ECONOMIC FEASIBILITY OF PRODUCING ETHANOL FROM DRY PEA AND CORN AS FEEDSTOCK IN NORTH DAKOTA: A RISK PERSPECTIVE

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

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ABSTRACT

Goel, Abhishek; M.S.; Department of Agribusiness and Applied Economics; College of Agriculture, Food Systems, and Natural Resources; North Dakota State University; December 2007. Economic Feasibility of Producing Ethanol from Dry Pea and Corn as Feedstock in North Dakota: A Risk Perspective. Major Professor: Dr. Cole Gustafson.

Dry pea has the potential to be an economical replacement for corn in North Dakota ethanol plants. Dry pea costs of production are less than corn because fewer purchased inputs are required and because dry pea offers a number of rotational benefits in small grain crop rotations. Dry pea can also thrive in arid regions of western North Dakota where annual rainfall is low.

This study develops stochastic economic models to evaluate the replacement potential of dry pea for corn as an ethanol feedstock. Results find that plant efficiency increases and input supply risks are reduced when dry pea replaces corn. However, at present corn/dry pea price ratios, dry pea is not competitive economically. Corn prices would have to rise more than 20% for dry pea to become competitive.

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LIST OF ABBREVIATIONS

CFDC ....Clean Fuel Development Coalition

CDS ....Condensed Distillers Soluble

DDGS ....Distillers Dried Grains and Soluble

ERS ....Economic Research Services

MTBE ....Methyl Tertiary Butyl Ether

NASS ....National Agricultural Statistics Services

RFA ....Renewable Fuels Association

USDA ....United States Department of Agriculture

1. INTRODUCTION

A large expansion of ethanol production is underway in the United States. The United States Department of Energy (USDOE) reported that the ethyl alcohol or grain alcohol, popularly called ethanol, is commonly used as an alternative fuel or as an octane-boosting, pollution-reducing additive to gasoline (USDOE, 2007). Starch is the primary raw material for the production of ethanol, and it is obtained throughout the world from various feedstocks such corn, sugarcane, and cellulose (plant fiber) biomass.

In 2006, the Renewable Fuels Association (RFA) reported that the world ethanol production reached about 13.5 billion gallons, led by the United States and followed by Brazil, India, and China (RFA, 2006). In the United States, ethanol production is led by Iowa, followed by Nebraska and Illinois, and it is expected to reach to 10 billion gallons by 2009 (RFA, 2006).

North Dakota ranks 12th in the production of ethanol with 3 operational plants producing 33.5 million gallons per year (mgy). Additionally, 3 new ethanol plants are currently under construction with an expected production capacity of 50 mgy, which would take the total production capacity to 83.5 mgy (RFA, 2006; Westcott, 2007).

Corn has been the principal source of starch to produce ethanol in the United States. Due to the rapid increase of ethanol production in the United States, demand and prices of corn have increased since 2004. The United States Department of Agriculture (USDA) estimated in early 2007 that corn prices would increase from the current average of $3.00/bushel to $3.75/bushel by 2009-10, as the percentage of corn consumed for ethanol production continues to rise (Westcott, 2007). Ethanol production consumed 14% of the corn produced in the United States in 2006, and it is estimated to grow to more than 30% of the crop by 2009-10 (USDA, 2007).

A small change in corn price has a huge impact on production cost. The profit/gallon of produced ethanol decreases by $0.035 for every dollar increase in the price of corn/bushel (Eidman, 2007). Since 2002, the increased average price of ethanol has lead to the growth of the ethanol industry compared to 1996 when average ethanol prices were lower ($1.35/gallon) than current prices ($2.5/gallon). However, a high price of corn reduces the profitability of an ethanol plant significantly.

North Dakota is facing a challenge to increase the production of corn as the existing plants expected to consume the crop produced in 2006 (Senate Bill 2391, 2007). Therefore, new ethanol plants will have to import corn from other states, further increasing the transportation cost.

In 2007 corn harvested acres in North Dakota increased by about 1 million acres and it is expected to further increase by 2 million acres in the next 2 years (Davidson, 2007). The expansion of corn industry in North Dakota may be constrained due to limited availability of corn varieties tailored to the arid and northern climate of the state. Lack of moisture and frost are two perils that have historically reduced corn yields in the state and new drought resistant corn varieties are needed to increase the production further.

1.1. Problem Statement

Due to the rising demand and uncertainty about availability of corn in North Dakota, there is a need to consider alternative crops for the production of ethanol. Previous research suggested that dry pea can partially replaces corn in ethanol production (Wilhelmi et al., 2007). Dry pea contains a high quantity of starch and protein, which is an important factor for the feasibility of ethanol production. Moreover, dry pea is available locally at lower prices than corn in North Dakota. The variability in prices of dry pea is less than the variability in prices of corn. Therefore, dry pea may be a suitable crop to partially replace corn in ethanol production by lowering the uncertainty of availability of corn and increasing the profitability of the plant.

1.2. Objective

The objective of the research is to develop an economic stochastic model for a typical 100 mgy Midwestern ethanol plant to evaluate the profitability and risk of using dry pea as a partial replacement of corn feedstock in proportions of 10% and 30%.

1.3. Hypothesis

It is expected that the partial replacement of corn by dry pea in 10% and 30% proportions in the production of ethanol would increase the net profit of the plant and decrease the risk of supply of corn.

2. LITERATURE REVIEW

This chapter is organized in three sections. The first section provides a background of ethanol, the history of ethanol production, information on ethanol produced throughout the world and the United States, the causes of increased production of ethanol, and a description of the dry mill process to prepare ethanol. The second section introduces dry pea as an alternative source of starch for the production of ethanol. The section includes information of chemical composition, climatic conditions, utilization, and world and United States production data of dry pea. The production of ethanol by partial replacement of corn with dry pea is also described in this section. The third section provides a summary of different feasibility studies of ethanol production reported in the literature.

2.1. Ethanol

Ethyl alcohol or grain alcohol popularly called ethanol is commonly used as an alternative fuel or as an octane boosting, pollution-reducing additive to gasoline (USDOE, 2007). In 2006, about 5 billion gallons of ethanol were produced in the United States. Ethanol is increasingly becoming popular and its production is expected to increase to 11 billion gallons by 2009 in the United States (RFA, 2006). The main raw material to produce ethanol is starch, which is primarily obtained from corn in the United States. However, starch can also be obtained from other sources such as potatoes and dry pea.

2.1.1. History of Ethanol Production

In 1908, Henry Ford was the first to propose the idea of ethanol production. However, the idea was not seriously pursued until 1978, when the United States suffered a domestic oil crisis due to the Arab oil embargo. The Clean Fuel Development Coalition (CFDC) reported in 2006 that the first Energy Act was put into place in response to the oil crisis. The act granted a 4 cent federal fuel excise tax exemption on the gasoline blended with at least 10% ethanol. The objective was to promote the domestic production of ethanol as an alternative to oil, and to reduce the dependence from imported oil.

In 1984, the Tax Reform Act raised the exemption from 5 to 6 cents. Later, with the Omnibus Budget Reconciliation Act, the tax incentive was extended until 2000, and the incentive rate was decreased from 6 cents to 5.4 cents. In 1988, the Alternative Motor Fuels Act was enacted to provide credits to automobile manufacturers for undertaking research to produce cleaner and more fuel economical vehicles.

Later, the Energy Policy Act of 1992 proposed a 30% utilization of alternative fuels by 2010. The Act also required that the federal and state governments and private fleet operators acquired alternative fuel vehicles. The Transportation Efficiency Act of 1998 was passed which extended the ethanol tax incentive until 2007. The Acts have been an instrument for the promotion of the ethanol production (CFDC, 2006).

2.1.2. World and United States Production of Ethanol

As the concern about the future supply of petroleum, a non renewable source, continues to grow, countries all over the world are gradually moving towards the production of alternative renewable sources of fuel as ethanol. Worldwide ethanol production is rising exponentially. In 2006, the world production reached 13.5 billion gallons. The United States led the world ethanol production (5 billion gallons), followed by Brazil (4.5 billion gallons), India, and China (RFA, 2006).

The United States production of ethanol touched a high record in 2006 and the increment continued in 2007 as shown in Figure 1. The 134 bio-refineries located in 26 states across the country produced almost 7 billion gallons of ethanol which was about 2 billion gallon more than in 2006. Since 2000, ethanol production increased more than 300% (RFA, 2006).

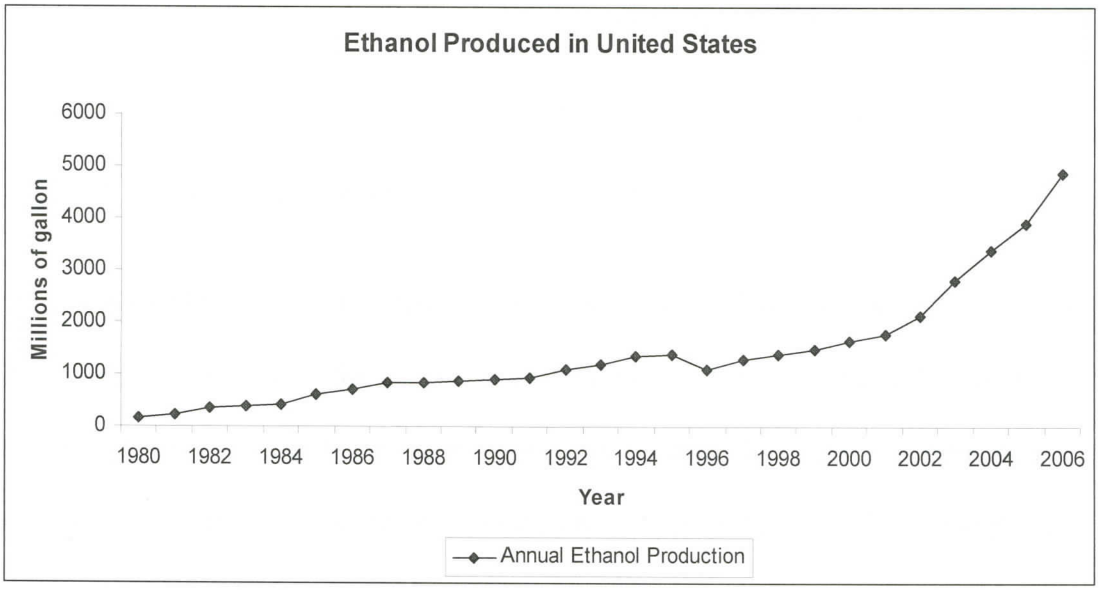

Figure 1. Ethanol Production in the United States.

