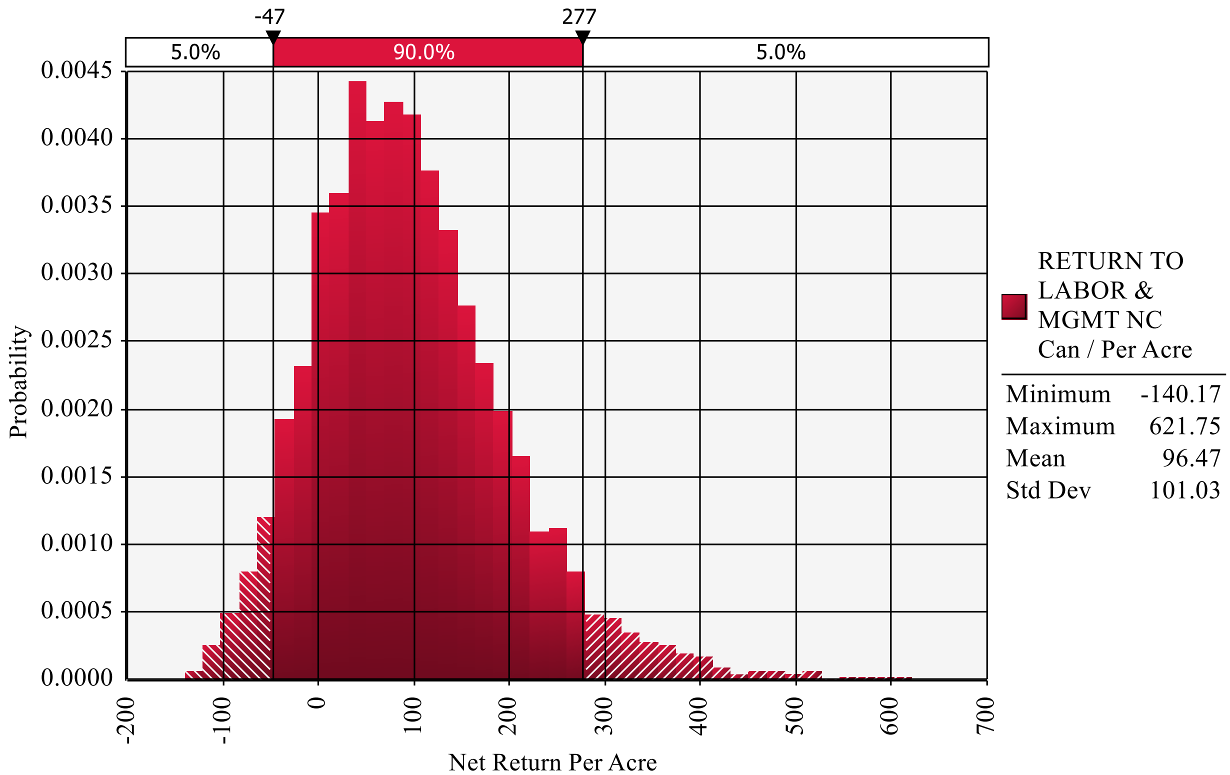
APPENDIX C. NORTH CENTRAL CORN



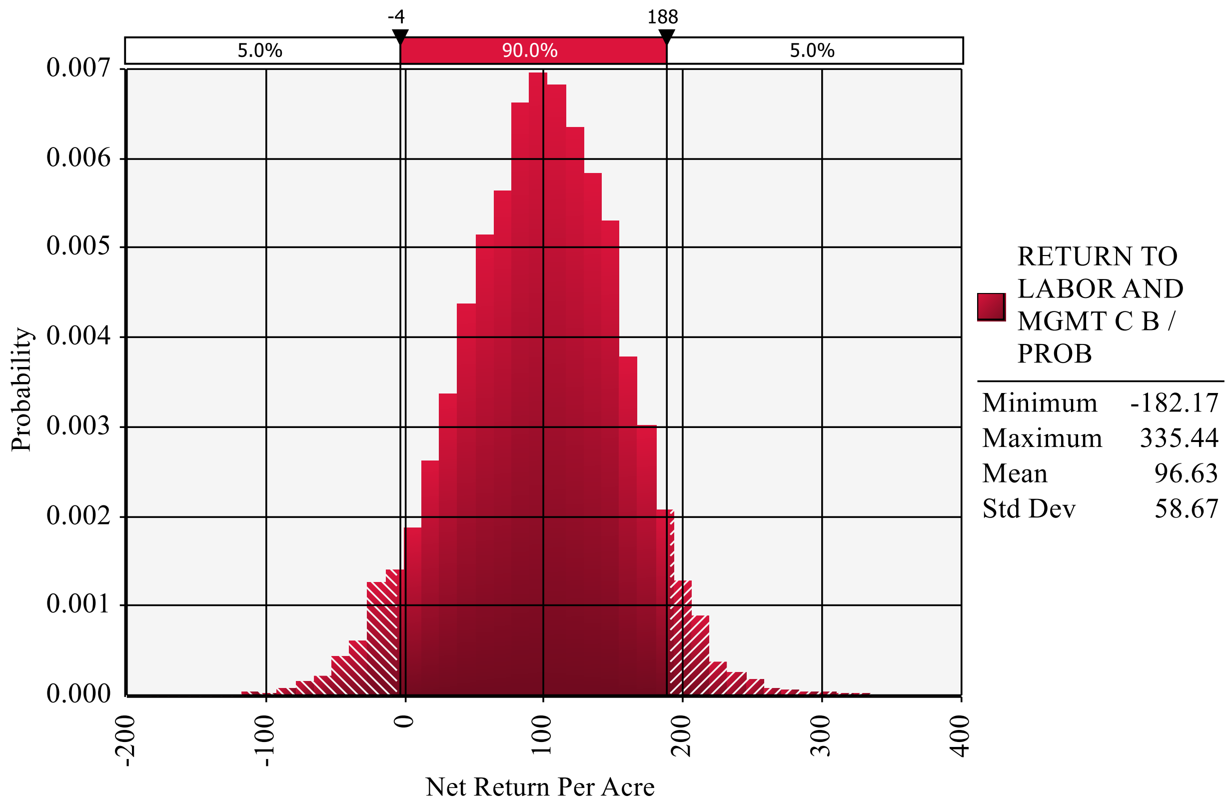
