APPLYING SERF ANALYSIS TO RANK PROCUREMENT STRATEGIES FOR A NORTH DAKOTA GREEN FIELD PEA PROCESSOR

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Bryant Robert Sanderson

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By

Bryant Robert Sanderson

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SUPERVISORY COMMITTEE:

Dr. Frayne Olson
Chair

Dr. Ryan Larsen

Dr. Kevin McPhee

Approved:

10/31/2014
Date

Dr. William Nganje
Department Chair

ABSTRACT

There are many crops grown in North Dakota, but only a few have a futures market for prices and are grown readily throughout the country. The specialty crops in North Dakota display many of the same characteristics such as a lack of a futures market, high standards for grain quality, and concentrated production areas. These characteristics create unique procurement risks for specialty crop processors. This project ranks procurement strategies for a green field pea processor located in North Dakota using stochastic efficiency with respect to a function (SERF) analysis. Through SERF analysis, it was found that geographic diversification and forward contracting are useful tactics to include in a green field pea processors procurement strategies. The methodology and model can be applied to other specialty crops in North Dakota that display similar risk characteristics seen in green field peas such as lentils, dry edible beans, and malt barley.

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CHAPTER 1: INTRODUCTION

Introduction

According to the United States Department of Agriculture from the Specialty Crop Competiveness Act of 2004 and the Food, Conservation, and Energy Act of 2008, specialty crops are defined as fruits and vegetables, tree nuts, dried fruits, and horticulture and nursery crops. Eligible plants must be intensively cultivated and used by people for food, medicinal purposes, and/or aesthetic gratification to be considered a specialty crop. Also, processed products shall constitute greater than 50% of the specialty crop by weight, exclusive of added water. There is a range of crops that are not classified as specialty crops in the United States. These crops include corn, soybeans, spring wheat, winter wheat, and rice. The state of North Dakota grows a total of 29 different crops that are recognized by USDA's National Agricultural Statistics Service (NASS) agriculture overview of North Dakota for 2013. Of the 29 different crops grown in North Dakota, only six, corn, soybeans, winter wheat, spring wheat, canola, and oats, have futures markets and are readily grown in North Dakota.

Specialty crops have certain characteristics that make them more risky to produce and process. Most specialty crops require atypical equipment to produce and harvest the crop. Conversely, almost all of the same equipment can be used to produce corn, soybeans, spring wheat, and winter wheat. Another specialty crop characteristic is the small areas of land where the crop can flourish. These small areas make it hard for processors to buy specialty crops due to the chance of having their entire buying area damaged. Along with small production areas, most specialty crops have high quality standards that make it difficult for farmers and processors to consistently meet the highest grades. Corn, soybeans, spring wheat, and winter wheat have more relaxed quality standards making them less risky to produce. Also, corn, soybeans, oats, canola, spring wheat, and winter wheat have futures markets to derive a price but specialty crops have no futures markets that can be used to assist price discovery or price risk transfer. North Dakota is unique in that is has many specialty crops with characteristics that make them riskier to produce when compared to the major crops.

This paper will use dry edible green field peas as the focused specialty crop but the methods can be applied to other specialty crops in North Dakota such as dry edible beans, malting barley, and potatoes since they demonstrate many of the same characteristics as green peas. Green peas are a cool season legume crop and are marketed as a dry, shelled product for either human or animal consumption (McKay, Schatz, and Endres, 2003). Green field peas are not the green peas that are marketed as a fresh or canned vegetable that are most commonly known. Instead, green field peas are mostly used in human cereal grain diets. They were primarily grown in Washington and Idaho but the upper Midwest started growing green peas in the 1990's with North Dakota and Montana producing the largest amount for the U.S. in recent years. In some instances, depending on the area, green peas have similar or higher yields when compared to spring wheat. They do well in cool, semi-arid climates but do not perform well when the growing season has been wet. When producing green peas, the main focus for growers and processors is producing high quality peas in order to receive premiums and avoid the substantial quality discounts that exist.

Problem Statement

This project will address the problem of procuring a predetermined amount of green peas by examining yield variability, quality characteristics, and price risk while taking into account transportation costs using stochastic efficiency with respect to a function (SERF) analysis to compare alternative purchasing strategies. The processor will be of medium to large size, operating under capacity or in other words searching for more peas to process.

A processor buying crops directly from farmers is a difficult task. It is especially difficult when buying specialty crops such as durum wheat, dry edible beans, malting barley, field peas, and others. North Dakota has a variety of crops that can be grown in the state with California as the only other state that grows such a large number of diverse crops. Specialty crops have small pockets of land where the weather and soil conditions are ideal for the crop to be grown making it difficult for processors to meet their demand due to the risk of disease and weather loss.

Green peas in North Dakota are no different. There are pockets of green peas grown in the northwestern, north central, and southwestern part of the state. Also, there are areas in Idaho, Montana, South Dakota, Nebraska, Washington and Canada that grow field peas. These areas of production are miniscule when compared to the areas of production for spring wheat, winter wheat, soybeans, and corn. These small areas of production are concerning for processors as a storm, disease, or any other cause has the ability to wipe out the entire green pea crop in that area. The processor needs to have ample supplies for their buyer's demands or risk having no inventory forcing the processor to buy from other processors or grain elevators where prices will be much higher. To avoid no supply and high prices, processors can buy from different locations that have uncorrelated yields along with their current buying region. In most cases, buying from different locations reduces yield variability but increases transportation costs. In order to diversify their risk, the processor needs to determine the type of procurement strategy that is best for their situation. This project analyzes this problem given that quality risk, yield variability, and price risk exist.

Quality Risk

Quality standards are an important factor for crops, particularly specialty crops. Specialty crops are used for human and animal consumption so the quality of the crop needs to be high in order to meet not only the USDA's safety standards but the buyer's preferences as well. Corn, soybeans, spring wheat, and winter wheat have basic quality standards as they are either being crushed, processed or sold as animal feed so quality is not as critical in most instances. However, soybeans, spring wheat, and winter wheat can also be used for human consumption, in which case the quality standards are stricter. Green peas, however, have high quality standards that make them suitable for human consumption, pet food, and other animal feed purposes where quality is important.

The high quality standards are another reason why it is riskier for farmers and processors to work with field peas. Farmers need to maintain strict growing practices to produce high quality peas but weather is a factor that cannot be controlled adding to the riskiness of producing green peas. Also, once farmers have their crop ready for harvest, slowing their equipment and augers speeds to avoid splitting is important. For example, processors prefer farmers use a belt conveyor instead of the traditional screw augers so the green peas will not split or get damaged. Like farmers, processors need specialized equipment and processes to maintain high quality.

The main quality factor for a processor of green peas is the color. A deep green pea indicates good health and taste that end consumers want. If the green pea is faded, bleached, earthed, or damaged, quality discounts will be implemented due to the buyer's and consumers considering them less desirable. Size is not as important in green peas as it may be in other crops but could develop into a more significant grade factor in the future as green peas are becoming an increasingly popular ingredient of human consumption. Larger seeds have larger endosperms meaning more starch content with energy contents that aid in metabolism. In addition, as green peas are being used more and more for human consumption, protein levels are becoming a more prevalent grading factor. Inbound green peas from the farmer to the processor are graded according the USDA's grades for number 1, 2, and 3 with premiums or discounts for color. However, outbound green peas from processor to buyer have varying quality standards that are typically not based on the USDA's grading standards. Instead buyers have their own quality preferences. The buyers have different quality standards as they supply markets that have more refined tastes and preferences than the USDA's grades.

Quality green peas can be hard for processors to obtain at harvest. An option for the processor to engage in is pre-plant and forward contracts in order to guarantee they will have a portion of their needs already under contract as well as ensuring that enough acres are planted. This forward contracting is difficult due to processors not knowing the quality they are buying. Therefore, depending on the quality of the crop, the processor will need to buy their remaining needs in forward contracts right before harvest when quality is better known or on the spot market after harvest to meet their buyer's demand in terms of quantity and quality. It is important for the processor to buy from different areas with knowledge of what the average yield and qualities are in each region so they will have the high quality green peas that are demanded by their buyers and the end customer. It is easy to say the processor should buy most of their inventory from the area that yields the highest quality but transportation costs and competing crops reject that generalization along with the possibility of a crop shortage. Buying in new areas also brings in the significant issue of buying from new farmers with limited knowledge of dependability in terms of delivering on time.

Price Risk

Specialty crops do not have future markets to derive prices and hedge risk. Every processor is deriving their price based on their expectations and what their buyers are bidding. The lack of a futures market makes it much more risky to buy and sell specialty crops as risk cannot be hedged. The farmers and processors cannot buy or sell opposite their cash position without cross-hedging. Cross-hedging is either buying or selling the opposite amount of a cash position in the futures market with a different crop that is highly correlated to the specialty crop. Green and yellow peas have had strong and weak relationships with corn providing some risk reduction through cross-hedging but the relationships will also need continuous monitoring (Flaskerud, 2006). However, while cross-hedging is possible in green peas, it is not common. Green pea price risk can be mitigated but an understanding of the relationship and constant analysis are required in order to avoid losses.

To avoid the risk of not having green peas and to avoid some price risk, processors can forward contract with farmers and elevators. Forward contracting is contracting a specified amount with a price agreed upon by both parties for delivery set at a future date. In forward contracts, processors are protected from quality risk by implementing discounts for low quality. With the overall quality of the crop unknown, they are unsure of the value for the various qualities when they are harvested. However, forward contracting can be used to guarantee planted acres. Some of the farmers that processors buy from will not grow green peas unless they are contracted because of the incentives available from other crops. Based on in-person interviews with those in the industry, taking a large short or long position and exposing the processor to price risk is not common in the field pea industry. Rather back to back sales are the most common so the processor can avoid price fluctuations and reducing their price risk.

The forward contract price is based on what the processor believes the value of the green peas to be and what they will be able to get for them from their buyers. Pricing on the spot market after harvest is much less risky due to the processor knowing the quality and what the buyers are demanding. However, the processor may need to buy more from the spot market if the amount of high quality green peas from their forward contracting did not meet expectations. The seller of the high quality green peas, whether it is a farmer, grain elevator, or another processor, can recognize the processor is short in the cash market and will be able to command a higher price than normal.

There are other important aspects that affect the price that will be captured using risk simulation and included in the SERF analysis. One is the processor may need to price differently for different growing regions they buy from for both spot purchases and forward contracts. Processors may need to bid higher in areas that are further away from their location to entice the farmers to plant the green peas and deliver to the processors location due to transportation costs and competition for acres from competing crops. Determining price differences based solely on transportation costs can be a fairly easy way to determine the price, but may not result in sufficient purchases. Determining what price to bid can be challenging due to the processor wanting farmers to plant the green peas but not wanting to pay so much that they lose money. Finding a balance is often determined through trial and error from experienced buyers and market analysis. Buying commodity crops is fairly standardized but there is no step by step instructional in determining the balance between risk and returns for specialty crops. Another price affecting aspect is bidding a price that is competitive with alternative crops. The processor has to know what other crops are being grown in the region they are buying from. For example, in northwest North Dakota there are few competing crops with green peas so the processor can bid lower compared to the bid in the central part of the state where soybeans are more commonly grown. Soybeans and other competing crops continue to expand in North Dakota due to varieties that are becoming more suitable for North Dakota. The expansion of competing crops not only affects peas, it also affects most specialty crops grown in North Dakota as they are easier and less risky to grow due to futures markets as well as lower quality issues.

Yield Variability

Yield variability is another reason for the in-depth analysis of a green pea processor in North Dakota. Yields for green peas vary from region to region across North Dakota and Montana with little to no correlation across regions. Besides the buying regions of pulse crops in the United States and Canada, pulse crops are also grown in Australia, Turkey, India, Asia, South America, and France. The analysis will only focus on two growing regions however, the north central (NC) and southwestern (SW) regions of North Dakota. The counties representing the north central region include: Bottineau, Burke, McHenry, McLean, Mountrail, Renville, and Ward. The counties representing the southwestern region include: Adams, Bowman, Grant, Golden Valley, Hettinger, Morton, Slope, and Stark. These two regions have yields and product qualities that are uncorrelated, meaning it is very seldom they both have good years and bad years at the same time. The yield correlations were tested using yield data derived from National Agricultural Statistics Service (NASS) as well as test plot yield data from Minot, ND and Hettinger, ND locations while the quality correlations were relied upon by industry sources. The NC growing region has a higher yield average based on industry and public information with a good supply of green peas that can support a processor as well as the market potential to buy from eastern Montana and southern Canada if the supply was short. The SW growing region has a lower yield average but the crop qualities are higher on average. However, the amount of green peas grown in this region is not enough to support a large processor with no other growing areas that are close enough to make it viable but there is potential in the future if the famer focus would shift more to expanding pea acreage.

Having multiple buying areas is theoretically good for the pea processor as it gives them the ability to reduce their production risk. The processor can ensure itself having sufficient inventory at harvest thereby reducing its production risk. The probability of both uncorrelated regions having very poor yields that drastically affects the processor and its bottom line is very low. However, this circumstance has happened before when in 2011 the pea production across North Dakota was extremely low due to a very wet spring where millions of acres did not get planted. On the contrary, Montana lost some acreage but not to the extent of North Dakota's. In 2011, a processor may have avoided large losses by having a different area to purchase from that included Montana. The yield variability and the different expansion options that give the processor new regions to buy from will be evaluated to compare alternative strategies.

Objectives

The primary objective of this project is to develop a model that ranks various procurement strategies using SERF analysis for a green pea processor operating under capacity facing risks and uncertainties. The risks and uncertainties of being a green pea processor involve prices, yield variability, transportation, and product quality. With these complexities, the processor needs to determine the best strategy to protect itself and ensure a stable future. This project will focus on four alternative procurement strategies available to the processor. The first strategy is the processor buying from their surrounding area in the NC region from the spot market only. A second strategy is buying from the current NC region and the new SW region all on the spot market. The third strategy is forward contracting a specified quantity in the NC region and buying the remaining needed peas on the spot market in both regions. Finally, forward contracting a specified quantity in both regions and buying the remainder on the spot market from both regions.

Diversifying into a new region and growing the company's foothold in the industry is an important element of the pulse industry. Diversifying is a strategy that needs to be analyzed in order for the processor to take advantage of any growth opportunities available. In the case of a green pea processor, there are obstructions to diversifying. There needs to be a strong resolve by farmers in the region to grow green peas so there is adequate and stable supply in order for the processor to buy from the region. This is a concern for green peas because it is a specialty crop with competing crops that are easier to grow, especially in North Dakota.

For this project, the processor has the option to contract in different regions with uncorrelated yields in order to reduce yield variability and quality variability. The option to contract in a new region also gives the processor the ability to be more precise in the quality specifications for the peas it is able to buy. Determining if diversifying is a good strategy and comparing diversification strategies are two of the main objectives in the analysis.

Forward contracting reduces the variability in prices by locking in a fixed price for delivery in the future making it a useful tool to procure grain. However, based on in-person interviews with buyers from JM Grain Inc and United Pulse Trading Inc, forward contracting is not very common. One objective of this project is to determine the effect forward contracting has on the ranking of the four procurement strategies. Also, another objective is to determine the impact alternative levels of forward contracting have for the processor's risk exposure and how the price levels of the forward contracts impacts the ranking of the strategies.

An important aspect in procuring any type of grain is the market share of the company in the buying region. The amount the processor can buy in any given year greatly affects their buying strategy due to the ability to consistently meet their customer needs and the ability to be selective in the quality they buy. Therefore, analyzing the effect market share has on the procurement strategies is an important objective for this project.

A very important objective of the project is to develop a methodology and model that can be modified to represent the unique situation for a specific company. The model is also easily adaptable to fit many of the other specialty crops grown in North Dakota that experience similar difficulties like those in the green pea industry.

Procedures

Stochastic simulation is used to represent the key variables for the model with various types of distributions. The distributions of the variables are then used to generate a distribution of outcomes for each procurement strategy. The distribution of outcomes for each procurement strategy are inserted into Simetar© where SERF analysis can then be used to rank the alternative strategies.

SERF is used to rank the procurement strategies for the processor while taking into account price risk, yield variability, quality risk, and transportation issues. There are four strategies for the processor that are modeled to derive the project discounted after tax net income for fiscal years 2014-2018. This methodology allows the processor to rank the alternative expansion and contract strategies to take advantage of the market opportunities in an easy to interpret manner.

Organization

Chapter two provides a review of past literature, while Chapter three discusses the methodology used to compare alternative strategies. Chapter four covers the empirical model that will be used with a description of the data sources. Chapter five will present the results from the model followed by the Chapter six that provides a summary and conclusion of the results and processes used with a discussion of areas for further research.

CHAPTER 2: LITERATURE REVIEW

Literature Review Background

Chapter 2 reviews literature that is associated with price risk for specialty crops, product quality risk, supply optimization, and stochastic efficiency analysis. The literature review explains the significant price risk facing specialty crop processors along with the quality risk they have to manage. Also, supply optimization through decision analysis literature is reviewed, displaying the need for correct analysis of yield variability by the processor. SERF is the methodology used to rank procurement strategies for the assumed scenarios. However, it is important to note there are a limited number of articles about specialty crops and almost none provide details regarding specialty crop processors.

Price Risk

Specialty crop production is commonly found in areas not suitable for the larger commodities. Pulse crop production increased in Saskatchewan, Canada between 1987 and 1998 due mostly to the higher yields harvested with higher profits compared to the cereal crops that had previously been grown on land that is more suitable to pulse crops due to the drier, less humid soil (Popp and Rudstrom, 2000). There are locations in North Dakota with soil types and weather patterns that are only well suited for a few crops, with many of them being specialty crops.