As a consequence of the increasing production of ethanol, the number of ethanol bio-refineries in the United States is also increasing. In 2007, 24 new bio-refineries were built and existing bio-refineries added 2 billion gallons of production capacity. Additionally, at least 73 bio-refineries were under construction or began construction in 2006, which were expected to add 6 billion gallons of additional capacity by 2009. Figure 2 shows the current locations of bio-refineries in production and under construction in the United States (RFA, 2006).

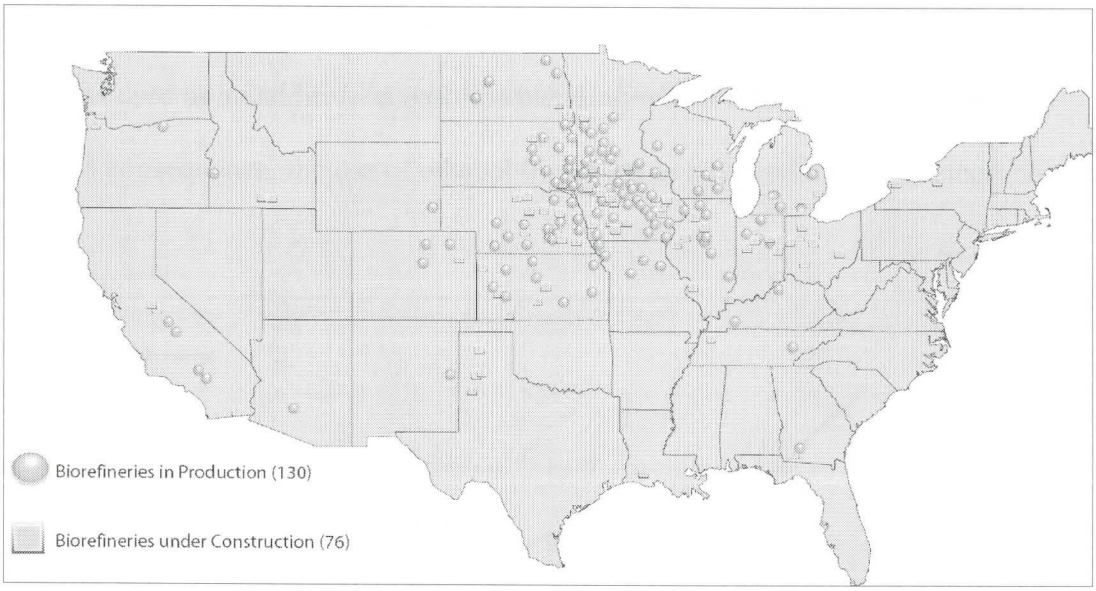

Figure 2. Ethanol Plant Locations in the United States.

2.1.3. Causes of Increasing Production of Ethanol in the United States

The primary reasons for the rise in ethanol production are the suitable market conditions backed by a steady rise in the price and demand of crude oil, and the policy incentives of the federal and state governments to the ethanol producers. Crude price averages which were $20 per barrel (refiners acquisition cost of import) in the 1990's reached approximately $56 per barrel in the summer of 2006 and the highest price with $100 per barrel in 2007 as shown in Figure 3. The price and demand of crude oil are expected to rise due to the world economic growth and the increased consumption from China, India, and other Asian nations (Westcott, 2007). In addition to the policy incentives of the federal and state governments, the Energy Policy Act of 2005 mandated that renewable fuel use in gasoline must reach 7.5 billion gallons by 2012. This policy also established provisions for gains in later years on line with growth of sold volume of gasoline or introduced volume in trade. Under the present law, tax credits equal to 51 cents are offered to blenders for each gallon of ethanol blended with gasoline. However, the legislation did not provide liability protection for methyl tertiary butyl ether (MTBE). MTBE was used as an additive in gasoline blending which was found to contaminate water, as a consequence, the use of ethanol increased as a fuel additive (Westcott, 2007).

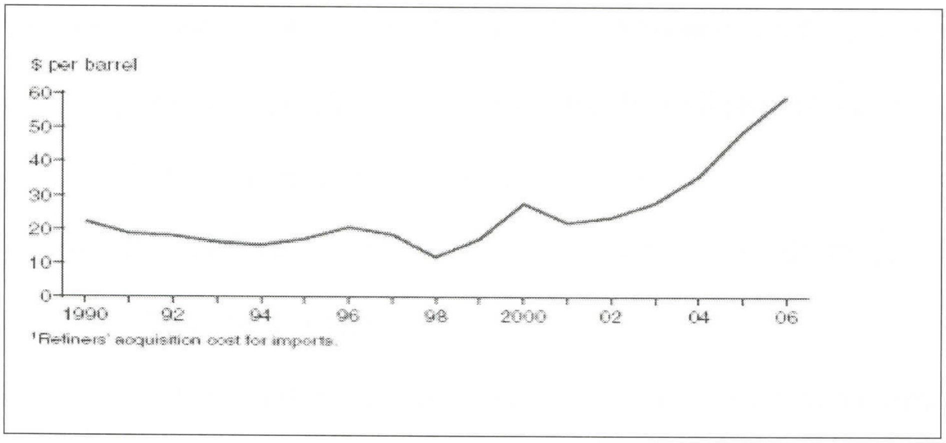

Figure 3. Crude Oil Price.

As per estimation of the RFA, 6 billion gallons of ethanol would be produced by 2009 which would result in a total production of 11 billion gallons. The expected production in future years will be above the mandate of the Energy Policy Act (7.5 billion gallons) as projected by the USDA in its long-term projections (Figure 4) (Westcott, 2007).

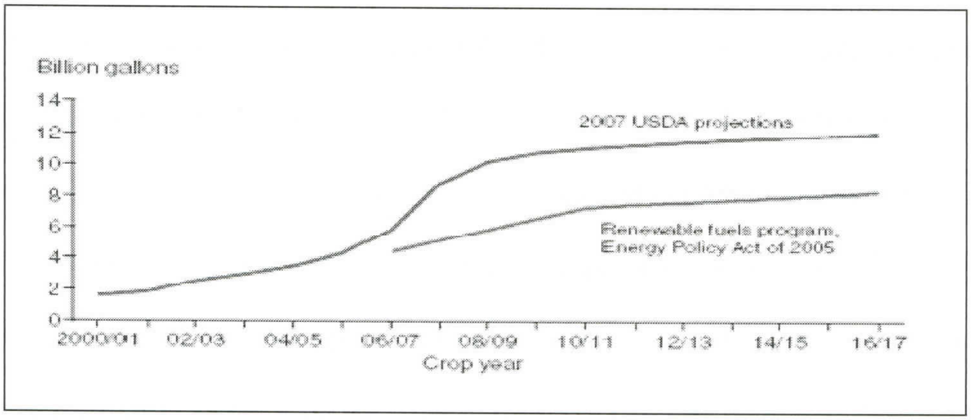

Figure 4. Projected Ethanol Production in the United States.

2.1.4. Production Process of Ethanol by the Dry Mill Process

Ethanol had been primary produced from corn starch by the dry or wet mill process. The principal difference between the processes is the initial treatment of the grain. This study focuses on the dry mill process, as the process was adopted by the majority of ethanol plants in the United States. As on January 2007, 82% of ethanol was produced from the dry mill process (RFA, 2007). The steps of the dry mill process are described as follows (RFA, 2007; Tiffany and Eidman, 2003).

Grinding: The entire corn is ground into flour by a hammer mill; the product of this step is commonly called "meal" in the industry.

Liquefaction: Water and the enzyme *alpha-amylase* are mixed with the meal and heated in cookers (120-150 °C) to liquefy the starch (conversion of starch to dextrose). The high temperature reduces the bacteria level in the mash. Ammonia is added as a nutrient for the yeast and for pH control.

Saccharification: After the liquefaction, the mash is cooled in cookers and transferred to a fermenter. The enzyme *gluco-amylase* is added for the saccharification process.

Fermentation: The process of fermentation is carried out for 40-50 hours in a tank. During the process, yeast is added to the mash to ferment the sugar producing ethanol and carbon dioxide. The mash is kept cool during the fermentation. The carbon dioxide produced during the fermentation process is collected and chilled to liquid. Carbon dioxide is used in the production of carbonated beverages or as flash freezing in food processing.

Distillation: During this process, the fermented mash, called "beer," is transferred to distillation columns to separate the ethanol from the residual mash called "stillage."

Dehydration: The alcohol solution collected from the distillation column is passed through a system to remove the water. Molecular sieves, consisting of ceramic beads, capture the remaining water from the ethanol solution. After undergoing the process, the ethanol is called anhydrous (without water).

Denaturing: Anhydrous ethanol is blended with about 5% denaturant (such as gasoline) to make it unfit for human consumption. Ethanol is finally ready for use.

Distillers Dried Grains and Soluble (DDGS): The residual mash is centrifuged to separate the solid fraction (coarse grain) from the liquid fraction (soluble). The liquid fraction is heated to form a solid concentrate called condensed distillers soluble (CDS). Then the CDS is mixed with the solid fraction (coarse grain) from which it was separated earlier to produce the DDGS. The DDGS, a high quality and nutritional livestock feed, contains 11% moisture content, 26% crude protein, 10% crude fat, and 12% crude fiber. The amino acid content and the balance of the DDGS depend on the type of process.