APPENDIX D. NORTH CENTRAL SOYBEAN



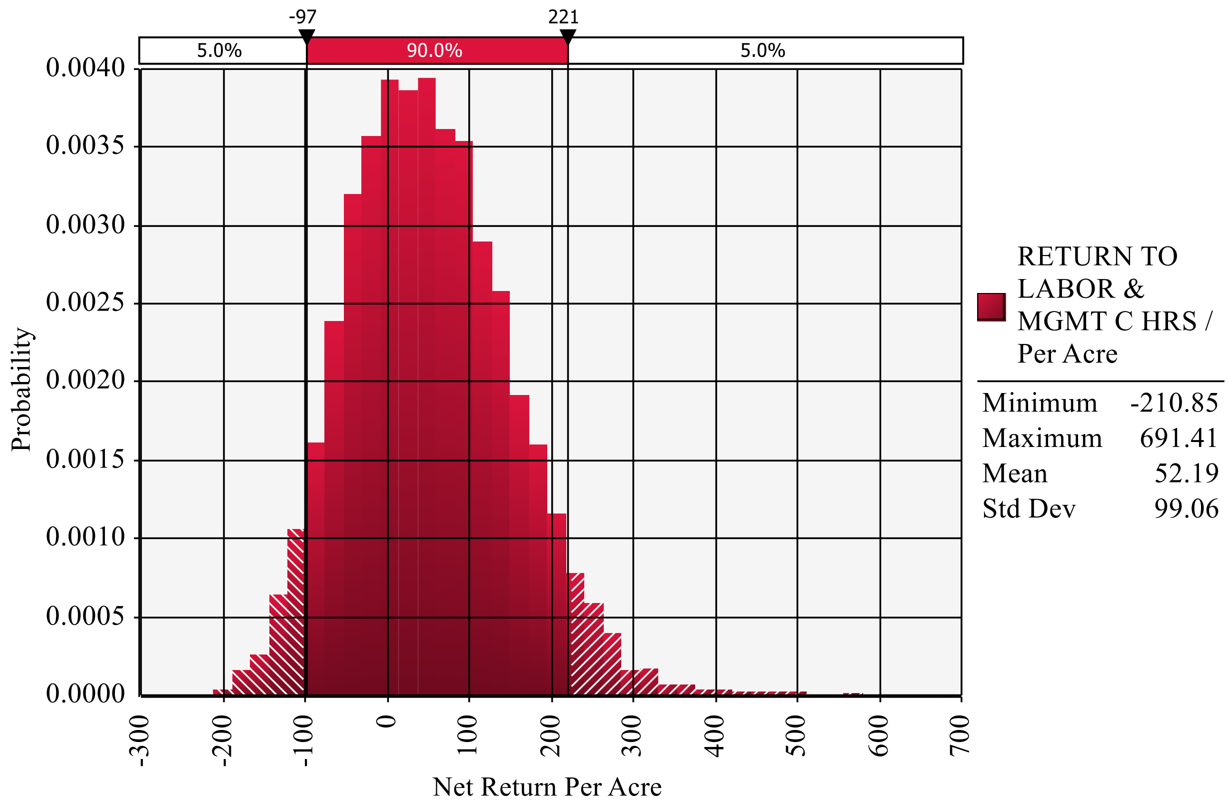
APPENDIX E. NORTH CENTRAL CANOLA