Specialty crops have several factors that add to the difficulty of producing an agricultural good. Input costs are higher due to factors such as increased labor intensity, storage issues stemming from segregation and identity preservation requirements, and specific or additional input requirements and field operations (Fulton, Pritchett, and Pederson, 2003). Contract terms need to reflect the additional costs and risks associated with the production of specialty crops to induce farmers to include them in their cropping plans. Specialty crops also do not have a futures market to help derive price and transfer risk. Risk management options for specialty grains are imperfect as crop insurance and futures and options markets are generally only available for larger acreage crops (Paulson and Babcock, 2007). Because of the absence of a futures market, processors have to rely on production contracts for one of their main marketing mechanism. This uniqueness of specialty crops means additional risks for both buyers and sellers.

Buyers and sellers have troubles in pricing green peas with prices being based on the current supply and demand, which is difficult to predict. For example, when weather patterns faced by an individual are similar to the area weather patterns; good yields are associated with poor prices (Weisensel and Schoney, 1989). The difficulty is predicting the yield output of the specialty crop with yields being largely based on weather. To avoid the variability of prices that are based on the yield variability, buyers and sellers engage in forward contracts.

A forward contract is where the buyer and seller agree to exchange a specified amount of a commodity at a certain date in the future with the price of the commodity agreed upon at the time of signing. This strategy reduces the risk for both the buyer and seller. The seller can lock in a price on a portion of their production based on their average input costs and other costs associated with producing the commodity. The forward contract does eliminate the downside risk in prices; however, it also excludes the buyer from receiving extremely high prices in times of price spikes (Carriquiry and Babcock, 2002).On the other hand, the company offering the forward contract will make money with the cheaper forward contract price compared to a spot price that may be higher. Also, the buyer gets a guaranteed amount of the commodity, ensuring them inventory at harvest making forward contracts key to a processors business strategy.

Wilson and Dahl (2009) provide analysis on the different contracts used in the upper Midwest for specialty crops and the different clauses that help both buyer and seller mitigate price risk. Wilson and Dahl (2008) analyzed the cost and risk of different procurement strategies to improve quality consistency in wheat. Their results illustrate that it is best for wheat suppliers and end-users to utilize contract requirements to improve quality consistency. Wilson and Dahl (2010) examined the contract structure in the canola industry in North Dakota and found forward contracting to be the preference and most profitable strategy across the state.

Wilson and Dahl (2011) examined the durum industry in North Dakota and found the overwhelming solution to price risk was forward contracting compared to not contracting. The durum and malt barley industries do not have futures contracts, making them comparable to green peas in that regard. Fumasi (2005) developed a model with stochastic variables to determine if contract pricing or cash market pricing were better for lettuce farmers in the Salinas Valley of California. The lettuce industry has similar characteristics to the green pea industry in North Dakota in that they are both grown in concentrated production areas with no futures market and are used for human food. The results from Fumasi (2005) along with the articles from Wilson and Dahl indicate that it is best for the farmers to partake in forward contracts to lower their price risk while examining their costs and profitability in the future. However, forward contracts do not completely eliminate all of the price risk for buyers and sellers. Instead, it is a strategy that mitigates some risk in an industry where there are very few options.

Yield Variability and Quality Risk

Specialty crops are often grown in small concentrated areas across North America. The small production areas yield differently making it important for buyers to understand the locations they buy from. Buyers need to understand where to buy, how much to buy, and who to buy from. Buying strategies have been researched and analyzed in many industries including agriculture.

Single supply sourcing and multiple supply sourcing have been studied quite extensively in other industries outside agriculture. Such as Larson's and Kulchitsky's (1998) work in analyzing the benefits of single sourcing and certification to buyers. It was determined beneficial for buyers to have a single, certified source, because it provides buyers with lower total costs and higher quality products. However, Larson and Kulchitsky (1998) did not examine the risk associated with having only one supplier. Hale and Moberg (2005) state the most important lesson from the past occurrences of terrorist attacks, dock strikes, regional blackouts, and natural disasters may be that firms fully realize the need to develop effective emergency response strategies within their supply chains to react and recover from inevitable supply chain disruptions. Although specialty crops in North Dakota do not face exactly the same risks as described by Hale and Moberg (2005), the idea of protecting a company's supply to meet demand is similar.

Decision analysis studies provide key details into determining the optimal number of suppliers in a given market. Berger, Gerstenfeld, and Zeng (2004) used a decision tree to show the general payoffs of having one supplier, two suppliers, and *n* suppliers. They also developed models to determine the optimal number of suppliers given the probability the entire product flow in the supply chain is disrupted, a disaster loss, and the probability of one single supplier's quantity supplied being down. The consensus from these supply sourcing articles was for buyers to purchase from different suppliers or locations in order to spread the risk of supply disruptions. Buyers of grain not only have to look at yield variability but have to examine the product qualities from different areas.

Consumers demanding high quality food have made government food safety regulation more prominent. The benefits of food safety regulation are reductions in illnesses and death caused by contamination from the food. New technologies, scientific discoveries, information about linkages between diet and health, and the mass communication of this knowledge to consumers lead to increased demand for higher quality foods (Caswell and Mojduszka, 1996; Caswell, 1998; van Ravensway, 1995; Valeeva, Meuwissen, and Huirne, 2004). This demand for high quality foods consists of specialty crops grown in the United States including green peas in North Dakota. Product quality is a major factor in buyer-seller contracts and merchandising. Product quality is so widely regulated due in part to the high variability in qualities as well as the possible harmful effects on animals and humans. Theoretically, an individual's demand for risky food depends of income, prices, the objective risk associated with the food, the perceived risk of the food, the likelihood that an individual will be exposed to the risk, and the individual's susceptibility to the risk (Antle, 1999). In developed countries, this demand for risky food is not high. Consumers are searching for food that has traceability with high quality and are willing to pay higher prices for it.

The Northern Pulse Growers Association has funded a pulse quality survey for 2011 and 2012. The survey discusses the importance of the different end use quality attributes for green and yellow field peas, lentils, and chickpeas. Among the quality attributes, moisture is tested to determine milling quality. Protein and total starch are also tested to indicate nutritional quality. The amount of ash is tested to indicate the total mineral content. Water absorption and unsoaked seed percentages are tested to determine cooking quality and canning characteristics. The test weight is determined so the sample density, size, and shape are known. Also, the starch properties are tested to indicate the texture, firmness, and gelatinization of starch. Color is a very important quality attribute for green peas because consumers prefer dark green peas. The 1000 seed weight is also tested to help determine the grain size and milling yield. Mineral micronutrients are calculated because they are essential to general well-being, for maintenance of healthy immune systems, and protection against diseases and several cancers. Phytic acid levels are tested as well because it inhibits the body's absorption of the essential minerals from the peas. These quality characteristics are very important for the varying uses of the green peas, but constantly achieving high quality is difficult due to the variability by growing region and across years.

Quality uncertainty is an important element in all crops but it is especially important in specialty crops, including green peas, due to the high grade standards food safety or nutrition demanded by processors and consumers. Quality can be affected for various reasons. One reason is the environment in which the crop is grown. Varietal release and control mechanisms provide a means to regulate quality for characteristics not capable of being easily measured in the market system (Wilson and Dahl, 1999). In Canada, there is a variety registration form to ensure that health and safety requirements are met. This type of regulation also has the added benefit of reducing variability in end-use (Wilson, 1995). Dahl and Wilson (1999) cite farmer choices as an influence on the overall quality of production. Even though good high end-use quality varieties may be available, farmers may opt for other lower end-use quality varieties because of agronomics, market incentives, and yields (Dahl, Wilson, and Johnson, 2004). In effect, the farmer's production choices can increase variability in quality.

Quality uncertainty increases search costs, inspection costs, defect rates, storage costs, and processing costs for buyers and processors (Wilson and Dahl, 1999). Processors can purchase by location, variety, and quality to increase quality and reduce variability as well as use loading plans, contract specifications, and other mechanisms to reduce quality uncertainty (Wilson and Dahl, 1999). Contracts provide farmers input supply control, input quality control, improved response to consumer demand, and operational efficiency due to the reduced transaction costs of raw materials, as well as negotiation and improved coordination of product delivery (Curtis and McCluskey, 2003). Including quality requirements in forward contracts protects buyers due to the large discounts for poor quality green peas, ensuring they get higher quality. Theoretically, this is accurate but empirically it is difficult to prove.

Alexander, Goodhue, and Rausser (2007) tested this theory in the tomato industry by examining fourteen tomato farmers over four years, where they engaged in forward contracts with quality specifications and forward contracts with no quality specifications, just a fixed price. With this data, they found tomatoes that were contracted with the quality specifications had higher quality than the tomatoes that did not have quality specifications in the contract. However, this strategy has a drawback in that the buying area may decrease because of competition offering more lenient contract specifications (Johnson, Wilson, and Diersen, 2001).

Johnson, Wilson, and Diersen (2001) developed a model to analyze the effects of quality uncertainty in spring wheat in nine different regions, each with different quality characteristics and contractual specifications. They found the different quality specifications resulted in different markets the wheat was sold through and higher or lower prices, due to the premiums and discounts, than normally seen in those markets. Another drawback is the incentive applied to a certain quality specification. Higher incentives for one quality aspect can result in lower quality in other aspects of the product (Goodhue, Mohapatra, and Rausser, 2010). Contract specifications are a good tool to use for a processor but constant evaluation needs to be done to ensure the contract is as successful as possible. However, even if processors and elevators follow these strategies strictly, quality is still an issue. Thus, quality and yield can variability have a significant impact on the procurement strategies of a green pea processor.

Stochastic Efficiency

Risk assessment calls for the determination of probabilities and preferences for a decision maker's set of outcomes. The decision maker's risk preferences need to be known so comparison of outcomes can be useful and a ranking can be made. In order to determine the shape of a decision maker's attitude towards risk, a utility function is needed. However, determining a specific utility function can be very difficult. That's where stochastic dominance or efficiency analysis can be used in ranking different alternatives. There are various methods of efficiency analysis that will be discussed in more depth in the methodology section but the method that will be used for this project is stochastic efficiency with respect to a function (SERF).

SERF orders a set of risky alternatives in terms of certainty equivalents (CEs) and risk premiums derived from the difference in CEs for a specified risk preference (Hardaker et al., 2004a). The CE value is the amount of certain payoff an individual requires to be indifferent between the payoff and the payoff of the risky alternative (Williams et al., 2012). The risk premium is the difference between CE values at a specific risk aversion level. It is the amount that an individual must be paid to switch from the less risky alternative to the more risky alternative. CE values increase as the risk aversion levels increase and higher CE values are preferred. There have been many studies using SERF analysis to determine their best risk strategy for a certain predicament.

Fathelrahmam *et al.* (2011) used various risk ranking methods to generate economic sustainability rankings for conventional and reduced tillage systems using 14 years of economic budget data collected from 35 treatments on 36 plots at the Iowa State University Northeast

Research station near Nashua, IA. Four tillage systems were analyzed: chisel plow, moldboard plow, no-till, and ridge-till. Results depended on the method used. The type of crop, gross margin or net return, and level of risk aversion were the factors that affected the SERF analysis. This analysis found that there was no tillage system alternative that was ranked as the best for all methods. SERF is a useful tool for ranking tillage system strategies but the decision maker's selection of the best tillage system can be difficult due to environmental and managerial changes and production cost instability.

Regier, Dalton, and Williams (2012) determined if genetically modified (GM) corn was associated with higher returns, lower risk, or both for small corn farmers in KwaZulu-Natal, South Africa using stochastic dominance and SERF methods. The farmers in this area do not have insurance or their own finances to reduce the risk of a bad crop. Also, they may lose vital food supply for themselves, ability to pay loans, and ability to send their children to school. Using these methods, they were able to compare farmers who plant different varieties. Using GM corn reduced the net return risk while dominating among the methods.

Hristovska, Watkins, and Anders (2012) evaluated the profitability and risk efficiency of no-till for the typical rice-soybean rotation used in Arkansas. They used crop prices, yields, and stochastic expenses for their simulation to analyze the profitability between no-till and conventional tillage. Data for the profit functions was extrapolated from the 2010 Arkansas Rice Research Verification Program. The net returns per hectare for the rice-soybean rotation were estimated using simulation with 500 iterations that was inserted into the SERF method. Results showed no preference between tillage systems in rice but the no-till method was preferred for soybeans.

Williams *et al.* (2012) similarly determined the net returns of tillage systems in the central plains using simulated price and yield distributions then inserted these values into the SERF method to determine the best tillage system. They then used sensitivity analysis with prices and yields to determine how net returns and risk preferences changed. They determined a no-till winter wheat-soybean rotation was the best for all risk aversion levels. Tzouramani, Karanikolas, and Alexopoulos (2008) used simulation for net returns then the SERF method to compare organic and conventional farming in Western Greece. The stochastic variables were prices and yields for the organic or conventional crop. Their results varied across different crops and risk aversion levels with the general acceptance that risk preferences and weather are going to be the key to the rankings.

Lien, *et al.* (2007) determined the optimal tree planting decision that required knowing the optimal rotation strategy of the stand, given stochastic timber price and volume growth and a risk-averse decision maker. They determined the net present value (NPV) of the decisions and simulated the resulting NPVs then used the SERF method to determine the optimal strategy. Lien, Hardaker, and Flaten (2007) did similar analysis evaluating organic and conventional cropping systems for a representative farm in Eastern Norway. Watkins *et al.* (2010) evaluated profitability and risk efficiency of grazing stocker steers on conservation tillage winter wheat pasture using simulation and SERF as well.

Richardson, Lemmer, Outlaw (2007) analyzed the profitability and economic stability of a bio-ethanol plant in South Africa from wheat supplied by the winter rainfall region. They used stochastic simulation to estimate the distributions for NPVs of the five policies then used SERF to rank the scenarios similar to what has been in other literature. Barham *et al.* (2011) used stochastic cotton prices and yields to simulate a whole-farm financial statement to determine the best combination of irrigation levels, put options, and crop insurance for an irrigated cotton farm in Texas Lower Rio Grande Valley under 16 combinations of risk management strategies. SERF was used to rank the combinations.

CHAPTER 3: METHODOLOGY

Efficiency Analysis

Risk is where the distribution of outcomes is known either a priori or statistically through past experience and uncertainty is where the probabilities cannot be quantified (Knight, 1921).. In general, risks are considered to add to the costs of operation for a processor with a risk-averse decision maker and thus reduce economic efficiency (Robison and Barry, 1987). A risk-averse decision maker is not one that avoids risk; rather they prefer a risk premium above the return on an investment with complete certainty. In other words, the alternative return must be high enough for the risk-averse decision maker to accept the risk. A risk premium is the difference between the expected return on the risky alternative and the return on the riskless alternative which leaves the firm indifferent (Robison and Barry, 1987). These risks and risk premiums add to the costs for a risk-averse processor that affects it optimality.

Efficiency analysis is the basis of the methodology used in this project. Efficiency analysis relies on assumptions made for a decision maker or the decision maker's utility. There are bounds placed on the levels of risk aversion and the results that lie within the risk aversion bound will be efficient or inefficient. Risk aversion is when a decision maker prefers a situation that has no risk to a situation with the same expected outcome that has risk. The inefficient set or sets are those that are dominated or preferred by efficient sets based on the decision maker's preferences. In order for the decision maker to determine an optimal set, the preferences need to be consistent with the assumptions made about the nature of the utility function in deriving the risk-efficient set with the probability distributions for outcomes used for the individual and the assumed analysis are identical. Efficiency analysis can be more applicable with fewer restrictions placed on the utility function, but weak assumptions can limit the ability to rank alternatives.

Likewise for strict restrictions, tight restrictions may lead to the omission of the optimal efficient set for the decision maker.

Mean-Variance Efficiency

Mean-variance methodology was introduced by Markowitz (1952) for financial securities where the wealth is maximized and the variance is minimized for a portfolio. Decision makers using mean-variance efficiency must be risk averse. In general terms, if alternative 1 has a greater than or equal to expected value of alternative 2, and the variance of alternative 1 is lower than the variance for alternative 2, then alternative 1 is dominant over alternative 2 and is the preferred alternative for the decision maker. For mean-variance efficiency to be applied, decision makers must have a normal distribution of outcomes or a quadratic utility function. Since normal distributions are the exception rather than the rule in decision analysis and since a quadratic utility function implies the unlikely characteristic that absolute risk aversion increases with level of payoff, the mean-variance model criterion is best regarded as an approximate rule only (Hardaker et al., 2004b). For that reasoning, the mean-variance model will not be used in this project. Also, when a decision maker is not risk averse, the efficient set may be left out of the analysis. However, what mean-variance efficiency lacks it is made up for in its ease of determining the means and variances of outcomes to order alternatives.

SEU Hypothesis

Risk assessment for strategies in agriculture depend on the decision makers preferences for risk and outcomes. Subjective expected utility (SEU) hypothesis can be used in determining which strategy is best with a set of risk preferences by the decision maker (Anderson, Dillon, and Hardaker, 1977). In order to assess the risk alternatives as the shape of the utility function to reflect an individual's attitude toward risk, the SEU hypothesis claims the decision maker's utility function for outcomes is needed. Also, the utility of a risky alternative is the decision maker's expected utility for that alternative. King and Robison (1984) and Anderson and Hardaker (2003) have used the SEU hypothesis in risky agriculture strategies but found the results to be unsatisfactory because it was not exceptionally discriminating. Instead of using the SEU hypothesis, where only one utility function is used, stochastic dominance and efficiency models have been developed.

FSD and SSD

Stochastic dominance is used in instances to rank risk alternatives where the decision maker has a set of risk preferences that follow the utility functions provisions. One problem with stochastic dominance is the efficiency of the theory. The utility function can have few restrictions to give results that can be applied to a wide range but the ranking of the risk alternatives will not be as strong as a utility function with more restrictions. One stochastic dominance criterion that has been developed is the first-degree stochastic dominance (FSD) by Hadar and Russell (1969) and Hanoch and Levy (1969). By use of FSD it is possible to order alternatives for decision makers, who prefer more wealth to less and have absolute risk aversion with respect to wealth, $r_a(w)$, between the bounds $-\infty < r_a(w) < +\infty$ (King and Robinson 1984). For example, two alternatives, 1 and 2, each with a probability distribution of outcomes, x, defined by cumulative distribution functions (CDFs) $F_1(x)$ and $F_2(x)$, 1 dominates 2 in the first-degree if: $F_1(x) \leq F_2(x)$ for all x. The graph of alternative 1's CDF should always lie below and to the right of the CDF of alternative 2 for 1 to dominate 2. However, if the graphs intersect at all, neither alternative will dominate in the first-degree.