2.2. Dry Pea: An Alternative Source of Starch for the Production of Ethanol

Due to the use of corn in the ethanol production, the price of corn has increased. During 2006, about 14% of corn produced was consumed for the production of ethanol. Long-term projections indicate that more than 30% of the corn crop will be used for the production of ethanol by 2016-17. USDA long term projection indicates that the average corn price will be around \$3.75/bushel as ethanol production expands and then decline to \$3.30/bushel by 2016-17 due to the slowdown of ethanol expansion (Westcott, 2007).

In 2006, 20% of the corn produced in North Dakota was used for the production of ethanol. However, with the new ethanol plants, a consumption of 80% of the produced corn is expected. Therefore, for the future increase in ethanol production, alternative feedstock will be required. Dry pea is a suitable alternative feedstock to corn for the production of ethanol, due to the available content of starch (30%-50% starch). A feasibility study (Nichols et al., 2005) suggested that ethanol can be produced from starch obtained from dry pea by partially replacing corn starch from corn.

2.2.1. Dry Pea Introduction

Dry pea or field pea (*Pissum sativum L.*), a native crop of Southwest Asia, was one of the first crops cultivated by the man. It is a cool season annual legume crop that converts nitrogen from the atmosphere into nitrogen nodules on the plants roots. Presently dry pea is grown on over 25 million acres worldwide (McKay et al., 2003; Smith and Jimmerson, 2005). A wide variety of dry pea is available. The yellow cotyledon dry pea is the most widely produced followed by the green dry pea which is mainly produced in the United States (McPhee, 2003)

2.2.2. Chemical Composition of Dry Pea

Dry pea contains 18%-30% protein, 30%-50% starch, 4%-7% fiber, and 7% oil (Mcphee, 2003). Nichols et al. (2005) reported that dry pea is composed of roughly 46% starch, 23% crude protein, and 1.4% oil. However, the exact composition of dry pea varies slightly between sources. The dry pea tends to contain higher starch and lower protein as the production moves northward (Wilhelmi et al., 2007). The protein of dry pea contains high levels of lysine, making it a good dietary complement of cereals. The high dietary value has helped to sustain the worldwide consumption of dry pea (Mcphee, 2003).

2.2.3. Climatic Conditions Required for Dry Pea

A cool weather with evenly distributed rainfall and well-drained soil is required for the growth of dry pea. The optimal temperature range is from13 to 18°C. However, dry pea can also grow without considerable loss in productivity when temperatures range from 25 to 30°C. The growing period of dry pea is the same as wheat and it is harvested in the month of August, requiring an average of 60 days from planting to bloom and 100 days to mature (Oelke et. al., 1991; Mcphee, 2003).

2.2.4. Utilization of Dry Pea

Dry pea is an important source of protein for human consumption. Food applications include: canned, split, and whole pea markets. Protein, starch, flour, and fiber contained in dry pea are used in baked foods, baked mixes, soup mixes, breakfast cereals, processed meats, health foods, pastas, and purees. Dry pea is also cooked and eaten directly (Skrypetz, 2006). As animal feed, dry pea is the most important feed for hog followed by others such as poultry, cattle, livestock, swine, and ruminants (Skrypetz, 2006).

Dry pea is a rotational crop due to its ability to source its nitrogen requirement from the atmosphere by forming a relationship with the *Rhizobium* bacteria in the soil. The amount of nitrogen fixed varies with the species, soil condition, and climatic factors. Nitrogen fixed in the soil is then available for the succeeding crop. This process of nitrogen fixing is called inoculation. Dry pea provides a nitrogen credit of 40 pounds per acre (Haugen, 2007). This process helps to increase the fertility of the soil, increases yield, and reduces soil erosion. Dry pea also reduces the cost of nitrogen fertilizer and protects the soil from insects and many diseases (Skrypetz, 2006; Gregoire, 2007).

2.2.5. Production of Dry Pea

Dry pea was first grown in India, Pakistan, and adjacent areas of the former Union of Soviet Socialist Republics and Afghanistan. In 2004, 84 countries in the world produced 12.5 million ton of dry pea. For the past decade, the total production of dry pea has been stable. Since 1998, the concentration of production has shifted from France, to Canada and the United States. Production in dry pea in Canada increased as producers received higher returns by producing dry pea rather than traditional grains. In 2006, Canada was the largest producer of dry pea followed by France, China, Russia, and the United States.

The production of dry pea had increased in the United States due to government incentive programs for dry pea growers. Since 2002, dry pea growers were eligible for the benefit of the Farm Program. The program helped farmers to receive higher returns on their investment making dry pea cultivation viable (Price, 2002; Skrypetz, 2006).

In 2006, the United States accounted for about 8% of the world pea production with 902,000 acres producing the crop (Skrypetz, 2006). Total acreage of land under cultivation of dry pea in the United States has steadily increased since 2000 as shown in Figure 5 (USDA, 2007). North Dakota is the highest producer of dry pea followed by Washington, Montana, Idaho, and Oregon (Smith and Jimmerson, 2005). The USDA and the National Agricultural Statistics Service (NASS) reported that North Dakota produced 9,332 thousand hundredweight of dry pea in 2006 (USDA, NASS, 2007). The production of dry pea has increased steadily in North Dakota since 2000 (Figure 6) due to higher returns to the farmers, higher yields, and benefits received from the Farm Bill as discussed earlier (Haugen, 2007).

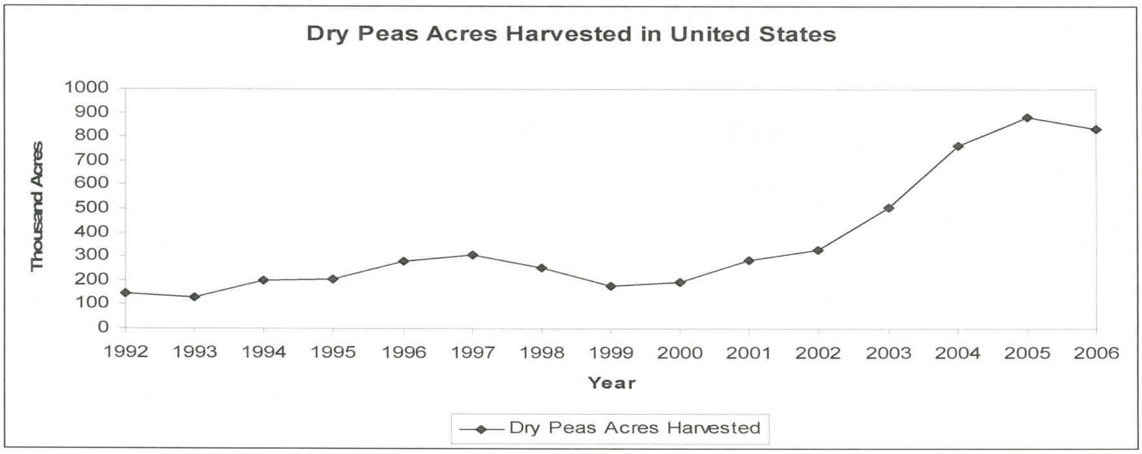

Figure 5. Dry Pea Acres Harvested in the United States.

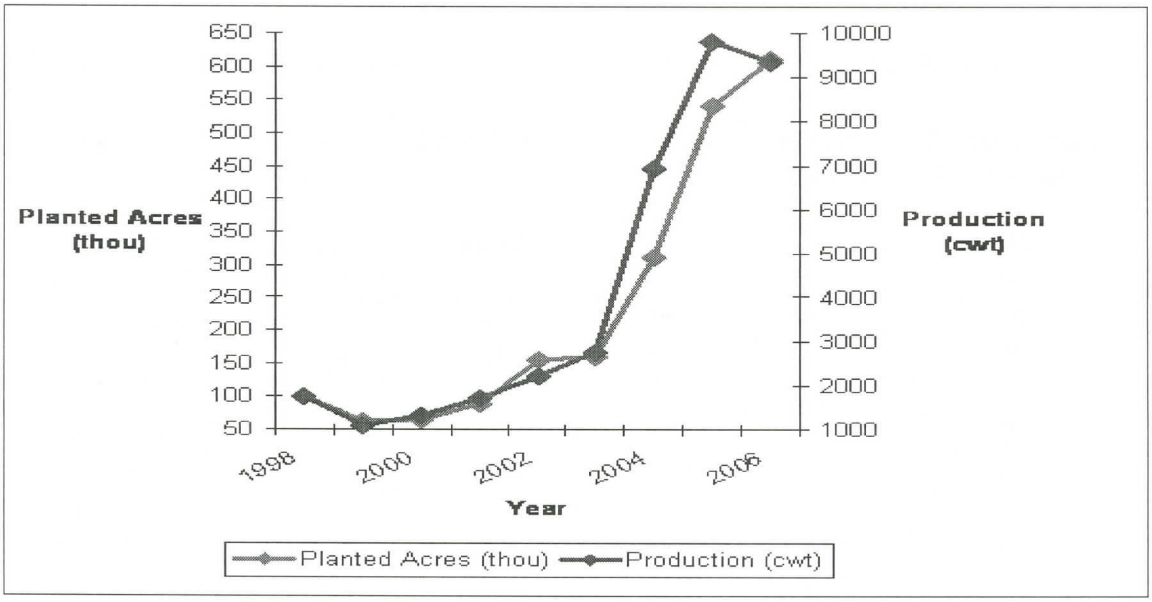

Figure 6. Dry Pea Harvested and Produced in North Dakota.