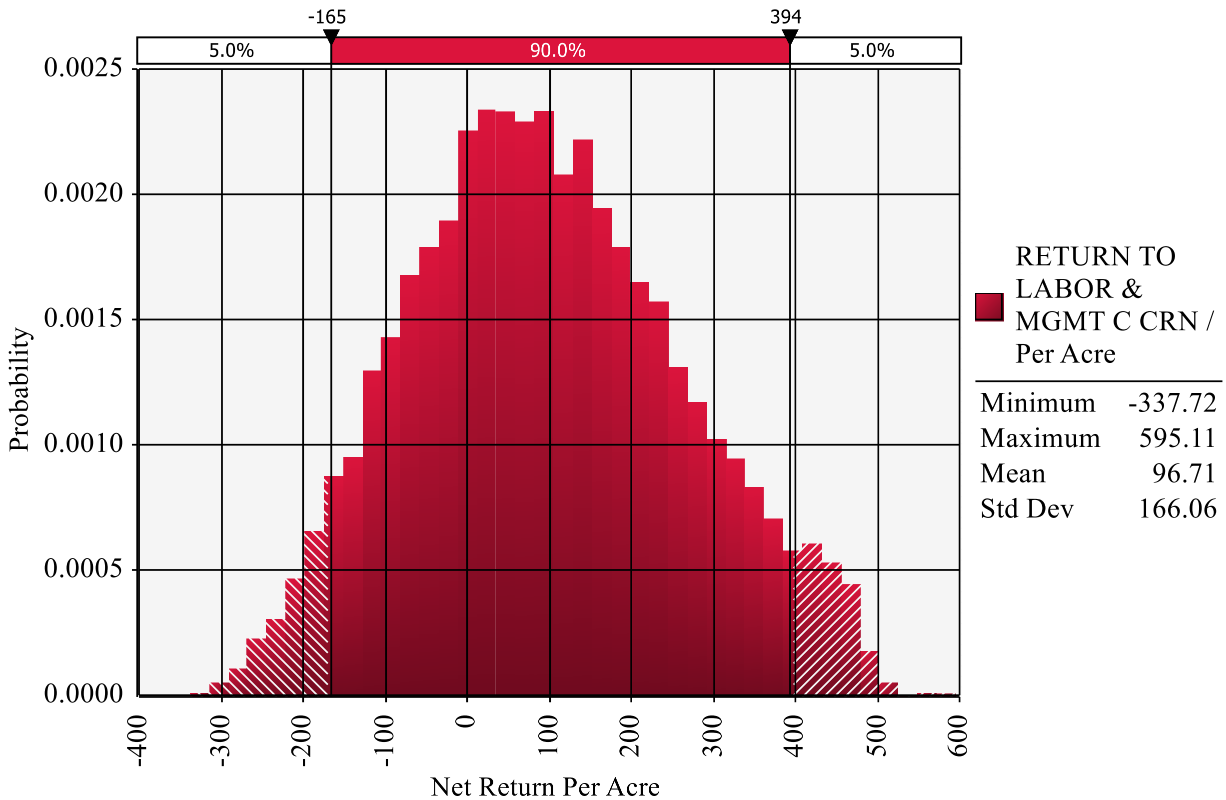
APPENDIX F. CENTRAL BARLEY



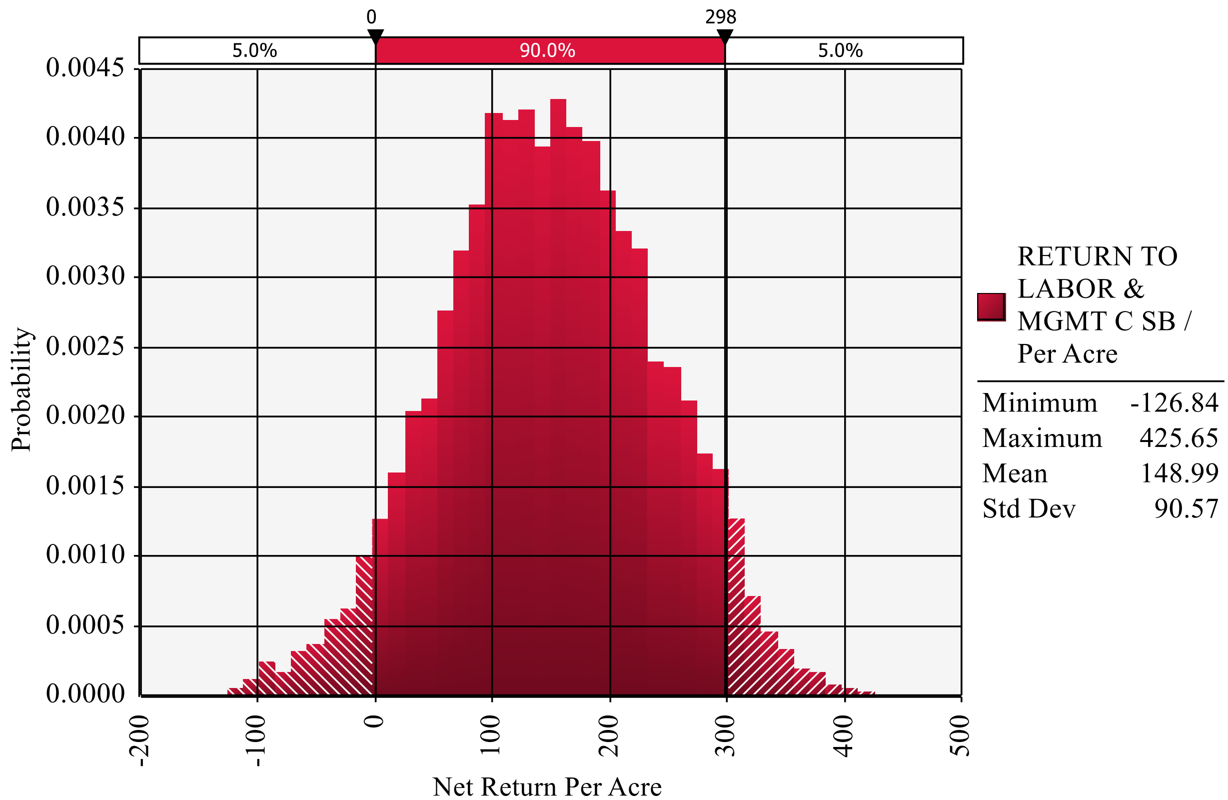
APPENDIX G. CENTRAL HARD RED SPRING WHEAT



APPENDIX H. CENTRAL CORN



APPENDIX I. CENTRAL SOYBEAN



APPENDIX J. CENTRAL CANOLA