Second-degree stochastic dominance (SSD) is then introduced into efficiency analysis. SSD assumes the decision maker prefers more income to less and is not risk preferring, so the risk aversion bounds will be $0 < r_a(w) < +\infty$. SSD recognizes that decision makers may have a risk aversion parameter large enough that the utility of a small difference at the lowest observant is very important. The distributions of outcomes are compared based on areas under their CDFs. SSD has more discriminatory power than FSD and the efficient set under SSD is a subset of that under FSD (Hardaker et al., 2004b).

King and Robison (1981, 1984) found these two stochastic dominance criterions to be insufficient because they are not discriminating enough to produce significant results. When FSD and SSD are not sufficient in that there are still too many choice alternatives in the efficient set, third-degree stochastic dominance (TSD) can be used. TSD has the same assumptions as SSD but with the additional assumption that the coefficient of absolute risk aversion is decreasing with wealth, creating new areas that can be compared. However, this new restriction gives only a small amount of discriminating power over SSD making TSD less useful than other efficiency measures due to the larger number of restrictions and is not practical for the methodology.

SDRF

Stochastic dominance with respect to a function (SDRF) was introduced by Meyer (1977) using stricter risk aversion bounds. The risk aversion bounds are reduced to $r_L(w) \leq r_a(w) \leq r_U(w)$ with the ranking of risk alternatives defined by lower, $r_L(w)$, and upper bounds, $r_U(w)$ for the decision maker's absolute risk aversion function. Determining the risk aversion bounds may be easier than developing a specific utility model. The utility function requires assumptions to be made as well with a different utility function resulting in different results that are not of significant importance. The method is sequentially to select utility functions, U, which has risk aversion coefficients within the bounds, and then to use pairwise comparisons between alternatives to discover whether one dominates the other (Hardaker et al., 2004b). SDRF is not as transparent and discriminating enough as the methodology that will be used in this project.

SERF

Stochastic efficiency with respect to a function (SERF) will be used for this project. Instead of determining dominated alternatives, SERF uses utility efficient alternatives for ranges of risk attitudes. SERF orders alternatives in terms of certainty equivalents (CE) as a selected measure of risk aversion varied over a defined range (Hardaker et al., 2004a). SDRF may not select the smallest efficient set due to it only selecting the pairwise dominated alternatives. However, SERF can determine an efficient set because it picks the utility efficient alternatives and compares them simultaneously. SERF is also simpler in that it can be used in a standard spreadsheet and the results are graphed in an easy to read manner when compared to the SDRF method.

In order to compute the CE's, a utility function, $U(w)$, is used with the performance criterion being wealth, *w*. Wealth is stochastic due to the outcomes of the risky alternatives being uncertain. The probability density functions (PDF) describing *n* risky alternatives outcomes are represented by $f_1(w), f_2(w), \dots, f_n(w)$ and the cumulative distribution functions are represented by $F_1(w), F_2(w), \dots, F_n(w)$. The SEU hypothesis states that the utility of any risky alternative is the expected value. The exact shape of the utility function is unknown, meaning the decision maker's exact risk aversion is unspecified, the problem is solved where the absolute, relative or partial risk aversion function $r(w)$ of the decision maker lies everywhere between the lower and upper bounds $r_L(w)$ and $r_U(w)$ (Hardaker et al., 2004a). The function for utility for each risk alternative with respect to risk aversion and the stochastic outcome of wealth, *w*, is defined as:

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

where the second term of the expression represents the continuous case and is converted to its discrete approximation in the third term for computational purposes. $P(w_i)$ is the probability for states *i* and there are *m* states for each risky alternative. The function for utility for each risk alternative with respect to risk aversion and the stochastic outcome of wealth implies (Hardaker et al., 2004a):

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

Equation (1) is a discrete function that will then be evaluated for an adequate amount of discrete points of $r(w)$ describing the relationship between U and $r(w)$ for each alternative.

The CE of a risk alternative is the point at which the decision maker is indifferent between the utility value and the risky outcome. The CE is usually less than the expect money value (EMV) and greater than or equal to the minimum value for a risk averse decision maker with the risk premium being the difference between the EMV and the CE. To determine CE values the inverse of the utility function is needed:

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

The utility function determines the calculation of CEs. CEs are preferred to be represented by utilities because they are easier to examine than utility values and it includes the EMV for each alternative in cases where $U(w, r(w))$ is undefined for $r(w) = 0$. SERF determines a vector of CE values for the *n* alternatives within the risk aversion bounds for values of $r(w)$. The alternative with the largest CE is the only efficient value at each $r(w_i)$. Only those values which have the highest CE values for some value in the range of $r(w)$ are utility efficient and all other alternatives are dominated in the SERF sense (Hardaker et al., 2004a). The CE results are shown in Figure 1 with CE values on the vertical axis and risk aversion on the horizontal axis over the range $r_L(w)$ and $r_U(w)$.

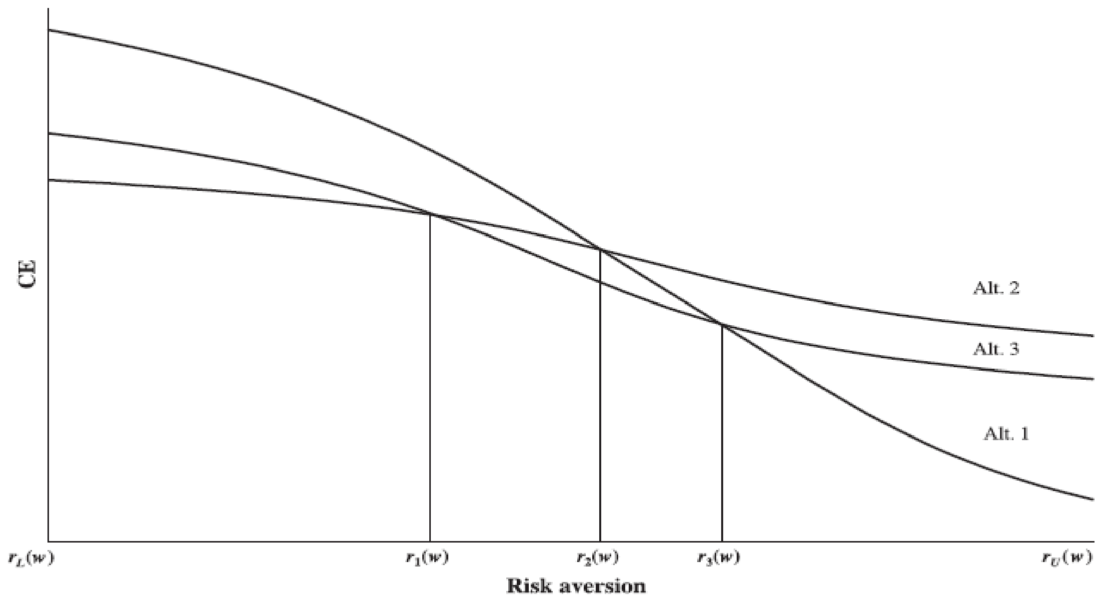

Figure 1. Example SERF results (Hardaker et al., 2004a)

Figure 1 shows graphically the CE value of three alternatives over a risk aversion range of $r_L(w)$ and $r_U(w)$. In the graph, alternative 1 is dominating the other alternatives to the risk aversion level of $r_2(w)$ then beyond that level alternative 2 is the dominant choice. Alternative 3 is not utility efficient because it is being dominated by one of the alternatives at every point. However, if the SDRF method were used, there would be no eliminated alternative because all three alternatives intersect with one another at some point.

McCarl (1988) developed Riskroot which takes the breakeven risk aversion coefficients (BRAC) to determine the best alternative. SERF simply determines at which point the dominance switches between alternatives and allows for estimation of the utility-weighted risk premiums between alternatives to provide a measure for comparing the payoffs between the risky alternatives by examining the graph and determining the intersection point.

SERF and SDRF

The SDRF method uses pairwise comparison to rank the risky alternatives. The utility function with lower and upper bounds for all values of $r_a(w)$ can be sequentially evaluated as:

$$\int [F_2(w) - F_1(w)]U'(w)dw$$

where the cumulative density functions $F_1(w)$ and $F_2(w)$ represent two risky alternatives and $U'(w)$ is the first derivative of $U(w)$. If the minimum of the utility function with lower and upper bounds for all values of $r_a(w)$ is above zero, the utility (CE) for $F_1(w)$ is preferred to the utility (CE) of $F_2(w)$ for the decision maker whose risk aversion level is within the defined risk aversion range. Contrarily, if the minimum of equation (2) is below zero, the utility (CE) for $F_2(w)$ is preferred to the utility (CE) of $F_1(w)$ and if the value is zero the decision maker is indifferent to either alternative. For SDRF, determining if there is dominance, $F_2(w)$ and $F_1(w)$ switch locations in the bracket and the evaluation procedure is repeated. Equation (2) is simply measuring the difference between utilities of distributions $F_2(w)$ and $F_1(w)$, therefore, applying the change-in-variable technique to integrate, let $dv = f_1(w) - f_2(w), v = F_1(w) - F_2(w),$ and $u =$ U(w) then using integration by parts (Hardaker et al., 2004a):

$$\int U(w)[f_1(w) - f_2(w)]dw = U(w)[F_1(w) - F_2(w)]_{-\infty}^{+\infty} + \int [F_2(w) - F_1(w)]U'(w)dw$$

$$= \int [F_2(w) - F_1(w)]U'(w)dw.$$

The utilities of alternatives $F_1(\int U(w)f_1(w)dw)$ and $F_2(\int U(w)f_2(w)dw)$ are order within the defined bounds of $r_a(w)$. The SERF compares with this traditional SDRF method, however, the SERF method is more direct and informative. The SDRF method is able to allow risk aversion to vary within defined bounds as the outcome measure varies. The SERF method does not allow this with the measure of risk aversion needing to be constant for all outcomes being considered (Hardaker and Lien, 2010).

The advantages of simultaneously comparing many risk alternatives with SERF over SDRF are (Hardaker et al., 2004a):

1. SERF can identify a smaller number of alternatives in an efficient set than pairwise SDRF over a given range of risk aversion.
2. SERF provides an ordinal ranking of alternatives at each risk aversion level between the lower and upper risk aversion bounds customarily tested by SDRF.
3. SERF is a one step process that is 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 presentation of ordinal rankings for decision makers with different risk preferences.
4. SERF provides a cardinal measure of the decision maker's conviction for preferences among alternatives at each risk aversion level by interpreting the differences between CE values as risk premiums.
5. Unlike the traditional SDRF method, SERF can be used to process data presented in different formats not only in terms of the same fractile values for all the distributions to be compared.
6. SERF numerically evaluates CE values for alternatives over many years of $r(w)$, and then graphically displaying ordinal and cardinal rankings for many different groups of agents across a spectrum of risk aversion levels which can be as wide or as narrow as the

situation warrants, that is, risk preferring through risk neutral to strongly risk adverse , or only moderately risk averse within a narrow range.

Measures of Risk Aversion

Risk aversion is not easy to quantify. It is represented by the curvature of the decision maker's utility function. The second derivative can be applied to the utility function to obtain three possible attitudes toward risk. If the second derivative of the utility function is less than zero, risk aversion is implied, whereas if the second derivative of the utility function is equal to zero, the decision maker is indifferent to risk. Additionally, if the second derivative value were above zero, risk preference is implied. It is difficult to determine the value of risk aversion because the utility function is defined only up to a positive linear transformation. The simplest measure of 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 $U^2(w)$ and $U^1(w)$ represent the second and first derivatives of the utility function (Hardaker et al., 2004b). In theory, the absolute risk aversion coefficient (ARAC) $r_a(w)$ will decrease when wealth, w, increases. In other words, as people have more wealth, they are willing to take on more risk. The ARAC is not the same for different types of currency because wealth is represented in the currency being used such as dollars. To avoid the currency problem, relative risk aversion function can be introduced:

$$r_r(w) = wr_a(w).$$

Currency is not an issue because the relative risk aversion coefficient (RRAC) $r_r(w)$ is independent of wealth, w. $r_a(w)$ and $r_r(w)$ are functions and not a constant so they may vary when wealth varies. Arrow (1965) suggested the RRAC is likely to be 1 when there is hardly any information about risk aversion from the decision maker. Anderson and Dillon (1992) developed degrees of risk aversion based on the level of the 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.

The decision maker determines where they are on the scale by how much they are willing to risk with respect to how much wealth they currently have. The RRAC values suggest that a value of one from previous literature is a conservative number.

The absolute risk aversion function can be categorized for the increase, constant, or decrease in wealth represented by increasing absolute risk aversion (IARA), constant absolute risk aversion (CARA), and decreasing absolute risk aversion (DARA). Likewise, the relative risk aversion function can be categorized for the increase, constant, or decrease in wealth represented by IRRA, CRRA, and DRRA, respectively. Constant absolute risk aversion (CARA) means that preferences are unchanged if a constant amount is added to or subtracted from all payoffs (Hardaker et al., 2004b). Similarly, the constant relative risk aversion (CRRA) is unchanged if all payoffs are multiplied by a positive constant.

Utilities

In order to determine the CEs using SERF, a utility function needs to be used. There are many utility function forms that are used in efficiency analysis with different implications on risk attitudes. One such function is the negative exponential utility function with a CARA coefficient associated with it where: $U = 1 - \exp(-cw)\,, c > 0$ which $r_a(w) = c$ (constant) and $r_r(w) = cw$. CARA is not considered a desirable property but only having to estimate a single CE makes it easy to use. Large values of *w* in association with large values of *c* can cause problems for the negative exponential function along with utility values close to 1.0 possibly being rounded off in computation. Also, reducing or increasing all payoffs by the same amount would improve the results because of the constant risk aversion value. A negative exponential utility function conforms to the hypothesis that managers prefer less risk to more given the same expected return (Lien, Hardaker, and Flaten, 2007). With this assumption and the CARA assumption, managers view a risky strategy for a specific level of risk aversion the same without regard for their level of wealth (Fathelrahmam, et al., 2011). Thus, this project will use the negative exponential utility function.

Logarithmic and power functions are used for DARA and CRRA functions, respectively. The logarithmic function is represented by: $U = \ln(w)\,, w > 0$ with $r_a(w) = w^{-1}$ and $r_r(w) = 1.0$. The power function is: $U = \{\left(\frac{1}{1-r}\right\} w^{(1-r)}, w > 0$ with $r_r(w) = r$ and $r_a = r/w$. The logarithmic function must replace the power function for values of *r* close to 1.0. Problems arise using these functions that can be remedied by scaling the range of *w* by dividing all payoffs by the maximum payoff. For values of *r* of 4 or more the function implies very high marginal utility for low values of *w* with a sharp fall to give essentially zero marginal utility for higher values (Hardaker et al., 2004b). This risk preference is highly unlikely with risk aversion levels hardly ever reaching this level.

Using CEs instead of expected utility values in analyzing risk alternatives is commonplace because of the advantage of CEs. One being CEs are easier to compare and interpreted than expected utility values. The difference between CEs can be calculated where as it is not possible to do so for expected utility values. One CE can be expressed as a proportion of another, or two CEs can be subtracted, resulting in easy interpretation between independent alternatives. In other words, it is beneficial to convert expected utility values to CEs. There are two main ways of converting (Hardaker et al., 2004b):

1. If the utility function exists as a plotted curve, it is straightforward to read from a given expected utility value on the vertical axis to a value on the horizontal axis representing the CE.
2. If the utility function has been estimated via a particular algebraic equation, it will usually be possible to solve the equation for w given a value of U.

Summary of SERF

Determining a proper procurement strategy for a processor or any other entity is very difficult to determine. This analysis examines the green pea industry in North Dakota for a processor trying to determine their best procurement strategy for their attitude towards risk while accounting for the vast assortment of risks being faced. The SERF model will be used due to the ranking of risky alternatives over a range of risk aversion it is capable of doing while making it easy to interpret and understand through the graph presentation.

CHAPTER 4: EMPIRICAL MODEL

Introduction

SERF analysis is the method that will be used to rank the set of risky alternatives that are being analyzed in this project. Procuring grain is very risky due to an abundance of factors. Procuring green peas in particular presents a set of risks that are not seen in the major commodity crops. A green pea processor must have a procurement strategy in place that best explains the risks they face. This project uses SERF analysis to rank procurement strategies for a green pea processor located in north central North Dakota. SERF analysis ranks the strategies over a range of risk aversion levels. In other words, the processor is able to determine their best procurement strategy based on their attitude towards risk.

The previous chapter summarized efficiency analysis and SERF. This chapter provides the empirical model, its components, and the strategies being analyzed. The data and its sources will also be discussed. The last part of this chapter reviews the stochastic simulation process used and the sensitivities of assorted variables in the model.

Model Features

The empirical model is used to determine the discounted after tax net income for a green pea processor located in North Dakota with various assumed procurement strategies for five years into the future. The mathematical formula for discounted net income is (Bussey, 1978):

$$P_0 = \sum_{t=0}^{N} \frac{Y_t}{(1+i)^t}$$

where P_0= the discounted net income after tax

Y_t= the net income after tax at the end of period t

i= discount rate

t= the point in time under consideration

N= the life of the project.

The net increase or decrease in after tax net income from the profit functions are used to determine the discounted net income of the strategies. To find the discounted net income, the net income for each year is multiplied by a discount rate then summed.