Dry pea is popular among farmers due to the capacity of dry pea to fix nitrogen thus, reducing the cost of fertilizer. Table 1 shows the projected direct cost of producing dry pea as compared to lentils and chickpeas for Northwest North Dakota. The lower cost of production is attracting farmers to grow dry pea (Haugen, 2007). Table 2 shows the returns from dry pea as compared to other crops in North Dakota (Haugen, 2007).

Table 1. Projected Direct Cost of Producing Dry Pea, Lentil, and Large Chickpea in North Dakota

Cost	Dry Pea	Lentil	Large Chickpea
Seed	19.20	13.30	78.00
Herbicides	20.00	23.50	20.50
Fungicides	-	-	49.00
Insecticides	-	-	-
Fertilizer	6.47	4.70	5.36
Crop Insurance	3.81	7.71	8.15
Fuel and Lubrication	10.97	10.96	11.36
Repairs	10.61	10.95	11.80
Miscellaneous	4.00	4.00	6.00
Operating Interest	3.10	3.10	7.84
Total Direct Cost/Acre	78.16	78.22	198.01

Table 2. Projected Return on Direct Cost for Crops Grown in North Dakota in 2007

Crop	Price ($)	Bushel/Acre	Income ($)	Direct Cost($)	Return Over Direct Cost ($)
Lg. Chickpea	0.265	1100	292	198	93
Y. Mustard	0.168	900	151	61	90
Mltg. Barley	3.300	47	155	76	79
Corn	2.900	63	183	104	79
Lentils	0.115	1350	155	78	77
Safflower	0.150	950	143	67	75
Canola	0.136	1370	186	121	66
Oil Sunflower	0.137	1210	166	100	66
Buckwheat	0.136	850	116	56	60
Durum	4.620	29	134	81	53
Millet	0.075	1300	98	45	52
Field Peas	3.960	31	123	78	45
Winter Wheat	3.590	32	115	71	43
HRSW	4.230	28	118	77	41
Flax	5.650	19	107	71	36
Oats	1.810	58	105	72	33
Feed Barley	2.320	47	109	76	33
Rye	2.400	34	82	64	17

2.3. Ethanol Production by Partial Replacement of Corn with Dry Pea

Wilhelmi et al. (2007) developed a process model for an ethanol plant replacing corn by 10% and 30% of dry pea. Pryor (2007) estimated the benefits of replacing enriched dry pea starch with the initial starch from a corn feedstock in the proportion of 10% and 30%.

Wilhelmi et al. (2007) based the model on the dry milling process, in which the key step is the dry pea fractionation by air classification. The protein content of dry pea has a high economic advantage. Therefore, protein from dry pea is removed before entering the fermentation step through a dry milled air classification process. From the air classification, two fractions of dry pea are obtained, the protein and the starch. The removed fraction of the dry pea with a high protein content of 53.5% would be marketed as dry pea meal. It was estimated that an ethanol plant where corn was replaced with 10% and 30 % dry pea will produce 64,346,000 and 193,038,000 pounds of dry pea meal annually respectively (Wilhelmi et al., 2007). The remained part of dry pea with a high content of starch enters the process to obtain the starch.

The model which replaces 10% and 30% corn with dry pea was developed using Microsoft Excel. The model describes the steps to obtain starch from the dry pea and calculates that an actual yield of 0.48 grams of pea starch can be produced from 1 gram of dry pea. The starch produced from dry pea is later mixed with starch produced from corn. Ethanol could be produced from starch obtained from corn and dry pea following the steps mentioned in the previous section. The results suggests that a 100 mgy ethanol plant replacing 10% and 30% corn with dry pea will require 5,424,823 and 16,274,343 bushels of dry pea per year respectively (Wilhelmi et al., 2007).

However, due to limited availability of data on the protein content of dry pea grown in North Dakota, the model has as a limitation a fixed 24% of protein content (Wilhelmi et al., 2007). Further experiments need to be conducted to estimate the chemical composition of dry pea grown in the state and for estimating the probable change in the ethanol output.

Due to the additional equipment required for the processing of dry pea, a preliminary equipment cost and annual power cost was estimated for ethanol plant replacing 10% and 30% dry pea (Wilhelmi et al., 2007). The initial investment cost results were higher than the expected due to unavailability of equipment of the desired scale for the production process. The estimation was calculated by using multiple small units of the equipment driving the equipment cost very high. An investment cost of $28 million was estimated for a pea-fractionation plant capable for processing 10% dry pea plant. Similarly, it is estimated that an investment of $86 million will be required for a pea-fractionation plant capable of processing 30% dry pea plant.

Pryor (2007) conducted research to determine if the supplementation of enriched pea starch for 10% or 30% with the initial starch from a corn feedstock had a measurable impact on either ethanol yield or production rate when compared with conventional dry-milling corn ethanol fermentation. The results showed that a higher fraction of pea starch increased the rate of fermentation. The yields followed a similar trend although the mean yield for a 10% pea starch fermentation was slightly higher than that for a 30% supplementation. Therefore the ethanol plant processing with a replacement of corn with dry pea in proportion of 10% or 30% would be able to increase production by 10% without change in capital cost.

2.4. Feasibility of Ethanol Production

Ethanol feasibility production studies from various feedstocks, such as corn, sugarcane, and biomass, have been reported. These models used a net profit concept to estimate the feasibility. Most of the studies (Outlaw et al., 2003; Tiffany and Eidman, 2003; Sakamoto, 2004; Ribera et al., 2007) used the annual net profit equation (Eq. 1) implicitly as follows:

$$\pi = Total\ Revenue - Total\ Cost \tag{1}$$

The studies identified the input and output cost factors to calculate the net profit, and the variables changed with the feedstock used for the production of ethanol. The total revenue was calculated by multiplying the prices of the final output with the quantity of ethanol produced. The total cost was calculated by adding fixed and variable costs of production.

Reutlinger (1970), Outlaw et al. (2003), Richardson et al. (2006), and Ribera et al. (2007) proposed the use of the Monte Carlo, or the stochastic simulation, method to estimate the variability in the input and output variables. Monte Carlo simulation measures the risk of the important variable or "key output variables" by means of the probability distribution showing the risk of success and failure (Richardson, 2006).

Researchers differed in their methods to estimate the effect of risky variables. Pouliquen (1970), Reutlinger (1970), Richardson and Map (1976), Richardson et al. (2006), and Ribera et al. (2007) proposed to measure the variability among the risky variables through the Monte Carlo simulation method. However, Bryan and Bryan

International (2001) and Tiffany and Eidman (2003) proposed a deterministic way of estimating the input and output variables. The deterministic method uses the estimated points of the important factors. This method is reprimanded by researchers as it "assumes perfect knowledge and ignores risk" (Outlaw et. al., 2003). The stochastic simulation or the Monte Carlo method for analyzing important variables has been adopted by several researchers (Reutlinger, 1970; Outlaw et al., 2003; Richardson et al., 2006; Ribera et al., 2007).

The risky factors varied based on the feedstock used to produce ethanol and the prices of the variables which had high volatility. Tiffany and Eidman (2003) considered capital cost, ethanol yield per bushel, price of ethanol, price of DDGS, and price of corn as important variables in the feasibility study to produce ethanol from corn. Richardson et al. (2006) considered the prices of natural gas and unleaded gasoline, interest rates, and inflation rates in addition to above factors in a similar study.

However, Ribera et al. (2007) identified different risky factors for ethanol production from sugarcane. The factors included yield of sugarcane, sugar content of starch, price of sugarcane, price of unleaded gasoline, price of electricity, price of grain sorghum, price of DDGS, and price of ethanol. A feasibility study conducted by Sakamoto (2004) for the production of ethanol identified different factors as price of chemicals and price of products. Therefore, the important factors varied with the type of feedstock used for the production of ethanol.

The final stage of the method is to add the deterministic and stochastic variables on the spreadsheet with their values and calculate the net cash flow. Similar annual Monte Carlo Financial statement models have been reported (Richardson and Mapp, 1976;

Cochran, et al., 1990; Outlaw, et al., 2003; Sakamoto, 2004).The net cash flow is simulated by using the Monte Carlo simulation using @ Risk to estimate the distribution of the net profit. The net profit helps investors to estimate the probability of profit under all expected situations.

3. THEORETICAL MODEL

The chapter develops a stochastic profitability model of a typical 100 mgy Midwestern ethanol plant. The model will be used to evaluate the profitability and risk of using dry pea as a partial replacement for corn feedstock.

The stochastic profitability model used in the study includes all fixed and variable costs for production of ethanol. The stochastic simulation method is used to simulate the net profit of two alternative options of replacing corn with dry pea in proportions of 10%, and 30%. A major component of risk in the model is the uncertainty and variability in both output and raw material prices as well as feedstock supply availability. Risk is a result of variability in prices of ethanol, prices of DDGS, prices of dry pea meal, prices of corn, and variability in corn production. BestFit, a distribution estimation procedure contained in @Risk, (Palisade Corporation, 2007) was used to estimate statistical distributions of these variables.

The chapter provides an overview of the general profit model for a competitive firm. The general profit model is then expanded to reflect specific input, output, and stochastic variables of an ethanol plant.

3.1. General Net Profit Model

A general net profit model is defined as net returns over total cost (McConnell and Brue, 2006) which is represented in Equation 2 where π represents profit, GR represents gross revenue, and TC represents total cost.

$$\pi = GR - TC \tag{2}$$

Gross revenue (GR) is the total amount of cash generated by selling the total output (Q) of the plant. Gross revenue is calculated by multiplying the price received for a single unit (P) produced with the plant by the total number of units produced (Q).

$$GR = PQ \tag{3}$$

Total cost (TC) is calculated by adding fixed cost (B) and variable cost (VC).

$$TC = B + VC \tag{4}$$

Fixed costs (B) do not change with level of output produced. Fixed costs (B) are calculated by estimating the cost that one has to bear even if the output of the plant is zero. These include depreciation (D) on equipments and buildings and interest (I) on borrowing (McConnell and Brue, 2006).

$$B = D + I \tag{5}$$

Costs that are variable and change with level of output produced are called variable costs (VC). Variable cost is calculated by multiplying cost of producing a single unit (C) with the number of output produced (Q) (McConnell and Brue, 2006).

$$VC = C(Q) \tag{6}$$

The above set of equations can be combined to represent a general profit function as

$$\hat{\Pi} = \hat{P}Q - \hat{C}(Q) - B , \qquad (7)$$

where the firm sells output Q at a certain price P with the cost [C (Q) + B], B represents fixed cost and C (Q) is the variable cost.