In order to determine the best strategy by examining the discounted after tax net income, the empirical model includes integrated financial statements in a Microsoft Excel spreadsheet. The foundation of the model is an input section that provided the core information needed to estimate the financial statements. It is comprised of prices, cost of goods sold, input and output coefficients, expenses, depreciation, loans, interest expenses, accounts receivable data, accounts payable data, investment information, production capacity, sales volume, and inventory requirements. Also, the model consists of a facilities and equipment detail section that is based on numbers from the input section. There is a section representing the tax tables for the processor that is used to estimate lax liabilities. In addition, there are output sections for owner's equity, financial ratios, depreciation schedule, debt information, amortization and account balances, and production and inventory information. Moreover, the model consists of prices from both regions that include the purchase price, sales price, discounts, and transportation costs for the various qualities that are inserted into the input section that is used to estimate the financial statements. A production and quality section is used to determine the quantity of each green pea quality that is purchased from two different growing regions. This information is then transferred into the input section that is then used to estimate the financial statements and ultimately determining the discounted net income after tax.

Once the distribution of discounted after tax net income is estimated for each of the five years, the values are summed and SERF analysis is used to rank the alternative scenarios.

Simetar©: Simulation and Econometrics to Analyze Risk is used to perform the SERF analysis. Simetar© is an Excel add-in developed by James W. Richardson, Keith D. Schumann, and Paul A. Feldman (2001) at Texas A&M University. The summed discounted after tax net income for the five years for each strategy will be simulated 10,000 times in @Risk. The outcomes for each strategy from the simulations are entered into Simetar© where SERF analysis is used to calculate the certainty equivalents (CE) that are graphed over a range of risk aversion levels. The results in the graph rank the four procurement strategies. There are four separate models for the four different strategies that will be evaluated.

Procurement Strategies

The hypothetical green pea processor is located in north central North Dakota and is assumed to be operating under capacity. Its current strategy is buying only from the spot market in the north central (NC) region of ND and is searching for procurement strategies that are best for their growth. The spot market is the cash market for the green field peas where the peas are immediately purchased and sold. The processor has the ability to expand into new locations to increase its market share and take advantage of the opportunities that exist. The first strategy that will be analyzed is buying from the NC region and the southwest (SW) region on the spot market. A map representing the different buying regions for the processor is shown in Figure 2. In the map, the NC region is represented by the shaded counties in the NC part of North Dakota. The shaded counties in the SW part of North Dakota represent the SW buying region. The second procurement strategy that will be analyzed is forward contracting a percentage of the green peas needed from the NC region and buying the remaining needed peas on the spot market from both regions. The third procurement strategy is forward contracting a percentage of the peas needed from both regions and buying the remaining needs from both regions on the spot market.

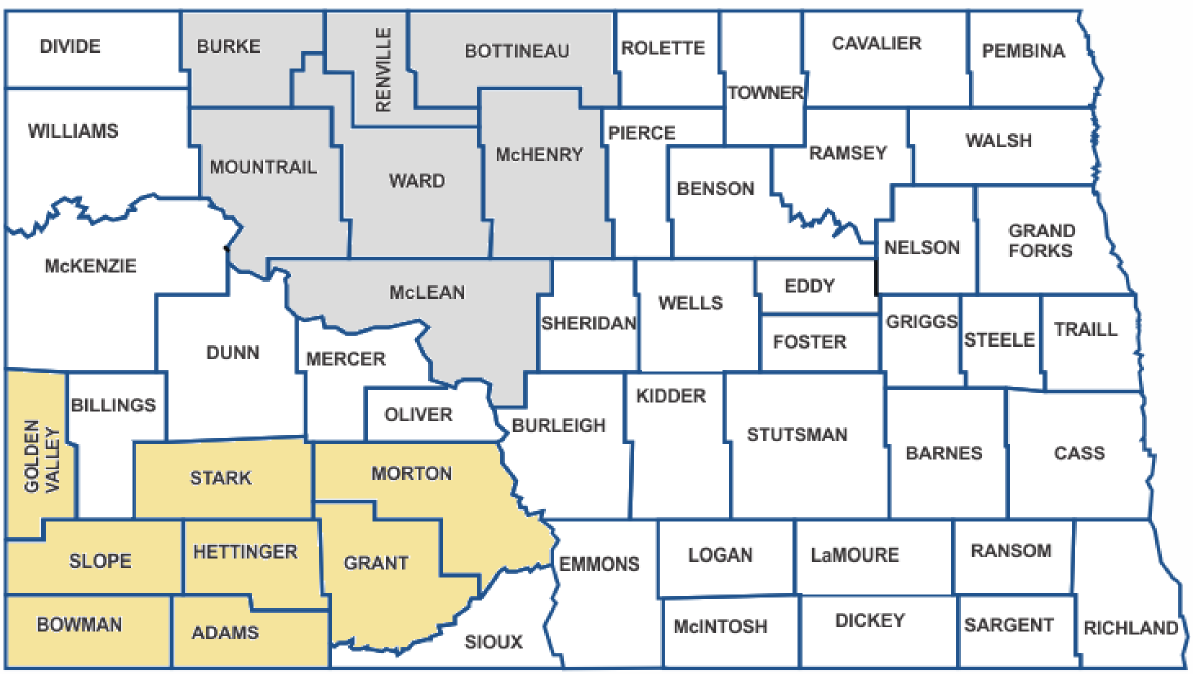

Figure 2. North Central and South West Buying regions

The model will be applied to the different procurement strategies for the green pea processor given various assumptions using SERF. In order to derive the after tax net income of each strategy, a profit function was developed. A general profit equation can be used to represent the four proposed procurement strategies:

$$\pi_t = [\left(\left(\sum_{i=0}^{n} SP_{rq}\right) - \left((\sum_{i=0}^{n} PP_{rq} + CC + VC\right)\right) * Q - FC]$$

where

π_t is the before tax estimated profit

$\sum_{i=0}^{n} SP_{rq}$ is the sum of sales prices for each quality and region (stochastic variable)

r represents the region the peas were purchased from

q represents the quality of the green peas purchased

$\sum_{i=0}^{n} PP_{rq}$ is the sum of the purchasing prices for each quality and region (stochastic variable)

CC denotes the cost of cleanout for off-grade quality peas (stochastic variable)

VC represents the variable costs associated with running the processing facility

FC represents the fixed costs for the processor

Q denotes the quantity (stochastic variable).

There are many components to the sales price represented by:

$$\sum_{i=0}^{n} SP_{rq} = \sum_{i=0}^{n} PP_{rq} + GM - CC - TC$$

$\sum_{i=0}^{n} SP_{rq}$ is the sum of the sales prices for each region and quality (stochastic variable)

$\sum_{i=0}^{n} PP_{rq}$ represents the sum of the purchase prices for each region and quality (stochastic variable)

GM is the gross margin for the processor (stochastic variable)

CC denotes the cost of cleanout (stochastic variable)

TC is the transportation cost (fixed variable).

Included in the gross margins is the profit margin the processor has incorporated for each type of quality. The gross margin is different for every quality category due to the various demands for a particular quality from the processor's buyers. The green peas are separated into three quality categories: premium, high, and off-grade. The premium quality peas are those that are a U.S. number one grade or higher. High quality peas are U.S. number one or two grades while the off-grade quality peas are a U.S. number three grade or worse.

Higher quality is associated with higher gross margins. In relation, the low quality peas have lower gross margins and purchase prices due to cleanout costs and quality discounts. All prices and costs are measured in hundredweight (cwt). The profit function is a general equation that includes all the prices and costs for the procurement strategies. Table 1 shows the stochastic variables and their distributions. The distribution of each variable does not change for the four procurement strategies.

Table 1. Stochastic variables

Stochastic	Distribution	Characteristics
Purchase Price	LogNormal	Mean: 14.71 Standard Deviation: (14.71*RiskInvgauss(0.14403,0.2008,RiskShift(0.16422)))
Gross Margin	Triangle	Maximum: 5.5 Minimum: 1.36 Most Likely: 3.41
Cost of Cleanout	Triangle	Maximum: 0.1 Minimum: 0.01 Most Likely: 0.03

Each strategy will have sales and purchase prices for each type of quality, contract, and region. The different components for each strategy are:

Table 2. Spot purchasing in only North Central region

	Purchases Prices	**Sales Prices**
Spot Market	NC Premium Quality	NC Premium Quality
	NC High Quality	NC High Quality
	NC Off-grade quality	NC Off-grade quality

Spot purchasing in only the NC region: There is a sales price for each quality in the NC region because that is the only region the processor is buying from. The sale price consists of the same components used in sales price equation. There is also a purchase price for each quality from the NC region.

Table 3. Spot market diversification

	Purchases Prices	Sales Prices
Spot Market	NC Premium Quality	NC Premium Quality
	NC High Quality	NC High Quality
	NC Off-grade quality	NC Off-grade quality
	SW Premium Quality	SW Premium Quality
	SW High Quality	SW High Quality
	SW Off-grade quality	SW Off-grade quality

Spot Market Diversification: There is a set of six sales prices, one for each quality from the two regions with the same components as in the sales price equation. Included in the purchase prices is the distribution of spot market prices for each quality from both regions.

Table 4. Forward contracting in only North Central region

	Purchases Prices	Sales Prices
Spot Market	NC Premium Quality	NC Premium Quality
	NC High Quality	NC High Quality
	NC Off-grade quality	NC Off-grade quality
	SW Premium Quality	SW Premium Quality
	SW High Quality	SW High Quality
	SW Off-grade quality	SW Off-grade quality
Forward Contracted	NC Premium Quality	NC Premium Quality
	NC High Quality	NC High Quality
	NC Off-grade quality	NC Off-grade quality

Forward Contracting in NC Region: There are sales and purchase prices for each quality from each region. However, the forward contract (FC) sales and purchase price for each quality for only the NC region is included in the model.

Table 5. Forward contracting in both regions

	Purchases Prices	Sales Prices
Spot Market	NC Premium Quality	NC Premium Quality
	NC High Quality	NC High Quality
	NC Off-grade quality	NC Off-grade quality
	SW Premium Quality	SW Premium Quality
	SW High Quality	SW High Quality
	SW Off-grade quality	SW Off-grade quality
Forward Contracted	NC Premium Quality	NC Premium Quality
	NC High Quality	NC High Quality
	NC Off-grade quality	NC Off-grade quality
	SW Premium Quality	SW Premium Quality
	SW High Quality	SW High Quality
	SW Off-grade quality	SW Off-grade quality

Forward Contracting in Both Regions: There are sales and purchase prices for each quality from each region. However, included in the model are forward contract sales and purchase prices for each quality for both regions.

Data

Specialty crop, especially green pea, data is difficult to discover because those in the industry do not want their private information to become public information because someone else in the industry may be able to back track the information. The data was also incomplete in some instances due to missing data points. Data for other variables used in the model did not extend far enough back in time to be sufficient. Green pea production data in North Dakota has only been recorded since 2005 compared to the numerous decades of data for wheat. The variables that needed data include prices, gross margins, quality, yield, transportation costs, and financial information.

Price Data

Weekly price data was obtained from USDA's Agricultural Marketing Service (AMS). Price data for the processor level and prices for the farmer level are reported, with a high and low price value, for each category being reported. The average of the reported high and low value was used to estimate the price distributions used in this analysis. However, this price information had gaps in the data series that were as large as several months. Therefore, North Dakota field pea prices obtained from selected elevators, accessed from Bloomberg information services, were used to fill the gaps in the AMS data set. The gross margin information for each quality category was obtained from interviews with experienced pea buyers. Figure 3 shows the estimated @RiskLogNorm distribution of purchase prices from the spot market for the processor.

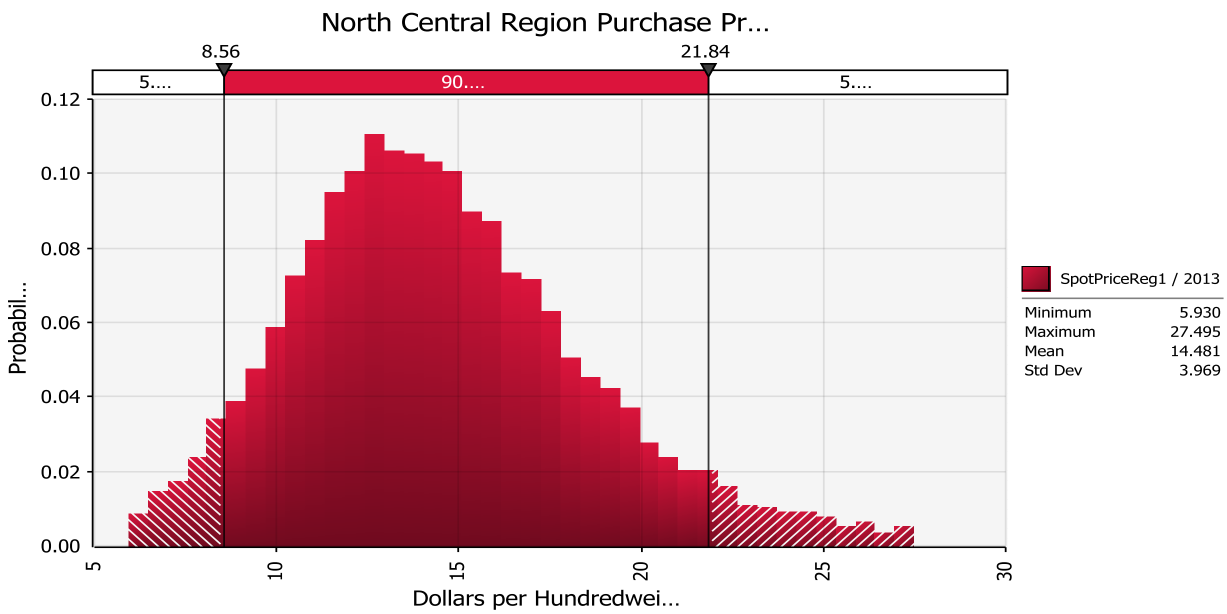

Figure 3. Probability density function of purchase prices for North Central region

In Figure 3, the prices are truncated at $5.92/cwt and at $27.5/cwt, which are the minimum and maximum prices provided by the AMS data set. The distribution graph in Figure 4 shows the sales price for peas that were purchased from the spot market.

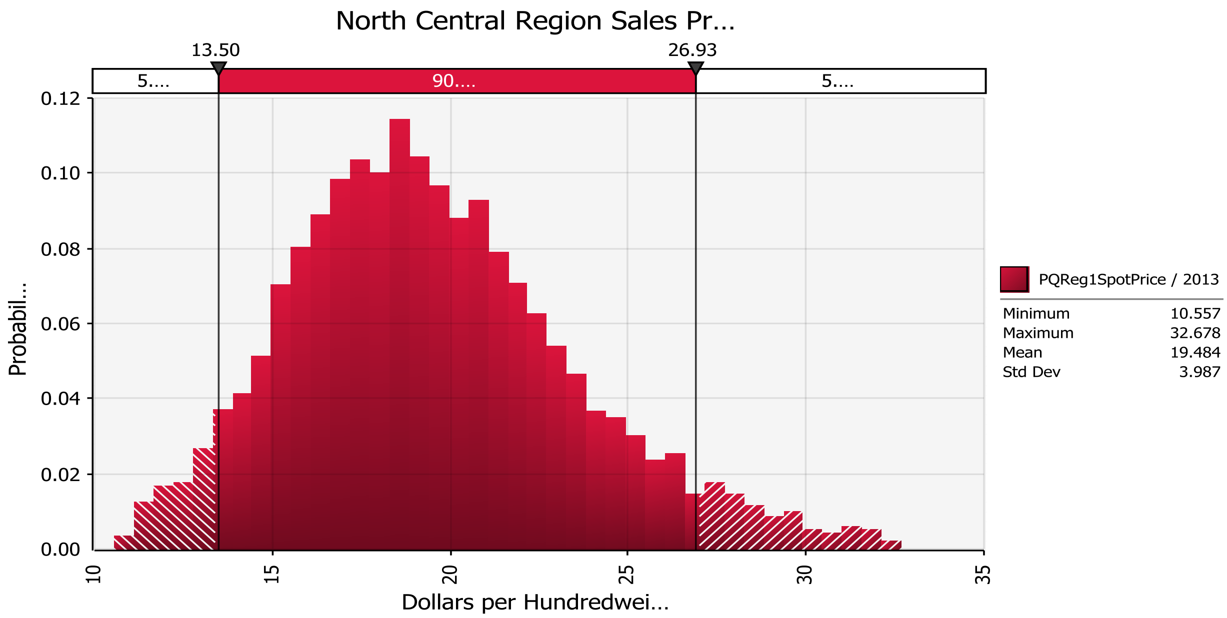

Figure 4. Probability density function of sales prices for North Central region

The distribution of sales price values are larger due to the added gross margins for that particular quality of pea with cost of cleanout, quality discount, and transportation cost included depending upon the specific strategy that was being evaluated.

Yield Data

It was difficult to obtain sufficient yield and quality data for green field peas. County average yield data was obtained from the National Agricultural Statistics Service (NASS) Quick Stats which provided yield data from 2005 through 2013. The yield data also had missing points due to reduced reporting. NASS also provided production data on the county level in terms of acres planted and harvested as well as total county production but it also contained missing data points. To remedy this problem, variety yield results from test plots were used. The variety yield data was obtained from Dr. Kevin McPhee, assistant professor and pulse crop breeder in the Plant Sciences Department at North Dakota State University. The yield data provided by Dr. McPhee included yield levels in hundredweight per acre for multiple varieties from 2009 through

2013 for North Dakota test plot areas in Hettinger, Minot, and Williston. The combination of the NASS and Dr. McPhee's yield data provided sufficient information and provided similar relative results by region. However, one problem was the higher yields that were found in the test plots compared to NASS' county yield averages. The test plot yields were reduced by a fixed factor in each region that made them more comparable and realistic with commercial scale production. The factor was derived from dividing the average yearly yield data from Dr. McPhee's data set by the average yearly yield from NASS. The yield data from Dr. McPhee's test plots were then divided by yearly factors for each location and implemented into the model as distributions.

Additional Data

The acreage values for green peas were obtained from the Farm Service Agency. The acreage values were reported on a county level collected for Bottineau, Burke, McClean, McHenry, Mountrail, Renville, and Ward counties to represent the NC region and Adams, Bowman, Golden Valley, Grant, Hettinger, Morton, Slope, and Stark counties to represent the SW region. A four year average acreage level for each region was calculated from the acreage values provided by the Farm Service Agency for 2010 through 2013 from an online dataset. These acreage values were then multiplied by the yield distributions to estimate the total production in the two regions. Figure 5 shows the estimated distribution of total production in the NC region. Figure 5 shows a bimodal distribution as that represents the different years where production is low or high. The distribution is bimodal due to the high and low yields that were derived from Dr. McPhee's and NASS' yield data. Also, the distribution is bimodal due to the probability of having high yielding years and low yielding years for the green peas produced in the NC region.

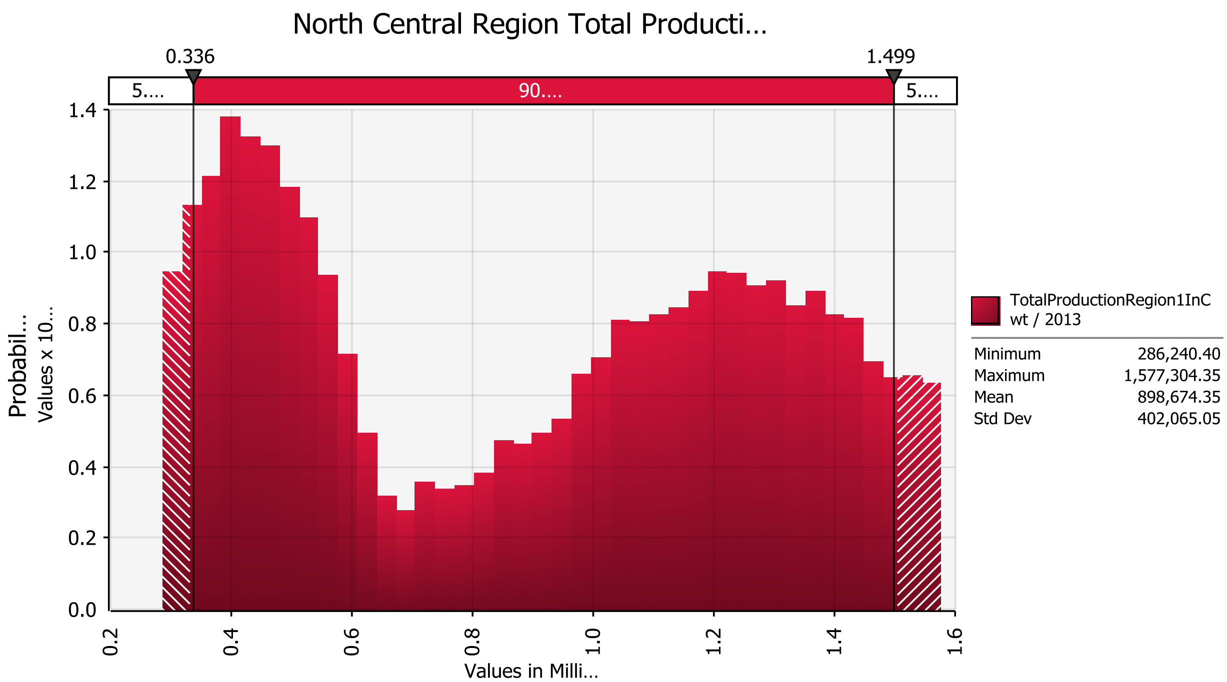

Figure 5. Probability density function of total production in North Central region

The probabilities for the yields in the NC region yields were 60% high quality and 40% low quality. The quality probabilities are fit with a @RiskDiscrete distribution so the yearly production in the NC region have high yields 60% of the time and low yields 40% of the time with this relationship shown in the Figure 5. The left part of bimodal distribution represent years in which yields are low and the right part of the distribution represents years in which yields are high. The x-axis of the Figure 5 represents the total production in hundredweight for the NC region with the values in millions of hundredweight. The total production from the SW region has an 80% probability of having high yields and a 20% probability of having yields being low. The distribution represented total production in the SW region is not bimodal due to the dominance of the 80% probability over the 20% probability.

The total production values were divided into premium quality peas, high quality peas, and off-grade quality peas for the separate regions using fixed quality probabilities derived from in person interviews with industry experts. These separate production values represent the particular quality amount for each region. The production amounts for each quality were then multiplied by the market share for the processor in each region to determine the amount of each quality peas they were able to purchase.

A complete set of integrated financial statements from a dry edible bean processor in the years 2001 and 2002 were the base case information for the assumed pea processor. The dry edible bean processor was used due to its similar size to the representative pea processor developed for this analysis. Selected information from a 2014 field pea processor survey, conducted by North Dakota State University for an economic impact study of pulses in North Dakota, was used to refine the base financial information to reflect current industries conditions. The numbers were not directly inserted into the integrated financial statements but rather used as a point of reference. Financial information was also cross checked from in-person interviews with buyers from United Pulse Trading Inc.

Additional Assumptions

The processor size of 400,000 cwt maximum production capacity is an assumption that was made based on the sizes seen in the industry with the goal being to represent a medium sized processor. Based on the processor size, the model is designed so that the processor will always buy premium quality peas from the NC region due to the low transportation cost and high gross margin. The amount of premium quality peas bought is limited to the assumed market share of the processor. The processor will then buy high quality peas from the NC region, premium quality from the SW region, or high quality from the SW region, depending upon the lowest net purchase price. If the processor does not meet their target processing capacity, they will then purchase the quality from the region with the next lowest net purchase price until their processing capacity is met. However, if the processor does not meet their demand from buying premium quality and high quality from both regions, it will then purchase off-grade quality green peas from the region that has the lowest purchase price. Therefore, in some instances the best strategy is to buy from the NC region depending on production levels and procurement costs.

The forward contract prices paid by the processor are fixed and assumed based on what is commonly seen in the industry by examining past prices. Also, the percentage of total production in a region that is forward contracted is fixed. It is assumed the processor is accepting all of the green peas that were forward contracted based upon the proportion available for each quality category. Connected to the forward contracting percentage, the market share for the processor in both regions is fixed based on what is seen in the industry with a processor of this size. It is also assumed that the input coefficients represent the amount of peas needed to produce one single green pea. The output coefficients represent the amount that is produced from one hundredweight of green pea. The output coefficients incorporate a cleanout amount that is dependent upon the quality of the green pea purchased. There is less cleanout for premium quality peas while there is a large cleanout amount for off-grade quality peas. The cleanout percentage is a value that was sourced from in person interviews from those in the green pea industry.

There are various assumptions made for the financial inputs of the processor based on what is commonly seen in the industry with a processor of the size assumed in this project. One is the $1.5 million investment in land, buildings, and equipment. Another is the interest rate of 5.5% for the line of credit. The minimum cash balance is assumed at $100,000 with 30 days for accounts receivable and payable. The number of days of raw product inventory is an assumed value of five days and three days of processed product inventory based on in-person interviews with United Pulse Trading Inc.

Risk Simulation

Simulation attempts to imitate a real-world decision setting by using a mathematical model to capture the important functional characteristics of the problem as it evolves through time and encounters random events, conditional on management's pre-specified operating strategy (Trigeorgis, 1996). Monte Carlo simulation models the project through a set of mathematical equations and identities for all the primary variables. Probability distributions are used to represent crucial variables, which are typically estimated from historical data. Sensitivity analysis can be done to determine which variables are important to the problem. A random sample is drawn from the probability distribution of each of the important primary variables to estimate distributions for the selected output variables. The process is repeated multiple times so a representative output probability distribution can be generated.

There were many stochastic variables that were used in the model to develop a distribution of outcomes for each strategy, which can then be ranked using SERF. Estimating the purchase price distribution from the spot market for the different qualities from each region involved several steps. The first step was filling in price gaps in the USDA AMS data by using local elevator prices and price trends. Once the gaps are filled, exponential weighted moving average (EWMA) is used to estimate price volatility. A lambda coefficient of 0.94 was used for the price data series from 2009 through 2013. These volatility values are then fit with a distribution that is used as the volatility value for the @RiskLogNorm distribution of purchase prices from the spot market for both regions. However, the fixed cost of transportation is added to the purchase price for the SW region. The off-grade quality purchase price includes the price distribution plus the cost of cleanout for the poor quality. The cost of cleanout has a @RiskTriangle distribution that originated through interviews with those in the industry. The off-grade quality purchase price from the SW region has the added cleanout cost and transportation cost. The forward contract purchase price from the NC region is a fixed value but the off-grade purchase price includes the added cost of cleanout. The forward contract purchase price from the SW region is a fixed price as well, but transportation costs and cleanout costs are added to the off-grade quality purchase price.

The sales price for all of the qualities, regions, and types of contracts equals the purchase price plus the gross margin. All of the gross margins have a @RiskTriangle distribution with only the values being varied among the qualities. The yield distributions varied among the regions. Table 6 shows the distributions for the different yields from each region. The yield distributions for each region were then averaged together and multiplied by the average acreage from the region to get total production in hundredweight.

Table 6. Yield distributions

Yield	**Distribution**	**Characteristics**
High yield in NC region	Normal	Mean: 2902.37 Standard Deviation: 746.92
Low yield in NC region	Gamma	Alpha: 25.375 Beta: 35.366
High yield in SW region	Weibull	Alpha: 5.3042 Beta: 1705.4
Low yield in SW region	Weibull	Alpha: 5.6254 Beta: 965.7

Sensitivities

The market share for the two regions, forward contracting percentage, correlation of yields between regions, forward contract price, and cost of transportation from the SW region to the processor are adjusted for the four procuring strategy models. The variables are adjusted to determine the effect on the rankings for the four procurement strategies.

Market Share

The market share for the processor was assumed to be at 35% in the NC region and 20% for the SW region based upon in-person interviews with those in the industry. Alternative market shares for the processor were tested at 45% in the NC region and 20% for the SW region.

Forward Contracting Percentage

The forward contracting share of the total production was assumed to be 10% for both regions. This number can vary from year to year depending on the processor's expectations about market prices and planted acreage in the future. Therefore, the assumed percentage that is forward contracted for both regions was increased to 20%. The expectation is an increase in forward contracting with decrease price risk, thus, increasing the strategies value.

Transportation Cost

Truck transportation prices have high variability. The assumed transportation cost was increased from the original value of $4/bushel/loaded mile to $6/bushel/loaded mile.

Forward Contract Price

The forward contract price for the base case is an assumed fixed price. Price is an important factor in forward contracting as it has a significant impact on profitability of the green peas that were bought under a forward contract. Therefore, the base forward contracting price, $14.71, was increased and decreased by 20% to determine the significance of forward contracting price differences.

Correlation Coefficient

The yield correlation between the two regions has a significant impact on the buying strategy for a processor. A negative correlation means that one region produces high yields and the other region produces low yields while positive correlation produces high yields and low yields in the same years. Under negative correlation, procurement diversification can reduce supply risk, while procurement diversification may have little impact on supply risk when the correlation is highly positive. In order to determine the effect of the correlation between yields, the yield correlations will be adjusted to a negative value of -0.8 and a positive value of 0.8 with a base correlation of zero between the two regions.

CHAPTER 5: RESULTS

Introduction

Stochastic efficiency with respect to a function (SERF) analysis was applied to a green field pea processor located in NC North Dakota to rank its procurement strategies. In order to derive the rankings and results, a model was first constructed with stochastic variables that were used to represent each of the green pea processor's strategies and develop the summed discounted after tax net income for five years in the future. @Risk simulation was then used with 10,000 iterations to estimate output distributions for each strategy that would be inserted into the SERF analysis to rank the strategies over a range of risk aversion measures. The four strategies are summarized in Table 7. The results of the base case along with the results from the sensitivities for the variables that have a significant impact on the ranking of the four procurement strategies are presented in this chapter. The chapter is divided into a section describing the base case and its results, results of the sensitivities and their implications, and a summary of the implications.

Table 7. Procurement strategies

Strategy 1	Buy from the spot market in the NC region only.
Strategy 2	Buy in both regions from the spot market only.
Strategy 3	Forward contract in the NC region only while buying remaining needed peas in both regions from the spot market.
Strategy 4	Forward contract in both the NC & SW region while buying remaining needed peas in both regions from the spot market.

Base Case Results

The base case for the model of each strategy has a 35% market share in the NC region, 20% market share in the SW region, no yield correlation between regions, $4/bushel/loaded mile transportation cost from the SW region, forward contract price of $14.71/cwt, and the forward contract percentage in each region at 10%. The remaining model variables do not change in the analysis. Figure 6 shows the rankings of the procurement strategies from SERF analysis using the negative exponential utility function. The strategies are ranked over a range of risk aversion levels. A high risk aversion level indicates the processor is willing to take on less risk. The certainty equivalents of each strategy are shown in thousand dollars of the discounted after tax net income. Based on the results shown in Figure 6, the dominant strategy for the processor is either forward contracting in the NC region or forward contract in both the NC and SW regions represented by the red and black line, respectively.

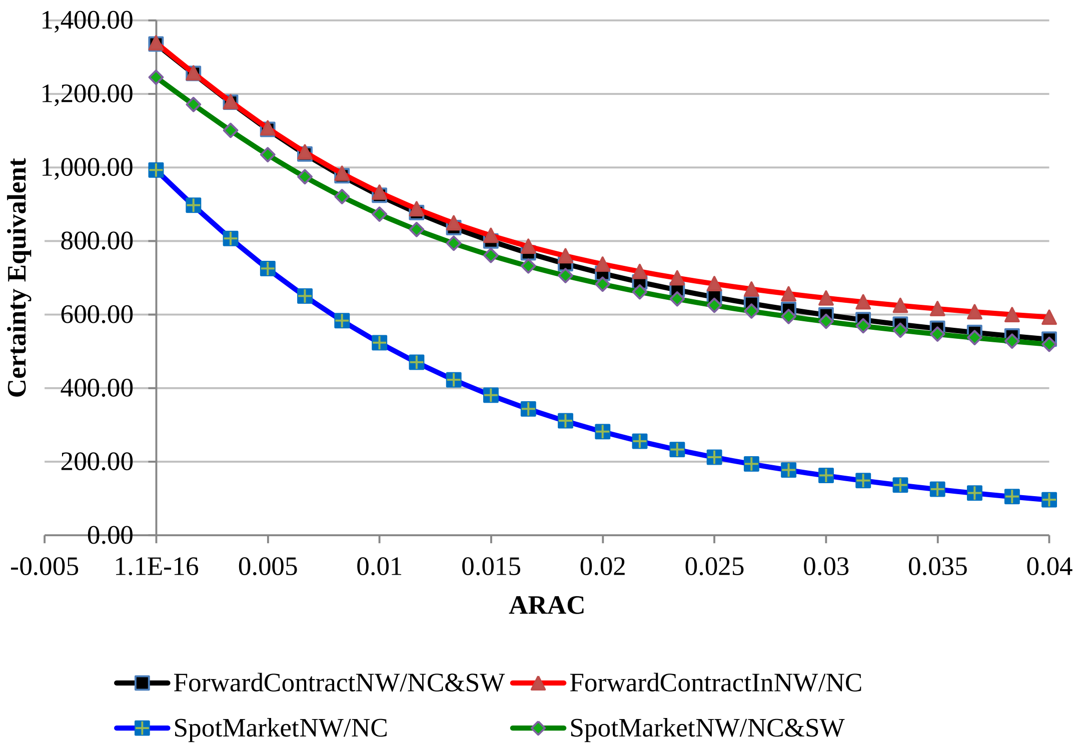

Figure 6. Base case SERF results

Once the absolute risk aversion coefficient (ARAC) reaches 0.02 and above, the processor is willing to take on less risk and prefers the procurement strategy of only forward contracting in the NC region while buying the remaining needed supplies from the spot market of both regions.

Determining the best procurement strategy for the green pea processor depends on the processor's attitude towards risk in the base case. There are only two strategies the processor needs to analyze in order to decide the best strategy based upon the results from the base case. The strategies of only buying from the spot market are dominated by the strategies that involve forward contracts. This indicates that, with the base case assumptions, forward contracting is the better strategy than only buying from the spot market as is shown in Figure 6. The forward contracting strategies rank higher than the spot market buying strategies because forward contracting mitigates price risk by locking in a price for future delivery with a farmer. Price risk in green field peas is large. Therefore, locking in a fixed price for a certain amount of green peas explains some of the price risk and provides higher profits. However, the processor is also facing the risk of buying off-grade green peas from forward contracting. This model assumes the processor accepts all of the peas that were forward contracted, regardless of quality, therefore reducing profits because there are lower gross margins for low quality peas than spot market purchases of higher quality peas. Yet, the forward contracting strategies do not significantly rank higher than the strategy of buying from the spot market from both regions. However, Figure 6 does show that diversifying ranks much higher than only buying from one region.

The important finding from the base case results is the difference between buying only from the spot market from the NC region and the strategy of buying from the spot market from both regions. Figure 6 shows buying from the spot market in both regions greatly increases profitability and dominates the other spot market buying strategy for all levels of risk aversion. The significant ranking difference is due to the processor being able to consistently meet their total procurement needs through buying from the SW region whereas only buying from the NC region on the spot market did not meet their needs, consequently, resulting in lower profits.

These results determine buying from both regions in the green field pea industry in North Dakota is an improved buying strategy when compared to only buying in one region from the spot market.

The results from the base case present a number of important conclusions. The main conclusion to note is the improvement on profitability that diversifying by buying from another region has. Some of the difference can be explained through the size of the market share as the size of the market share affects the amount and quality of peas the processor is able to procure. The market share is a variable that is analyzed later in the sensitivity analysis so this relationship will be tested. Another important finding to note is the improvement forward contracting has on profitability compared to only buying from the spot market in both regions. The findings also show that forward contracting in the NC region is the overall best strategy for absolute risk aversion about 0.20. This is due to the increased amount of off-grade quality green peas that were bought from forward contracting in both regions that resulted in lower profits. Whereas the forward contracting in only the NC region strategy did not procure as much off-grade quality green peas and was the best procurement strategy for very risk averse decision makers.