3.2. Net Profit Model for an Ethanol Plant Under Risk

This section presents a model to ascertain the impact on stochastic net profits when increasing proportions of dry pea are substituted for corn in the ethanol production process. The model estimates the quantity of corn to be partially replaced by dry pea in proportion of 10% or 30%.

3.2.1. Input Model

The production function of an ethanol plant is presented below, where Q is the output quantity; v_1 and v_2 are quantities of inputs of corn and dry pea respectively (Rowe, Jr. 1977).

$$Q = Q(v_1, v_2) \qquad (8)$$

The input cost function for producing Q quantity of ethanol is represented as follows:

$$IC = w_1 v_1 + w_2 v_2 , \tag{9}$$

where IC is the input cost for producing Q, and w_1 and w_2 are positive input prices. The cost minimization function for minimizing cost for a given level of output can be represented as (Rowe, Jr., 1977):

$$w_i = \lambda Q_i , \quad i = 1,2 , \tag{10}$$

where λ is marginal cost, subject to $F_{11} < 0$ and $F > 0$, where

$$F = \begin{vmatrix} 0 & Q_1 & Q_2 \\ Q_1 & Q_{11} & Q_{12} \\ Q_2 & Q_{21} & Q_{22} \end{vmatrix}$$

and F_{ij} is the cofactor of the element in the ith row and jth column. The input equations when the quantity of output is fixed can be represented as follows (Rowe, Jr., 1977):

$$\frac{\left(\frac{\partial v_j}{\partial w_i}\right)}{\left(\frac{\partial w_i}{\partial v_j}\right)_{Qcte}} = \frac{w_i v_i}{b\left(\frac{b}{\lambda v_i v_j}\right)} \times \left(\frac{F_{ij}}{F}\right) = Q_i \sigma_{ij} , \tag{11}$$

where Q_i is the positive proportion of total cost accounted for input i.

A profit maximizing firm will respond to the variation in output and input prices by changing the proportion of input consumption subject to price of the inputs, which can be represented as (Rowe, Jr. 1977):

$$P = \lambda = \frac{w_i}{Q_i}, \quad i = 1,2\,, \tag{12}$$

where P is the price of output, subject to $Q_{11} < 0$, and F* (= F_{00}) > 0, which implies also that $Q_{22} < 0$.

Therefore from the above equations, the effect of change of the input prices on the profit maximizing usage of the other can be represented as (Rowe, Jr. 1977):

$$\left(\frac{\partial v_2}{\partial w_1}\right)_{w_2, P\, cte} = \left(\frac{\partial v_1}{\partial w_2}\right)_{w_1, Pcte} = \left(\frac{F_{12}^*}{\lambda F^*}\right) = -\frac{Q_{22}}{\lambda F^*} \tag{13}$$

Therefore an increase in any input price will lead to a decrease or increase in the usage of the other inputs according to the cross partial derivative which can be positive or negative. The model estimates the influence of the change in price to replacement of pea.

Gross revenue of an ethanol plant using 100% corn as feedstock is estimated by adding the revenue generated by selling two output variables; ethanol and DDGS. However, ethanol plant partially replacing corn with dry pea will additionally produce dry pea meal as an output.

The total revenue of an ethanol plant using corn and dry pea is discussed below by adding the dry pea meal price as an additional output to the previous model. Total revenue generated by ethanol sales can be estimated by the number of gallons of ethanol produced (Q_1) multiplied with price of a gallon of ethanol (P_1). Revenue received from DDGS is estimated by multiplying quantity (Q_2) of DDGS produced with price of DDGS (P_2). Revenue received from dry pea meal is estimated by multiplying quantity (Q_3) of dry pea meal with price of dry pea meal (P_3). The equation is represented as follows:

$$\hat{G}\hat{R} = \hat{P}_1 Q_1 + \hat{P}_2 Q_2 + \hat{P}_3 Q_3 \tag{14}$$

Total cost for an ethanol plant using both dry pea and corn is calculated. The price of dry pea was not included in the model for corn based ethanol plant. Total cost (TC) is calculated by adding fixed cost (B) and variable cost (C (Q)) as mentioned in the previous section. Fixed cost was calculated as follows:

$$B = D_1 + I_1, \tag{15}$$

where D_1 represents depreciation expenses and I_1 represents interest expenses. Variable cost of producing 1 gallon of ethanol can be estimated by the following equation:

$$\hat{C}(Q) = Q^*(\hat{W}_1 + \hat{W}_2 + \hat{W}_3 + E_1 + E_2 + L_1 + Y_1 + C_1 + L_1 + A_1 + M_1 + M_2 + R_1 + L_1) \tag{16}$$

Variable cost of production is calculated by adding all the variable costs related to the production of 1 gallon of ethanol where W_1 is cost of dry pea, W_2 is the cost of corn, W_3 is the higher cost of transportation which the plant has to bear due to corn production risk, E_1 is the cost of electricity, E_2 is the cost of enzyme, L_1 is the cost of labor, Y_1 is the cost of yeast, C_1 is the cost of chemicals, A_1 is the cost of water, M_1 represents the miscellaneous expenses, M_2 is the plant maintenance and repair expenses, R_1 represents the real estate expenses, and L_1 represents the expenses related to licenses and fees. The total variable cost is estimated by multiplying the quantity of ethanol produced with the cost of production of 1 gallon of ethanol. Finally the net profit of the ethanol production is derived by subtracting the total cost from the total revenue.

There are several sources of price risk for the ethanol plant as represented in the above equations. Some of the important risks are the low prices for the plant outputs as ethanol, DDGS, and dry pea meal or rise in production cost due to rise in prices of single or multiple input factors as corn and dry pea. These factors are represented in the above equations by (^) indicating that the variables are random and a distribution is used for their values. BestFit is a distribution estimation procedure available in @Risk that provides the most accurate distribution of the data set. (Palisade Corporation, 2007). BestFit is used to estimate the statistical distribution curves of the variables.

The net profit model is stochastically simulated using the Monte Carlo method. As per Jorion (2001), the Monte Carlo simulation is "the most comprehensive approach of measuring market risk". The Monte Carlo simulation offers flexibility and overcome many of the problems associated with the parametric methodologies and historical simulation. Other advantage in the Monte Carlo simulation is the ability to vary parameter distributions and evaluate "what-if" scenarios (Linsmeier and Person, 2000). This aspect along with the ability to incorporate unlikely extreme scenarios, fat tails in the distribution, and passage of time makes it a superior tool (Jorion, 2001).

The Monte Carlo simulation is based on the same principle of historical simulation, in which return are generated for numerous possible scenarios. The Monte Carlo simulation requires the user to assign an appropriate statistical distribution to each price variable that adequately approximates its possible changes (Linsmeier and Person, 2000).

Once statistical distributions have been assigned to each price risk variables, pseudo- random values are generated for each risk variable, constructing N possible overall return values for the net profit in consideration. Linsmeier and Person (2000) describe that N is a significantly large number greater than 1,000 and, in some cases, greater than 10,000. These N possible returns are then treated just as those in historical simulation. Finally the net profit values are ranked in order of magnitude.

4. DATA SOURCES, DISTRIBUTIONS, AND SIMULATION PROCEDURES

This chapter is divided into three sections. The first section identifies the three different models under study: the ethanol plant partially replacing corn by dry pea in the proportions of 0%, 10%, and 30%. The second section provides a description of the data sources and statistical summary of data used to empirically calibrate each of the risk models. The third section discusses the simulation method that is used to obtain the empirical results.

A stochastic profit model was developed to evaluate the profitability and risk of using dry pea as partial replacement of corn as feedstock. Three scenarios were evaluated, an ethanol plant with 100% as a feedstock and ethanol plants replacing 10% and 30% corn with dry pea. In the base model, the ethanol was produced using latest technology with corn as 100% feedstock. The location of this new plant was assumed to be Jamestown, North Dakota. The location was selected due to the availability of corn from the surrounding region. It was also assumed that the plant would source 70% of its corn supply needs within the 60 miles radius of the plant. The balance corn was expected to be hauled in from Fargo, ND which is about 100 miles away from Jamestown, ND.

It was further assumed that the balance corn will be hauled to Jamestown, ND by semi. The cost of transportation is expected to be about $ 0.20/bushel. The figure is based on semi capacity of 930 bushels of corn and transportation cost per mile of $2.00 for a semi (Personal Communication, Jon Iverson). It is also expected that the dry pea would be delivered by farmers at the site of the ethanol plant (Jamestown, ND) and the transportation charges will be borne by the farmers.

4.1. Data Sources

The sources of data used in the study are described in this section. The first part contains the description of the variables (corn, corn production, dry pea, dry pea meal production, ethanol, and DDGS) and the second part describes the fixed and variable cost of production (ethanol plant cost, dry pea plant cost, and ethanol production cost). Data for estimating the profitability of the ethanol plant was collected from diverse technical reports and other published sources.

4.1.1. Price Data

Price of Corn: Monthly average cash corn prices received by farmers in North Dakota were collected from the USDA, National Agriculture Statistics Services (NASS) and North Dakota office from 1985 to 2006. Average annual prices of corn were calculated as a simple mean of the monthly prices. Figure 7 shows the annual prices of corn from 1985 to 2006.