Sensitivities

Market Share

Market share is an important factor in the model and in the pulse industry. Based on the preliminary results of changing the market share values, the market share has a significant impact on the profitability and ranking of the strategies, rightly so due to the processor being able to buy more discriminately. The level of market share in each region affects the amount of hundredweight the processor can buy as well as the quality of peas they are able to buy. The larger the market share the processor has the more premium quality and high quality peas they can buy and, thus, earn higher profits due to higher margins associated with better qualities. A large market share gives the processor the ability to consistently meet their buying demand and run at full capacity even in years when yields are low. A low market share means the processor is more susceptible to swings in production. A small decrease in production from the processor's buying region can vastly affect the processor's profitability. Conversely, a large decrease in production is needed in order to have a negative effect on a processor with a large market share. Based on in-person interviews with those in the industry, the market share was assumed to be 35% for the NC buying region and 20% for the SW region. The market share in the NC region was increased to 45% and the market share in the SW region remained the same in order to determine the effect on the ranking of the strategies and profitability.

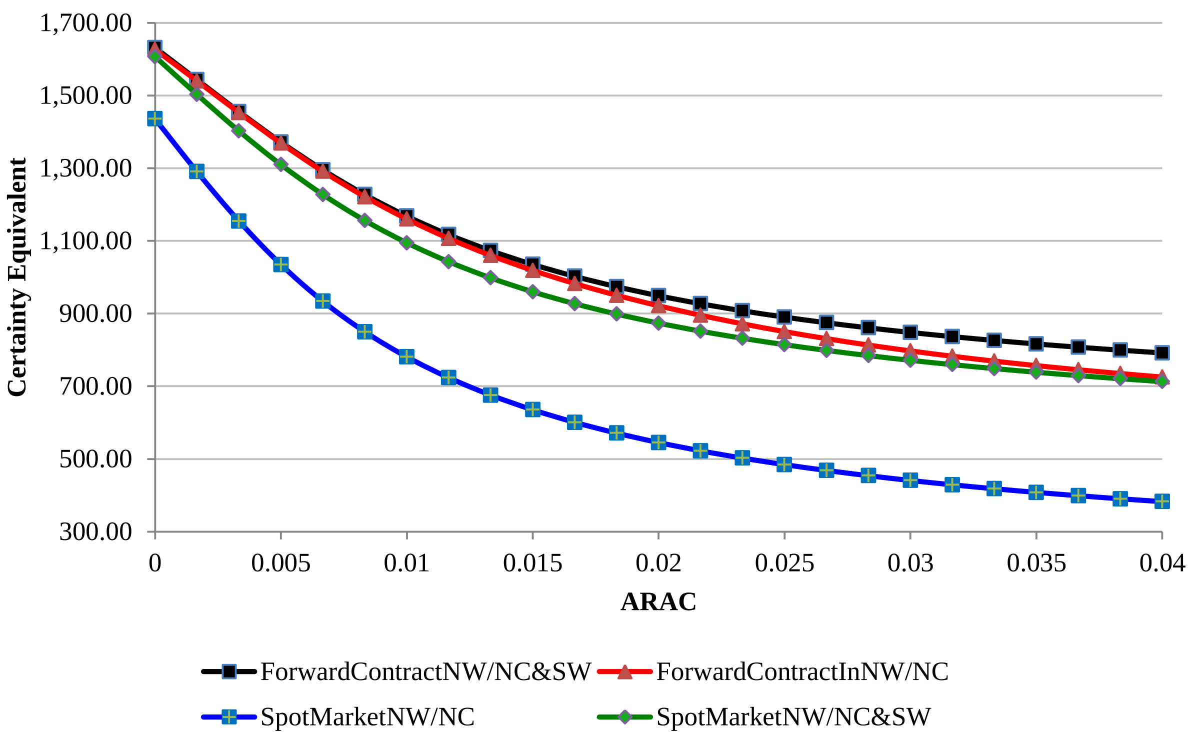

Figure 7. SERF results for increase in percent market share

The results in Figure 7 show that an increase in market share in just one region has an impact on the profit for all strategies. The profit levels for the strategies increased sharply compared to the base case represented by Table 8.

Table 8. Base case certainty equivalents vs. increase in market share certainty equivalents

ARAC	BC1	MS1	BC2	MS2	BC3	MS3	BC4	MS4
0	1,408.56	1,721.19	1,413.45	1,717.92	992.00	1,435.78	1,245.44	1,609.00
.0050	1,154.36	1,431.94	1,153.15	1,432.58	714.86	1,035.80	1,034.84	1,310.11
.0100	960.19	1,205.90	961.29	1,215.54	514.33	771.49	874.85	1,094.19
.0200	739.38	970.65	754.24	976.76	295.53	508.17	689.34	874.28
.0300	632.14	865.35	653.21	859.60	186.51	380.27	593.59	773.04
.0400	569.87	807.35	594.50	793.36	124.12	308.10	535.13	715.26

BC represents base case and MS represents increased market share in the North Central region. The value 1 represents forward contracting in both regions, the value 2 represents forward contracting in only the NC region, the value 3 represents spot market purchasing in only the NC region, the value 4 represents purchasing only in the spot market from both regions.

Table 8 represents the CEs from an increase in market share (highlighted cells in table) for the four procurement strategies and the CEs from the base case for the four procurement strategies. 1 is the forward contracting in both regions strategy, 2 is forward contracting in only the NC region, 3 is the spot purchasing in only the NC region strategy, and 4 is spot purchasing strategy in both regions. For example, BC1 stands for the CE values from the base case for the strategy of forward contracting in both regions. The increase in profit levels is due to the processor consistently being able to meet the capacity limits and the ability to purchase higher quality peas that are associated with higher margins when sold. When the risk aversion level is at zero, the processor is risk neutral, meaning that positive and negative outcomes are weighted equally; the forward contracting strategies and the spot market buying from both regions strategy are almost identical. The strategy of only buying in the NC region from the spot market, represented by BC1 and MS1 in Table 8, has the largest increase in profits compared to the other strategies. The large increase for the strategy of only buying in the NC region from the spot market is due to the low levels of hundredweight that were bought when the market share was only 35%. The processor is now able to buy much more hundredweight enabling them to meet their production capacity requirement more consistently, thus buying less from the SW region which has lower profitability due to the transportation costs.

The strategy of only buying from the NC region, represented by BC1 and MS1 in Table 8, from the spot market is dominated by the other strategies, even though profit increased greatly. An increase in market share does not change the premise that diversification through buying from different regions ranks higher than only buying from one region. A forward contracting strategy was also ranked the highest for all levels of risk aversion. In Figure 7, the forward contracting strategy of buying from both regions is the overall highest ranked strategy for all levels of risk aversion. The increase in market share gives the processor the ability to buy a larger amount of high grade green peas which offset the off-grade quality peas that were bought from forward contracting. The larger market share SERF results also indicate that forward contracting in both regions is ranked higher than only forward contracting in the SW region. This is due to the processor lowering their exposure to price risk and attaining more premium and high quality peas from the spot market due to the increase market share.

Increased Transportation Cost

The cost of truck movement from the SW region to the NC region can impact the cost of geographic diversification. Therefore, truck transportation costs were included in the SW region purchase cost. For the sensitivities, truck costs were included as they are relevant problems green pea processors are facing in the industry. The cost per loaded mile from the SW region was increased from $4/bushel/loaded mile to $6/bushel/loaded mile to determine if there is any notable impact on the strategies and their profitability.

The SERF results from an increase in transportation costs showed there was minimal effect on profits when risk aversion levels are low as shown in the appendix (Figure A.1). However, when the risk aversion levels increased, the profits decrease more rapidly compared to the base case results. A processor who is risk averse is more sensitive to the transportation costs than if they were less risk averse. The ranking of the strategies did not show meaningful changes from the base case. Though, one interesting result to note is the forward contracting strategies and the buying from both regions off the spot market strategy all converged onto each other as the risk aversion level reached high levels. With a high risk aversion level, the processor is almost indifferent between the three strategies; however, operating at the high risk aversion levels means the processor is very conservative. For most risk aversion levels, forward contracting in only the NC region was the best strategy overall for the reason that the processor avoids forward contracting in the SW region, consequently not paying the high transportation costs. Increased transportation costs shifted the relative benefits and costs of geographic diversification.

The combined impact of increased transportation cost and market share in the NC region was also estimated with the SERF results shown in the appendix (Figure A.2). The profits once again increased due to the increase in market share but were not as large as an increase in market share with no transportation costs adjustment, which is to be expected. The ranking of the strategies did change quite significantly. The forward contracting strategies were the highest ranked for the processor but there was no difference between the forward contracting strategies. In the sensitivities, when market share and transportation costs were increase separately, there was a clear best forward contracting strategy but in this case there is no difference over the range of risk aversion levels. A reason for this change may be due to the increase in market share and increase in transportation cost offsetting one another causing indifference between the two strategies.

Increase in Forward Contracting

According to the base case results, forward contracts are a useful tool to reduce the price risk faced by a processor. The strategy that utilizes forward contracting in both regions assumes 10% of the total production in each region is forward contracted while the other strategy using forward contracting has 10% of total production in the NC region only forward contracted for the base case. A sensitivity analysis was done by increasing the forward contracting percentages for both strategies from the assumed 10% level to 20% with the results shown in Figure 8.

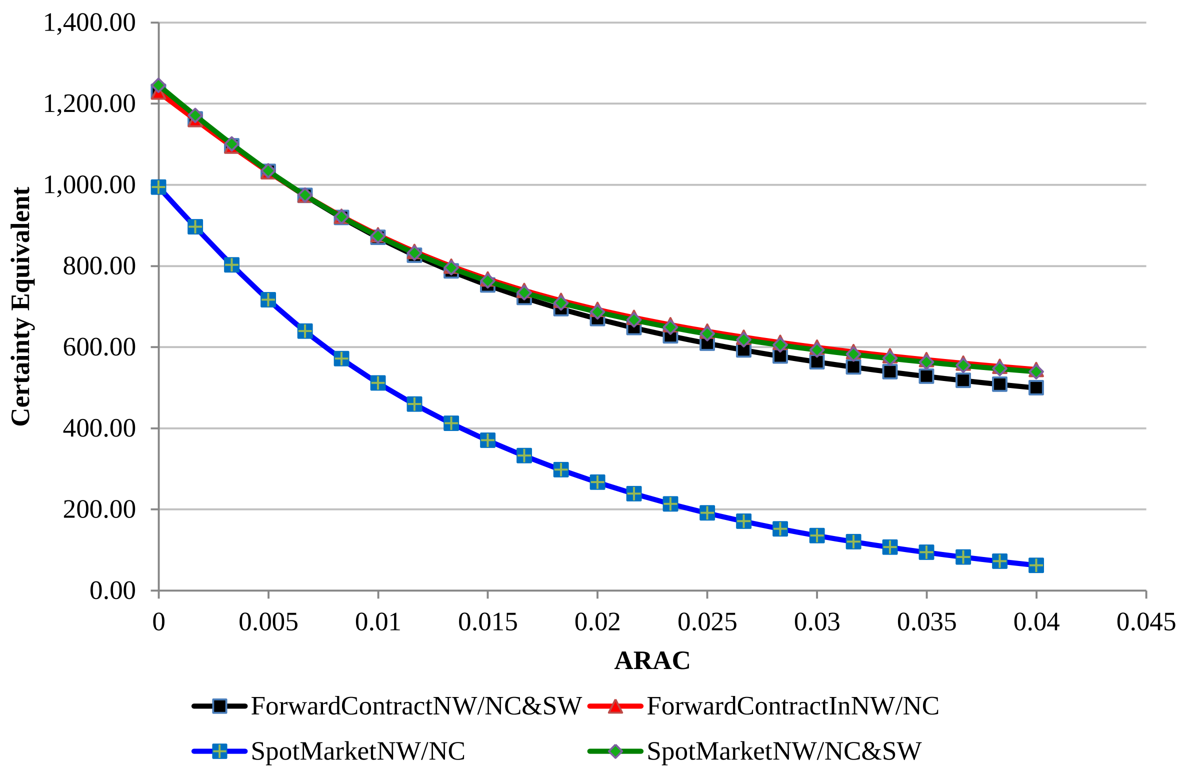

Figure 8. SERF results with forward contracting percentage increased

Forward contracting is an important feature in procuring grain and specifically specialty crops due to the lack of a futures market that can be used as a reference price as well to hedge price risk. An objective of this project is to determine if forward contracting is an effective tool to use in a procurement strategy. Based on knowledge obtained through in-person interviews, forward contracting is not a commonly used tool for green peas especially before planting. Additionally, through in-person interviews, forward contracts are used more commonly before harvest when the processor has a better idea of the quality of the green peas. However, forward contracting is becoming more common and increasing in importance.

The results presented an important aspect of forward contracting and the assumptions made for this project. In this illustration, an increase in forward contracting from 10% to 20% of total production reveals forward contracting is not the dominant strategy. The strategy of buying in both regions from the spot market is very similar to the forward contracting strategies. The base case results showed that forward contracting strategies ranked higher than the spot market strategies, but when the forward contracting percentage increased, the strategy of buying in both regions from the spot market was mutually the higher ranked strategy. The reason is due to the assumption that the processor is buying all of the green peas that are produced under the forward contracts. Therefore, the processor is going to accept off-grade quality peas leading to lower profits. As a result, an increase in forward contracting is associated with an increase in the amount of off-grade peas bought, leading to lower profits and decreasing the value of the strategy.

Increase and Decrease in Forward Contract Price

The amount forward contracted was found to have a noteworthy impact on the ranking of strategies. Increasing the amount forward contracted lowers profits resulting in the buying from the spot market in both regions strategy ranking as one of the best strategies for the processor to engage in. Figure 9 shows the distribution of after tax net income for the base case for the strategy of forward contracting from both regions and buying remainder from the spot market in both regions.

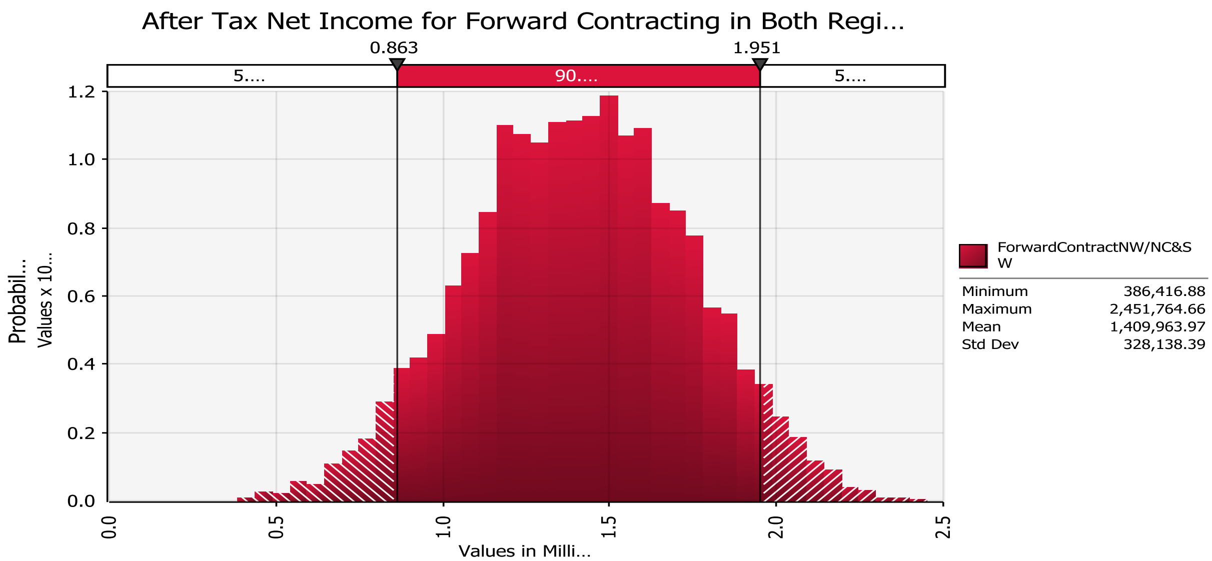

Figure 9. Probability density function for forward contracting in both regions for base case

An increase in forward contracting from 10% to 20% for the strategy of forward contracting in both regions results in smaller profits for the processor as shown in Figure 10 of the summed discounted after tax net income. Increasing and decreasing the forward contracting price is another scenario to the model that is an important aspect in forward contracting. For the sensitivity analysis the forward contracting percentage was reverted back to the 10% used in the base case and the forward contracting prices were increased and decreased by 20%. Under this scenario, the profits for a decrease in the forward contract price were noticeably higher than the base case profits and the forward contracting strategies were equally the best having increased the gap between the spot market buying strategies. The profits decreased due to the increase in prices paid but the forward contracting strategies were still better than the spot market strategies. The reason is the 20% increase was not large enough to affect the ranking of the strategies even though the profit levels were impacted.