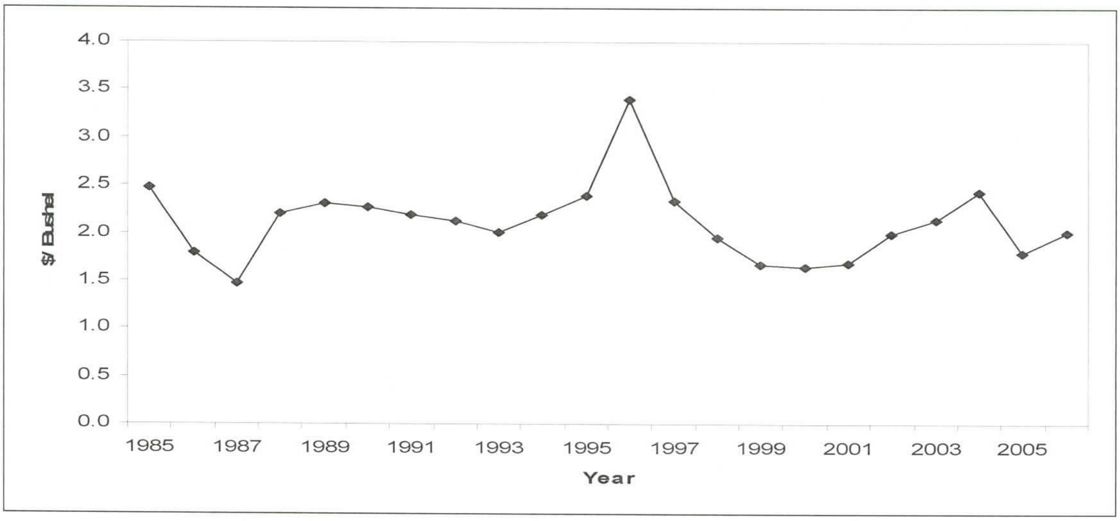

Figure 7. Annual Average Price of Corn/Bushel.

Corn is used for food, feeding livestock, and for export. Decreased corn acreages during 1980s resulted in an increased price of corn. Corn prices were record high in 1990's due to draught (Wisner, 2001). Corn prices have increased since 2004, due to increased consumption of corn for ethanol. During 2007, the annual average of corn prices has increased steadily at $3.50 /bushel.

For the period under consideration, the average corn price was $2.12/bushel, with a standard deviation of $0.40/bushel, where the lowest and the highest prices of corn were $1.48/bushel and $3.40/bushel, respectively. It was assumed that the ethanol plant would pay a premium of $0.10/bushel to purchase corn due to the increased basis in the geographic area surrounding a new ethanol plant (McNew and Griffith, 2000).

Corn Production: Annual corn county level production data from 1998 to 2006 within the 60 miles radius of Jamestown, ND was collected from NASS (2007). Figure 8 shows the produced corn in the counties within 60 miles radius of Jamestown, ND.

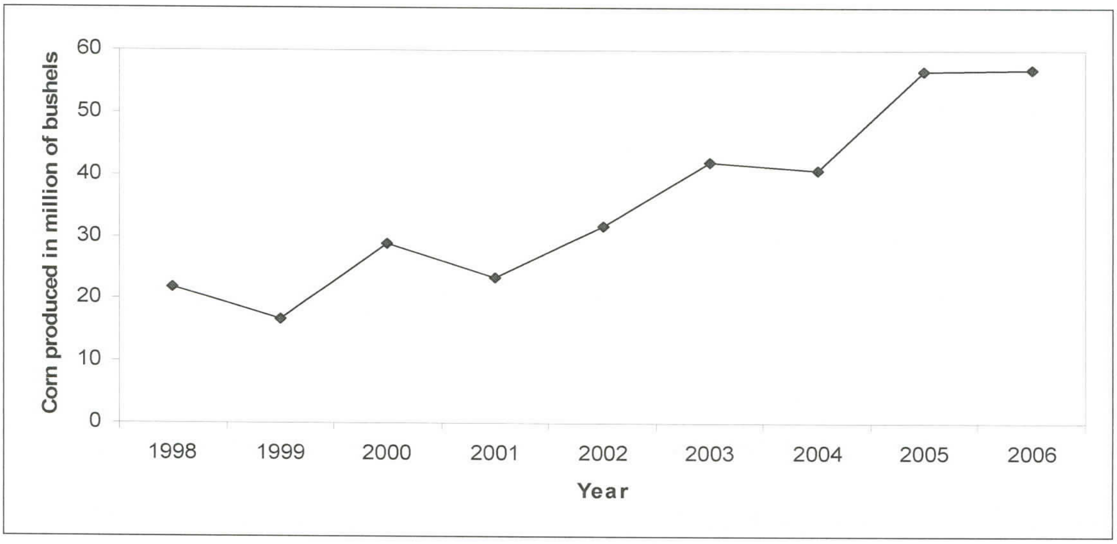

Figure 8. Annual Average Corn Produced Around Jamestown, ND.

Corn production is increasing steadily in this region due to the higher returns to the farmers compared to other crops and due to the availability of genetically modified seeds. Average corn produced was 35.45 million bushels with a standard deviation of 14.66 million bushels, where the minimum and maximum productions of corn were 16.7 million bushels and 57 million bushels.

Price of Dry Pea: Annual average cash prices of dry pea received by farmers in North Dakota were collected from Dry Pea and Lentil Council, Moscow, Montana from 1995 to 2006 (Scholz, 2007). Average annual prices of dry pea were calculated as a simple mean of the monthly prices. Figure 9 shows the annual dry pea prices from 1995 to 2006.

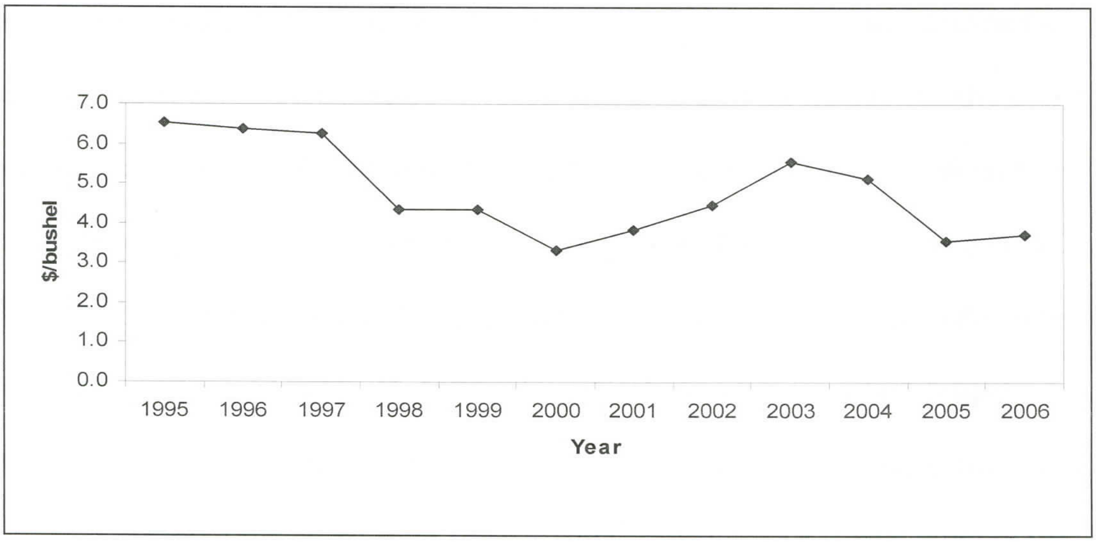

Figure 9. Annual Average Price of Dry Pea/Bushel.

Dry pea prices are influenced by the international demand and supply situation as a large portion of the production is exported. The mean price of dry pea was \$4.78/bushel with a standard deviation of \$1.16/bushel, where the minimum and maximum prices of dry pea were \$3.31/bushel and \$6.53/bushel, respectively. Prices of dry pea were increased by

$0.20/bushel, representing a 3% increase in the price, which was similar to the rise in prices of corn (McNew and Griffith, 2000).

Dry Pea Meal Prices: The rich protein content of dry pea separated through air classification is an important output of an ethanol plant that replaces corn with dry pea as feedstock. The produced meal has a protein content of 53.5%. At the present dry pea meal is not available in the market. Dry pea meal is expected to be used as feed for livestock replacing soybean meal due to the presence of high protein content. Soybean meal is used as feed for cattle and livestock along with other purposes as preparation for oil.

Monthly average cash prices of soybean meal from 1983 to 2006 at Illinois were collected from USDA, Economic Research Services (ERS) (2007). The prices of soybean meal prices were adjusted according to the protein content percentage to calculate the expected price of dry pea meal based on recommendations of Dr Gregory Lardy, Livestock Specialist (Lardy, Personal Communication, 2007). Soybean meal contains about 55% protein, while dry pea meal contains about 53.5% protein. Prices were adjusted in the proportion of the protein content. Dry pea meal was expected to be sold partially in North Dakota and in the nearby states. However, the study does not account for transportation cost as it would be a new product and the distribution logistics of the product needs to be determined. Average annual prices of dry pea were calculated as a simple mean of the monthly prices. Figure 10 shows the historical average annual assumed prices of dry pea meal. Soybean meal prices have been highly variable due to the demand as feed and vegetable oil production. The mean price during the period was $187.46/short ton with a standard deviation of $33.19/short ton, where the minimum and the maximum prices were $132.37/short ton and $259.17/short ton, respectively.

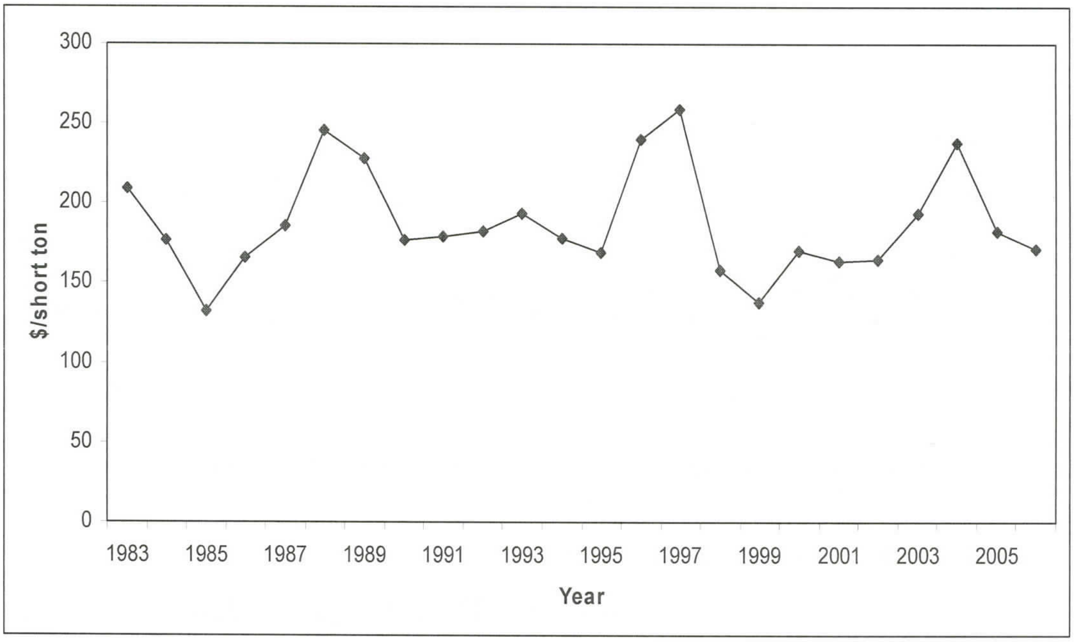

Figure 10. Annual Average Price of Dry Pea Meal/Short Ton.

The soybean meal prices reached high in early 1990 due to the high demand for soybean meal for the crushing industry. However, due to increased supply and availability, the meal prices fell during the next few years. Soybean prices have increased since 2000, due to higher use of soybean for feed purposes. Dry Pea meal is expected to have a high demand as feed due to high protein content.

Price of Ethanol: Monthly average ethanol price per gallon from 1982 to 2006 were collected from Nebraska State Government Energy Office. The prices are free on board prices to Omaha, Nebraska as local historical prices are not available due to the low and late start of ethanol production in the state. Data of consumption of ethanol produced in the state is not available. Therefore, the transportation cost that may be incurred by the plant were not considered. Average annual prices of ethanol were calculated as a simple mean of the monthly prices as shown in Figure 11.

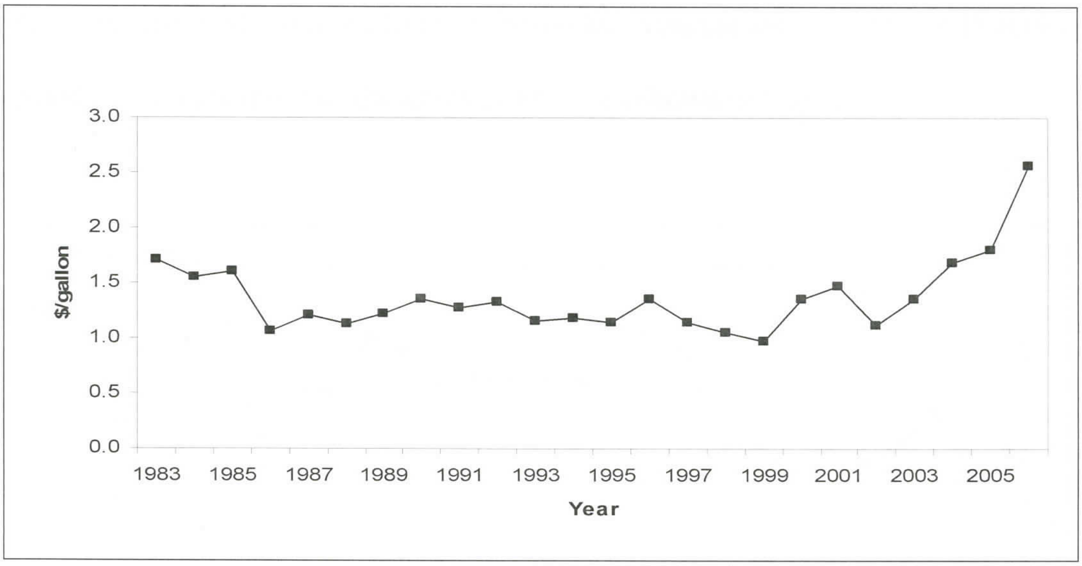

Figure 11. Annual Average Price of Ethanol/Gallon.

Ethanol prices are positively correlated with gas prices which makes ethanol prices highly volatile. Average annual ethanol prices have risen approximately 1.6 times since 2002, due to the increase in the gas prices in the same period. Gas prices have increased in recent years due to increase in demand from developing countries accompanied by limited or no increase in gas production. The gas prices are expected to rise further in the future as the demand remains steady. Average annual ethanol price during the period was $1.37/gallon with a standard deviation of $ 0.34/gallon, where the minimum and maximum prices of ethanol were $ 0.98/gallon and $2.57/gallon, respectively.

Price of DDGS: Average monthly wholesale cash prices of DDGS from 1982 to 2006 per ton at Lawrenceburg, Indiana were collected at freight on board basis from ERS, USDA (2007). As the local prices of DDGS prices are not reported, the national average prices of DDGS were applied. It is expected that the local DDGS prices would follow the national prices tendency. Due to the unavailability of point of consumption data the transportation cost was not considered in the model. Average annual prices of DDGS were calculated as a simple mean of the monthly prices as shown in Figure 12.

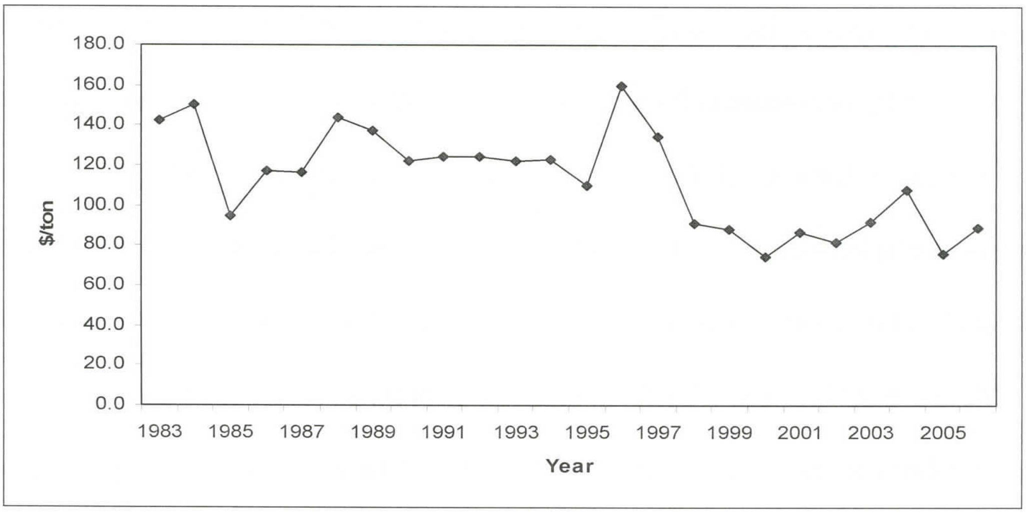

Figure 12. Annual Average Price of DDGS/Ton.

DDGS is used as feed for poultry and livestock. DDGS prices vary locally and are linked historically with corn prices, soybean meal prices and local demand and supply relation (Coltrain, 2004). DDGS price peaked in 1994 following corn before falling in 1997 and 1998 due to lower soybean prices. DDGS prices are rising in recent years due to an increase in demand as livestock instead of corn because corn price has increased. The average DDGS during the period is $112.84/ton with a standard deviation of $24.65/ton, where the minimum and maximum prices were $74.77/ton and $159.56/ton.

4.1.2. Cost of Production

The fixed and variable (Eqs. 15 and 16) production cost of a 100 million gallon ethanol plant from 100% corn as feedstock was estimated following the recommendations of Dale and Tyner (2006). According to the study conducted by Dale and Tyner (2006), the expected cost for an ethanol plant from 100% corn as feedstock was expected to be $1.03/gallon which was similar to the estimation of BBI International (2003).

However, an ethanol plant partially replacing corn with dry pea will have a higher capital cost (Wilhelmi et al., 2007). An additional $28 million will be required for an ethanol plant replacing 10% corn with dry pea as compared to an ethanol plant using 100% corn as feedstock. An ethanol plant replacing 30% corn with dry pea will require an additional $86 million in capital cost as compared to a 100% corn ethanol plant. The plant is expected to get the capital from two sources: a) equity from investors and b) long-term debt from a leading financial institution in the ratio 40:60 (Tiffany and Eidman, 2003). Interest and depreciation cost per gallon of production is calculated in the model. Interest rate is taken as 7%, and the plant is depreciated at 10%. The plant life is expected to be 15 years (Tiffany and Eidman, 2003).

The additional capital cost required for the ethanol plant producing ethanol by partial replacement of corn by pea is higher due to non availability of equipment in commercial scale. This equipment cost is calculated by simply replicating smaller machines to obtain needed capacity. The limitation of the study is that it overestimates the investment cost due to non availability of equipment of required size.

The variable cost of production for 1 gallon of ethanol from corn was compared from various sources (Dale and Tyner, 2006; USDA, 2005; Tiffany and Eidman, 2003). The variable cost of production of ethanol for 100 million gallon plant is expected to be $0.34/gallon. Ethanol plant using 10% and 30% dry pea as partial replacement of corn as feedstock will incur in an additional power cost of $0.01/gallon and $0.03/gallon, respectively (Wilhelmi et al., 2007).