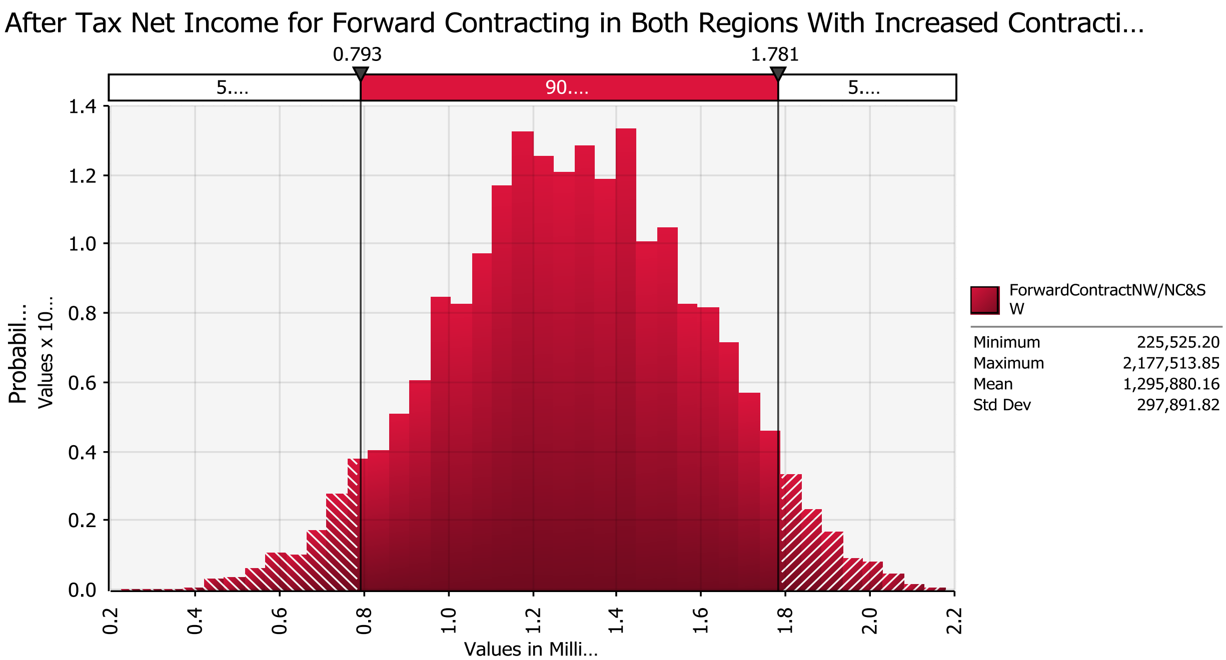

Figure 10. Probability density function for forward contracting in both regions with increase in forward contract percent

A sensitivity analysis was done to determine if an increase in forward contracting percentage and an increase in the forward contracting price had any bearing on the rankings. The forward contract prices for the two strategies that had contracting were increased by 20% of the original price while the forward contracting percentage was increased to 25%. The increase to 25% also increased the market share in the SW region, which was originally 20% in the base case. The results, shown in Figure 11, illustrate the magnitude these increases had on the rankings of the strategies.

The highest ranked strategy is easily buying in both regions from the spot market while the strategy of forward contracting in both regions dropped below the forward contracting in only the NC region strategy. The strategy of buying in both regions from the spot market is dominant for all levels of risk aversion due to the increased amount of off-grade quality green peas that were bought from increasing the amount forward contracted.

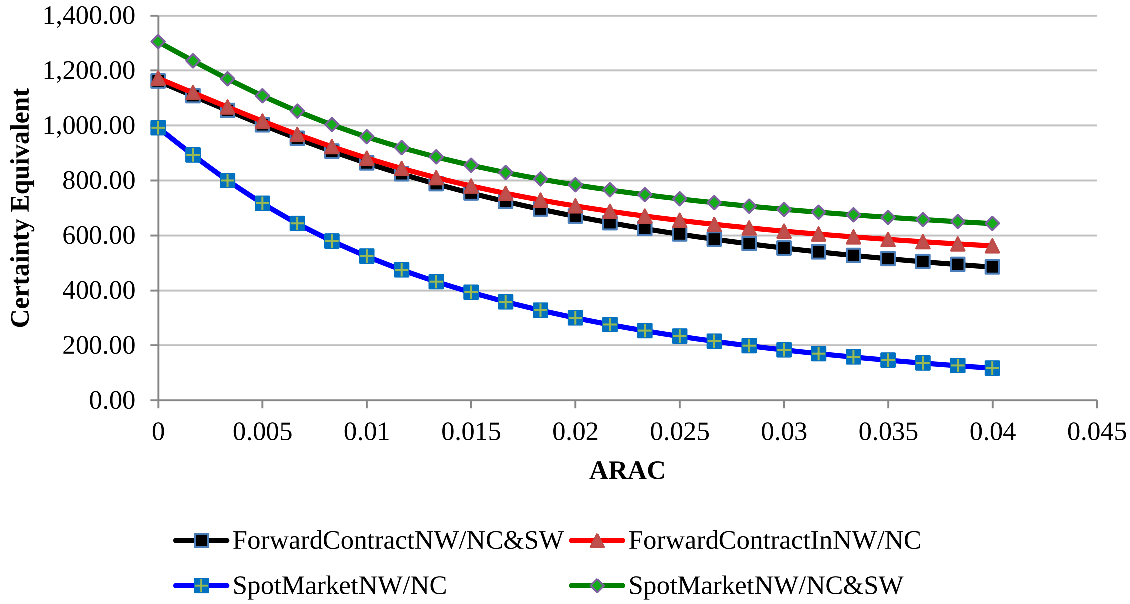

Figure 11. Increase in forward contract percentage and increase in forward contract price

Table 9 shows the CEs for the base case and the CEs from an increase in the forward contract price and amount forward contracted, represented by the shaded cells. The profits for the strategies that used forward contracting dropped greatly. The strategy of forward contracting in both regions had the larger decrease compared to only forward contracting in the NC region.

Table 9. Base case certainty equivalents vs. increase in forward contract price and forward contract amount certainty equivalents

ARAC	BC1	FC1	BC2	FC2	BC3	FC3	BC4	FC4
0	1,408.56	1,233.41	1,413.45	1,241.51	992.00	994.84	1,245.44	1,245.30
.0050	1,154.36	1,025.09	1,153.15	1,038.15	714.86	712.61	1,034.84	1,033.34
.0100	960.19	849.62	961.29	874.18	514.33	495.87	874.85	871.93
.0200	739.38	624.30	754.24	674.46	295.53	238.61	689.34	674.99
.0300	632.14	508.20	653.21	569.05	186.51	114.43	593.59	565.64
.0400	569.87	443.46	594.50	507.65	124.12	46.21	535.13	499.78

BC represents base case and MS represents increased market share in the North Central region. The value 1 represents forward contracting in both regions, the value 2 represents forward contracting in the NC region only, the value 3 represents spot market purchasing in only the NC region, the value 4 represents purchasing only in the spot market from both regions.

Positive and Negative Yield Correlation

The yield distributions for each region were correlated and cross correlated between one another. There is a distribution representing high yields and a distribution representing low yields for each region. There are a total of four yield distributions between the two regions and they are used to determine the production of green peas for a given year. In general, it is considered best to buy from regions where yields are negatively correlated because if one region does not have high production, the other region will. Whereas, positive correlation means that if one region has a high yielding year then the other will as well. Negative correlation is best when buying from two different regions to lower the risk of not having enough supply to meet demand of the buyers. The results from changing the correlation from uncorrelated to 0.80 positive correlation and 0.80 negative correlation are as expected and are shown in the appendix (Figures A.3 and A.4). The profits from negative correlation increased from the base case and the profits from positive correlation decreased from the base case. Once again, including forward contracting in the processors procurement strategy ranked the highest. However, the spread between the forward contracting strategies and the buying from the spot market in both regions increased in both instances relative to the base case results. This is due to forward contracting reducing some price risk and the processor being more exposed to price risk for buying in both regions versus the spot market strategy.

Summary

Four procurement strategies were ranked using SERF analysis from simulation data. The base case results indicated using only forward contracting in the NC region and buying the remaining needed green peas in both regions from the spot market was the best strategy. The results also indicated implementing a forward contracting strategy in one or both regions was better than only buying from the spot market. Sensitivities were made to determine how key variables affect the rankings and profits on the four strategies. Market share has a large influence on the profitability and the ranking of the strategies. The results indicate that an increase in market share increases profits and ranks the strategy of forward contracting in both regions and buying the remaining needed peas from the spot market in both regions as the best strategy. The effect of transportation cost was also evaluated. An increase in transportation cost decreases the profitability of the strategies as well as reduces the spread between the rankings of the strategies.

Forward contracting is an important aspect to procuring grain and determining the effect on the ranking of the strategies is an important objective for this project. Increasing the forward contracting percentage or increasing the amount bought using forward contracting from 10% to 20% revealed it is not the best strategy to use forward contracting due to the increased amount of off-grade quality peas being purchased through the forward contracts. Increasing the forward contract price also revealed that profitability is reduced. Moreover, increasing the forward contract price and the amount forward contracted simultaneously results in buying from both regions in the spot market as the dominant strategy. Ultimately revealing that forward contracting is a useful tool but too much of it and at the wrong price can be costly for the processor based on the assumptions used for the contract design.

The correlation between the yields of the two regions did not have a significant impact on the processor’s procurement strategies as they were other variables that had a larger impact on profits such as the price, market share, or amount forward contracted. Profits decreased when the correlation was highly positive while profits increased when the correlation was negative but the ranking of the procurement strategies did not change in either case.

CHAPTER 6: SUMMARY AND CONCLUSIONS

Problem

Specialty crops are risky to produce and process. Many require atypical equipment to produce, harvest, transport, and process the crop while almost all of the same equipment can be used to produce corn, soybeans, spring wheat, and winter wheat. Specialty crops typically have small areas of land where the crop has a competitive advantage. These small areas make it hard for processors to buy specialty crops due to the chance of having their entire buying area damaged. Along with small production areas, many specialty crops have high quality standards as they are used for human consumption. Corn and soybeans have much more relaxed quality standards and many more options to sell to if the quality is exceedingly poor. Price risk is another important issue those working with specialty crops toil with. There is no futures market for farmers and processors to derive a price from or hedge positions for specialty crops. Many specialty crops are grown in North Dakota due to its diverse soil and weather attributes across the state. The focus of this study was on dry edible green field peas in North Dakota as they experience a wide range of risks and are a good representation of a specialty crop in North Dakota.

Procuring green peas in North Dakota is difficult. Green peas are grown in the northwestern, the north central, and the southwestern part of the state. Also, there are areas in Idaho, Montana, South Dakota, Nebraska, Washington and Canada that grow field peas but the focus for this project was the growing regions in NC and SW North Dakota. These small areas of production are worrisome for processors as a storm, disease, drought, or any other production problem has the ability to wipe out the entire green pea crop in that area creating significant challenges for a processor that only buys in the particular area that was affected. Production shortage in the buying area for the processor can result in no inventory for the processor forcing it to purchase from other processors or grain elevators, where prices will be much higher, to meet its buyer's demands. Buying from a different region with yields that are uncorrelated can be an effective procurement strategy. However, buying from another location introduces more yield variability and higher transportation costs along with the existing issues of quality and price risk.

Objectives

The primary objective of this project was to develop a model that ranks various procurement strategies using stochastic efficiency with respect to a function (SERF) analysis for a green pea processor operating under maximum capacity while facing risks and uncertainties. The risks and uncertainties of being a green pea processor involve prices, yield variability, transportation, and product quality. With these complexities, the processor needs to determine the best strategy to protect itself and ensure a stable future. This project assessed four various procurement strategies available to the processor. The first strategy was the processor buying from their surrounding area, in NC North Dakota, on the spot market. A second was buying from the current NC region and the new SW region all on the spot market. The third strategy involved forward contracting in only the NC region and buying the remaining needed peas on the spot market in both regions. Finally, forward contracting in both regions and then buying the remainder on the spot market from both regions was analyzed.

Diversifying buying regions was an important element of the strategies that were analyzed in order to determine if diversification really is valuable for green pea processors in North Dakota. There are obstructions to diversifying, however. There needs to be a strong resolve by farmers in the region to grow green peas so there is consistent adequate annual supply. This is a concern with green peas as they are a specialty crop with competing crops that are easier to grow. Determining if diversifying is a good strategy and what type of diversification strategy were two of the main objectives in the analysis.

Forward contracting is a useful tool to procure grain as it reduces the variability in prices by locking in a fixed price for delivery in the future. However, based on in-person interviews with those in the industry, forward contracting is not widely used within the industry. One objective of this project was to determine the effect forward contracting has on the ranking of the four procurement strategies. Also, another objective was to compare different levels of forward contracting to determine the impact on the processor's risks and returns, and how the price levels of the forward contracts impacted the ranking of the strategies.

An important aspect in procuring any type of grain is the market share in the buying region. How much can the processor buy in any given year greatly affects their buying strategy due to the ability to consistently meet their buying demand and the ability to be selective in the quality they buy. Therefore, analyzing the effect market share had on the procurement strategies was another objective for this project.

A very important objective of the project was to develop a model that is an easy to use tool that can be applied to the various specialty crops in North Dakota. Also, the model was constructed in a way that it can be used to assess processors of various sizes so results can be seen in a timely manner and modifications can be made without difficulty.

Procedures

SERF is used to rank the procurement strategies for the processor while taking into account price risk, yield variability, quality risk, and transportation issues. There are four strategies for the processor that are modeled to derive the summed discounted after tax net income for five years in advance from the current year, 2014. This methodology allows the processor to determine the best expansion and contract strategy that takes advantage of the market opportunities in an easy to interpret manner.

SERF

The project used stochastic efficiency with respect to a function analysis to rank the four procurement strategies. SERF uses utility efficient alternatives for ranges of risk attitudes. SERF orders alternatives in terms of certainty equivalents (CE) as a selected measure of risk aversion varied over a defined range (Hardaker et al., 2004a). SERF can determine an efficient set as it picks the utility efficient alternatives and compares them simultaneously. SERF is fundamental in that it can be used in a standard spreadsheet and the results are graphed in an easy to read manner.

Review of Results

Base Case

The base case for the model of each strategy has a 35% market share in the NC region, 20% market share in the SW region, no yield correlation between regions, $4/bushel/loaded mile transportation cost from the SW region, forward contract price of $14.71/cwt, and the forward contract percentage in each region at 10%. The remaining model variables do not change in the analysis. Figure 12 shows the rankings of the procurement strategies from SERF analysis using the negative exponential utility function. Based on the results shown in Figure 12, the best strategy for the processor is either forward contracting in the NC region or forward contract in both the NC and SW regions to a 0.20 level of risk aversion.

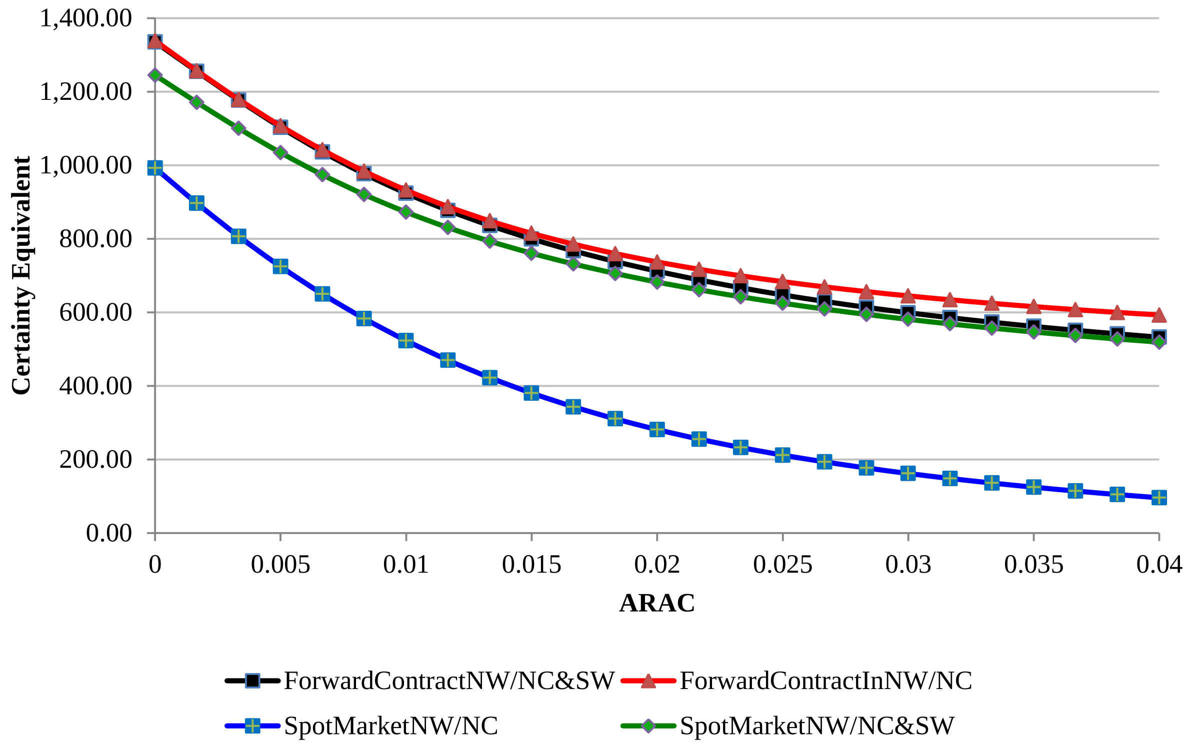

Figure 12. Base case SERF results

Determining the best procurement strategy for the green pea processor depends on the processor's attitude towards risk in the base case. The strategies of only buying from the spot market are dominated by the strategies that involve forward contracts. This indicates that, with the base case assumptions, forward contracting is the better strategy than only buying from the spot market as is shown in Figure 12. The forward contracting strategies are better than the spot market buying strategies due to the forward contracting buying strategies mitigating price risk through the fixed price. Price risk in green field peas is large and has considerable variability. Therefore, locking in a fixed price for a certain amount of green peas reduces some of the price risk and provides higher profits.

The main conclusion to note is the drastic improvement in profitability that diversifying by buying from another region has. Some of the difference can be explained through the size of the market share. Another important finding to note is the improvement forward contracting has on profitability compared to only buying from the spot market in both regions. The findings also show that at a 0.20 aversion level, forward contracting in the NC region is the overall best strategy. This is due to the increased amount of off-grade quality green peas that were bought from forward contracting in both regions that resulted in lower profits. Whereas the forward contracting in only the NC region strategy did not procure as much off-grade quality green peas and was the best procurement strategy for a certain range of risk aversion as a result.

Sensitivities

Sensitivities were made to determine how key variables affect the rankings and profits on the four strategies. Market share has a large influence on the profitability and the ranking of the strategies. The results indicate that an increase in market share increases profits and shows the strategy of forward contracting in both regions and buying the remaining needed peas from the spot market in both regions as the highest ranked strategy. The effect of transportation cost was also evaluated. An increase in transportation cost decreases the profitability of the strategies as well as reduces the spread between the rankings of the strategies.

Forward contracting is an important aspect to procuring grain and determining the effect on the ranking of the strategies was an important objective for this project. Increasing the forward contracting percentage, from 10 percent to 20 percent, or increasing the amount bought using forward contracting, from 35 percent to 45 percent, revealed it was not as favorable as expected. Increasing the forward contract price also revealed that profitability was reduced. Moreover, increasing the forward contract price and the amount forward contracted simultaneously resulted in buying from both regions in the spot market strategy was the dominant strategy. Ultimately revealing that forward contracting is a useful tool but a high level of forward contracting and at a high price level can be costly for the processor. As seen in Figure

13, for the processor, an increase in the forward contract price and an increase in the amount forward contracted resulted in forward contracting being a less attractive option.

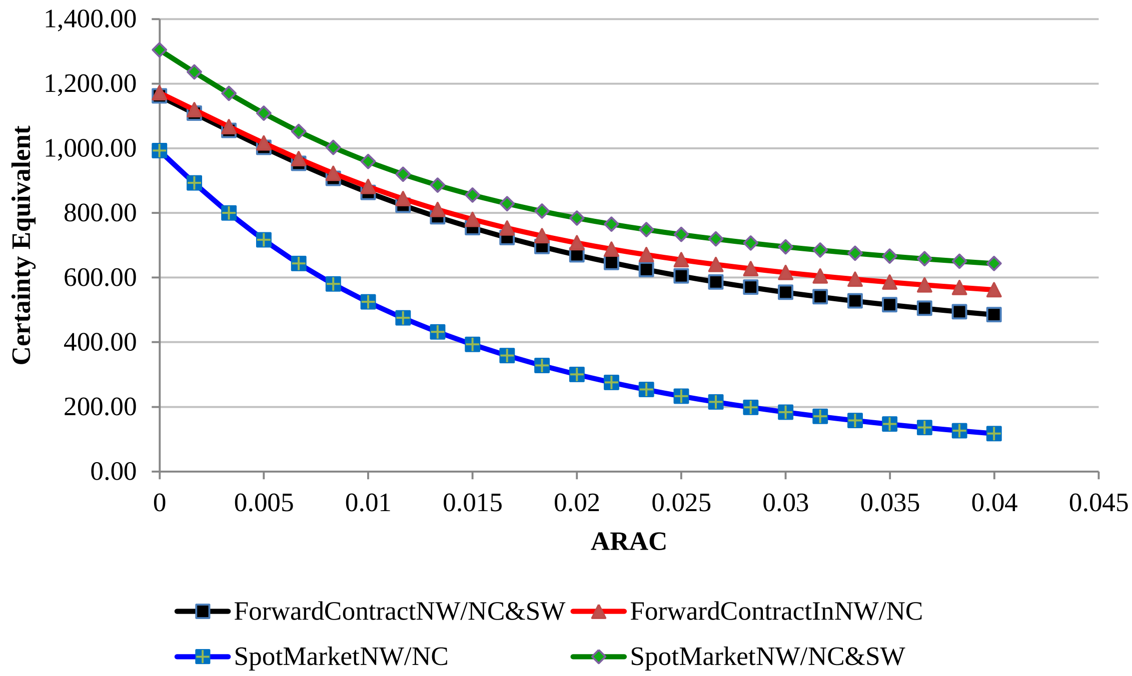

Figure 13. SERF results for increase in forward contract percentage and forward contract price

The correlation between the yields of the two regions did not have a noteworthy impact on the rank of the processor's procurement strategies. Profits decreased when the correlation was highly positive while profits increased when the correlation was negative but the ranking of the procurement strategies did not change in either case.

Processor Implications

The results from this analysis show that geographical diversification ranks higher than only buying from one region. For every scenario, buying from one region was the worst procurement strategy the processor could have implemented. It was also found that forward contracting is important to have in a procurement strategy for green peas. In most scenarios, some form of forward contracting was the highest ranked strategy. However, there is a point where forward contracting is no longer the best procurement strategy and profits start to diminish rapidly due in large part from the increase in off-grade quality peas purchased under the contract. There is a price level where forward contracting is no longer the best strategy as well. Determining at which level the amount forward contracted and at what price level profit starts to decrease for a particular processor is feasible through the model. From the assumptions made from in-person interviews, the data collected, and the results found, the best procurement strategy for a green pea processor is buying from more than one region while engaging in some forward contracting either in one or both regions.

Contributions, Limitations, and Further Research

This project contributes to the literature by modeling a green pea processor that is exposed to yield, price and quality risk and ranking its procurement strategies using SERF analysis. The results are obtained from the summed discounted after tax net income that was simulated with 10,000 iterations for each strategy for every scenario and are then ranked by SERF to compare strategies. The model includes financial statements for the processor and is easy to adjust the model for various processors working with alternative crops.

The modeling and methodology technique has not been used before in green field pea analysis, especially in ranking procurement strategies. There has been analysis done using SERF in agriculture but no one else has focused on green field pea processing.

The findings of this project are limited in that the data used to derive the yield distributions that are then used to estimate the total production in the regions were difficult to accurately measure. The yield data that is available through USDA NASS is from 2005 through 2013 but the information is not comprehensive due to the low number of usable reports in the counties that grow peas so yields were not recorded in some instances. In order to get realistic yield data, test plot data from Dr. McPhee at NDSU was needed. The plot data showed higher yields compared to those from NASS. Therefore the plot data was divided by a fixed factor that would give realistic yield distributions. The yield data recording is an area that needs improvement for green field peas in order for there to be accurate analysis.

Price data was also limited due to the lack of information available from USDA AMS. The price gaps within the AMS data were filled using elevator level price data and trends in prices. The quality information is also another important feature that is limited in its representation in the model. Data for green field pea quality at the point of first sale does not exist. Therefore, the quality probabilities and margins for quality were obtained through in-person interviews with those that work in the industry. The model is also somewhat limited as assumptions about processing costs are made for a processor of a certain size with firm level financial information derived from processors of similar size in other specialty crops in North Dakota.

There are many opportunities for further research from the model and methodology used. The specifications in the forward contracts are something that can be evaluated in more detail. In this project, it was assumed the processor was going to buy all of the green peas they forward contracted even if there were off-grade peas produced. Further research can relax this assumption and evaluate different contract specifications in the forward contracts. Such as evaluating how an Act of God clause influences the rankings. Another could be evaluating specific quality parameters in forward contracts. The forward contract strategies with different contract specifications can be ranked to determine the best way to forward contract. The model and methodology can also be used in other crops that embody similar characteristics to a green field pea processor, such as durum wheat, malt barley, potatoes, or dry edible beans. Furthermore, the model and methodology can be applied to analyze a portfolio of crops for processing instead of just one crop. As well as analyze more than two regions. Further research can use the model and methodology to analyze procurement strategies that source product from around the world.

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APPENDIX

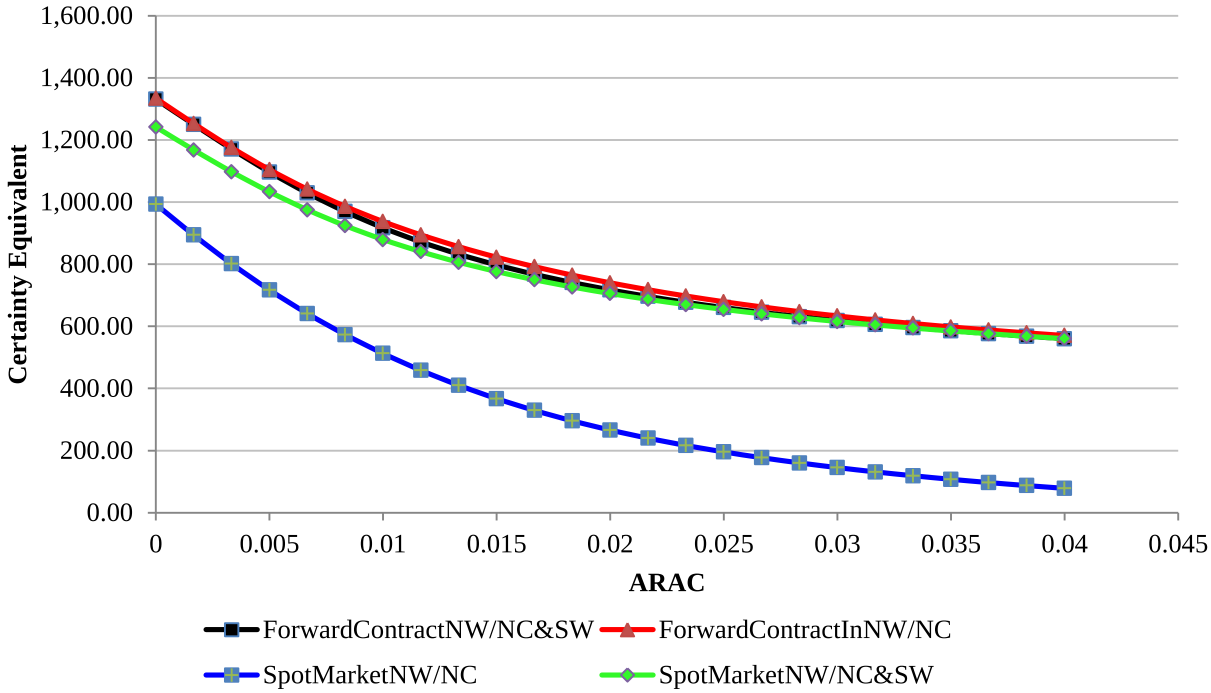

Figure A.1. Increase in transportation cost

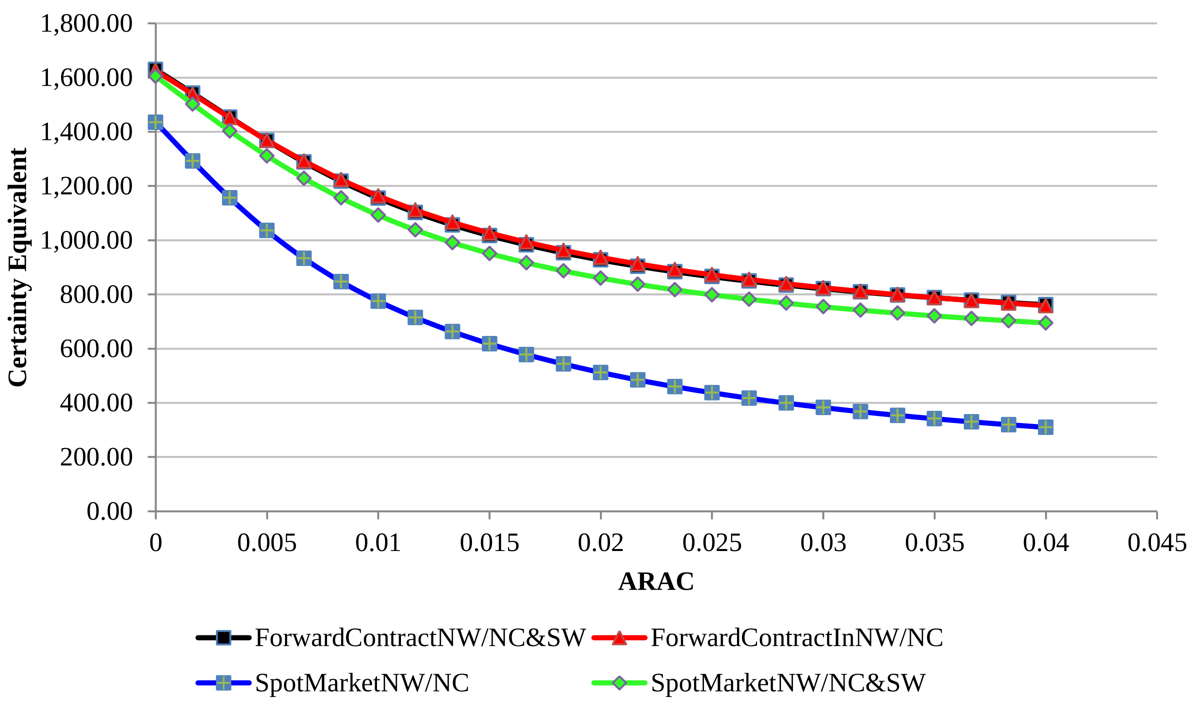

Figure A.2. Increase in transportation cost and increase in market share

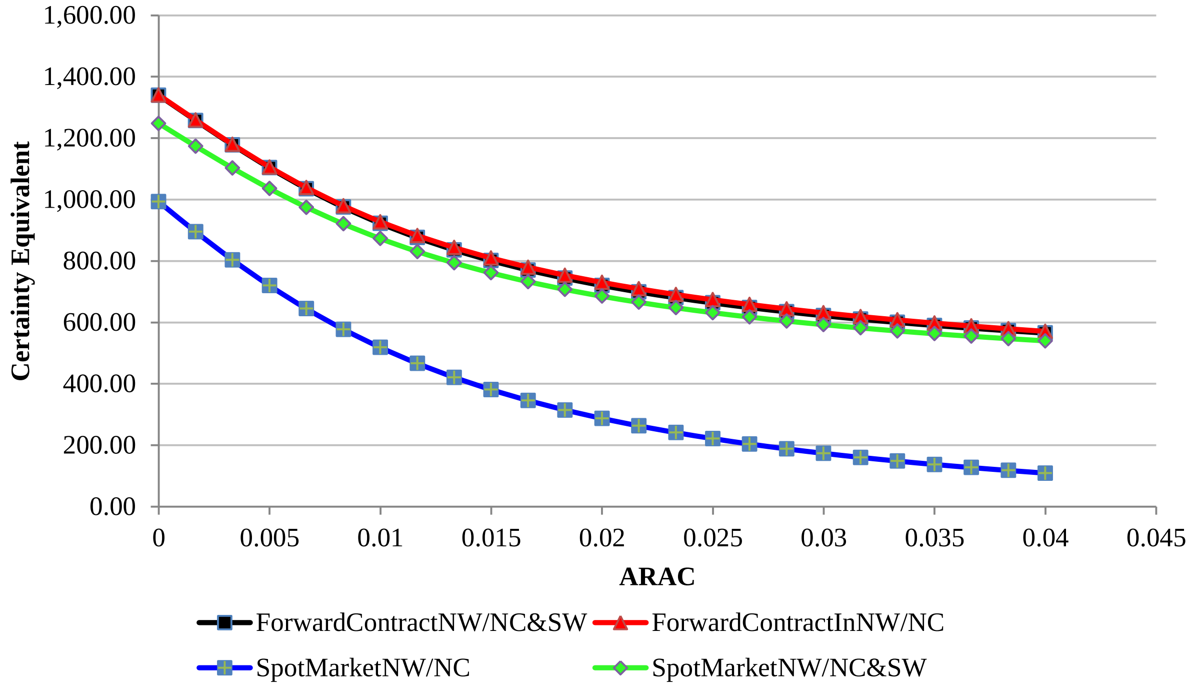

Figure A.3. Negative yield correlations between regions

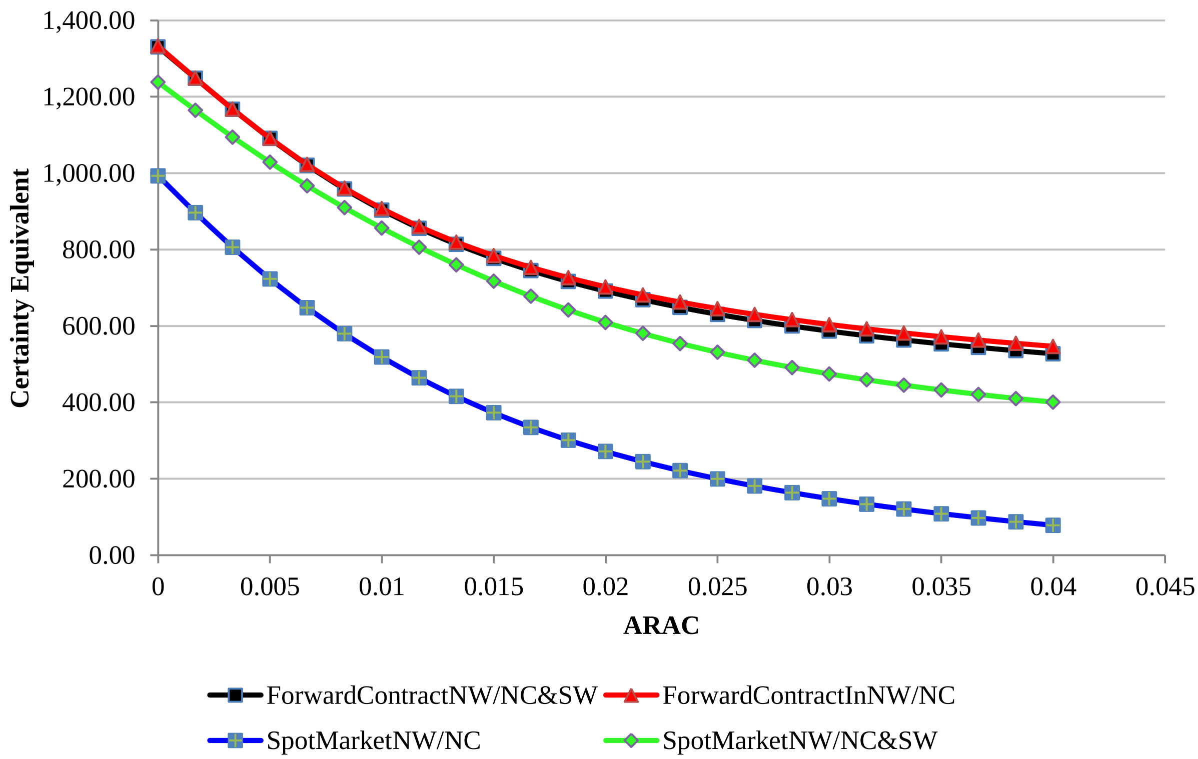

Figure A.4. Positive yield correlations between regions