The ethanol plant using 100% corn as its feedstock is assumed to produce 2.59 gallons of ethanol per bushel of corn and 17.5 pounds of DDGS per bushel of corn (Wilhelmi et al., 2007). Ethanol plant producing ethanol by 10% partial replacement of corn with dry pea is expected to produce 2.03 gallons of ethanol per bushel of dry pea, 2.59 gallons of ethanol per bushel of corn, 17.37 pounds of DDGS per bushel of corn, and 0.58 pounds of dry pea meal per bushel of dry pea (Wilhelmi et al., 2007; Pryor, 2007).

Similarly ethanol produced by ethanol plant producing ethanol by 30% partial replacement of corn with dry pea is expected to produce 2.03 gallons of ethanol per bushel of dry pea, 2.59 gallons of ethanol per bushel of corn, 17.13 pounds of DDGS per bushel of corn and 1.75 pounds of dry pea meal per bushel of dry pea (Wilhelmi et al., 2007; Pryor, 2007).

4.2. Introduction to the Data Distribution

A stochastic profitability model is used to evaluate the feasibility of producing ethanol by partially replacing corn with dry pea. The model includes all fixed and variable costs for the production of ethanol. The stochastic element of the simulation method is used to simulate the net profit model of three alternatives of replacing corn with dry pea in proportions of 0%, 10%, and 30%. A major component of risk in the model is the uncertainty and variability in both output and raw material price, and availability of corn in the region. More specifically, risk is a result of variability in price of ethanol, price of DDGS, price and availability of corn, and price of dry pea.

Statistical distribution functions of the random variables were determined based on the historical data. Price of ethanol and DDGS were calculated from 1982 to 2006, price of corn were calculated from 1985 to 2006, price of dry pea were calculated from 1995-2006, and corn produced in North Dakota were calculated from 1998 to 2006. Present mean prices and historical standard deviation of prices were used for the distribution due to increase in the average prices of corn, dry pea, and dry pea meal.

BestFit (Palisade Corporation, 2007) which estimates parameters for each possible distribution using maximum likelihood estimators was used. Different distribution statistics: Chi Square (CS), Anderson-Darling (AD), and Kolmogorov Smirov (KS) were used to evaluate the distributions of the variables mentioned above. It was assumed that the prices of the variables and their yields were independent in the local level as the prices varied due to national demand and supply situation.

4.2.1. Assumptions and Distributions of the Variables

Price of Corn: Risk Logistics distribution (2.1942, 0.2025) fitted the ethanol prices with the AD distribution statistics. The estimation of the variability in the prices of corn by AD distribution statistics was better than the CS and KS distribution statistics estimations. Risk Logistic was ranked first among the other distribution functions made by BestFit distribution (Palisade Corporation, 2007). The statistics of the distribution of CS was lower than other distributions, suggesting that Risk Logistics provided a better estimation. The critical value suggested that the distribution fitted the data more than 75% of the time. Due to the increase in the average corn prices, a mean price of $3.60/bushel was used which included a premium of $0.10/bushel as discussed above (McNew and Griffith, 2000).

Corn Produced Around 60 miles of Jamestown, ND: Risk Normal distribution (35454433, 14667356) fitted the corn production data as per CS and AD distribution statistics. The critical value suggested that the distribution fitted the data more than 75% of time.

Price of Dry Pea: Risk Extreme distribution (4.58, 0.893) fitted the ethanol prices best as per CS and AD distribution statistics. BestFit distribution ranked Risk Extreme distribution best as per AD statistics. CS distribution statistics suggested that Risk Extreme distribution function fitted the data better than any other distribution. The critical value suggested the distribution fitted the data more than 50% of the time. Due to the increase in the average prices of dry pea in 2007, a mean price of $8.08/bushel was used which includes an increase of $0.22/bushel due to expected rise in dry pea prices as discussed above (McNew and Griffith, 2000).

Price of Dry Pea Meal: Risk Normal distribution (187.45, 33.18) fitted the dry pea meal prices best as per AD distribution statistics. The critical value suggested the data fitted more than 50% of the time. Due to the increase in the average price of dry pea meal in 2007, a mean price of $284.45/short ton was used.

Price of Ethanol: Risk Log Logistic distribution (0.91953, 0.36278, and 2.5868) fitted the ethanol prices best as per CS distribution statistics and ranked second as per AD distribution statistics. CS distribution statistics value (1.417) and P value (0.8413) were higher than any other distribution. The critical value statistics suggested the distribution fitted the data more than 75% of the time.

Price of DDGS: Risk Normal distribution (112.84, 24.64) fitted the ethanol prices best as per AD distribution statistics. The critical value suggested the distribution fitted the data more than 25% of the time. The distributions selected for the used variables in the study are summarized in Table 3.

Table 3. Distribution Used for the Variables

Variable	Distribution and Values ($)	Logic
Price of Corn	Risk Logistic (3.60, 0.2025)	Average annual prices received by farmer in North Dakota from 1985 -2006 (NASS, USDA).
Corn Produced	Risk Normal (35454433, 14667356)	Annual production around 60 miles of Jamestown, ND from1998 -2006 (NASS,USDA)
Price of Dry Pea	Risk Extreme (8.08, 0.893)	Average annual prices received by farmers in North Dakota from 1995-2006 (Dry Pea Council).
Variable	**Distribution and Values ($)**	**Logic**
Dry Pea Meal Prices	Risk Normal (284.45, 33.18)	Average annual prices at Illinois from 1983-2006 (ERS, USDA).
Price of Ethanol	Risk Log Logistic (0.919, 0.362, 2.586)	Annual average prices at Omaha, Nebraska from 1982 – 2006 (Nebraska State Government Energy Office).
Price of DDGS	Risk Normal (112.84, 24.64)	Annual average prices at Lawrenceburg, Indiana from 1982 – 2006 (ERS, USDA).

4.3. Simulation Method

The objective of the study was to determine the profitability of an ethanol plant partially replacing 0%, 10% and 30% dry pea with corn as feedstock. The simulation of net return distribution of alternative adoption strategies were simulated in @ Risk (Palisade Corporation, 2007) on the basis of the equations discussed in the model. Each variable was defined as random or non random. For each model, ten thousand iterations were run.

5. RESULTS

This chapter presents the results of the stochastic profitability model that was developed to evaluate the economic feasibility of producing ethanol by partially replacing corn with dry pea. An ethanol plant with a production of 100 mgy was assumed to be located in central North Dakota. The model simulated the net profit of the ethanol plant under three scenarios: an ethanol plant using 100% corn as feedstock, an ethanol plant replacing 10% corn with dry pea, and an ethanol plant replacing 30% corn with dry pea.

5.1. Ethanol Plant Using 100% Corn as Feedstock

The net profit model for an ethanol plant using 100% corn as feedstock is presented in Table 4. The model was developed in Microsoft Excel, using the equations described before. This base scenario was developed to be compared with the ethanol plants replacing 10% and 30 % corn with dry pea.

The supply of corn is an important risk faced by an ethanol plant. The cost of corn increases $0.21/bushel when it is transported for 100 miles (Iverson, Personal Communication, 2007). For this base scenario, it was assumed that 70% of the corn locally grown was available.

The result of the net profit model suggested that the ethanol plant faced an expected supply risk of $0.009/bushel on-going basis because the local corn production in the surrounding region fell below the historical average. The distribution of the supply risk (Figure 13) showed that the cost of hauling changed with the availability of corn, incurring in an additional cost of hauling to an extent of $0.04/gallon per bushel. The mean profitability for this plant was -$0.15/gallon with a marginal profitability at present price ratios of corn and ethanol of $3.50/bushel and $1.38/gallon, respectively.

Table 4. Net Profit Model for an Ethanol Plant Using 100% Corn as Feedstock

Item	Prices/unit	Total
Plant Capacity (gallon)		100,000,000.00
Raw Material		**0% DRY PEA**
Dry Pea (bushel)		0
Corn (bushel)		38,610,039
Output		
Ethanol (gallon)		100,000,000
DDGS (ton)		306,481
Investment Cost		
Plant Investment Cost	$1.02	$102,000,000.00
Additional Equipment Cost for Dry Pea Plant		$0.00
Total Investment		**$102,000,000.00**
Debt Equity Assumptions		
Factor of Equity		0.4
Factor of Debt		0.6
Initial Debt		$61,200,000.00
Interest Rate		0.07
Interest Cost/Year		$4,284,000.00
Gross Revenue		
Ethanol Price ($/gallon)	$1.38	$138,603,610.32
DDGS ($/ton)	$112.84	$34,583,929.00
Dry Pea Meal ($/short ton)		0.00
Gross Revenue		$173,187,539.32
Gross Revenue ($/gallon)		**$1.73**
Input Cost		
Corn Cost ($/bushel)	$3.60	$138,996,139.00
Dry Pea Cost ($/bushel)		$ 0.00
Gross Cost of Input		$138,996,139.00
Input Cost ($/gallon)		**$1.39**
Operating Expenses ($/gallon)		
Corn Supply Risk Cost		$0.00
Electricity Cost		$0.04
Additional Electricity Cost for Dry Pea Equipment		$0.00
Fuels		$0.11
Water		$0.00

Table 4. (Continued)

Item	Prices/unit	Total
Denaturant		$0.03
Enzyme		$0.04
Yeast		$0.01
Chemicals		$0.02
Labor		$0.05
Maintenance		$0.05
Total Variable Cost ($/gallon)		**$0.34**
Fixed Cost ($/gallon)		
Depreciation (15 years/gallon / @10 %)		0.10
Interest (@7%)		$0.04
Total Fixed Cost ($/gallon)		**$0.14**
Net Profit ($/gallon)		-$0.14

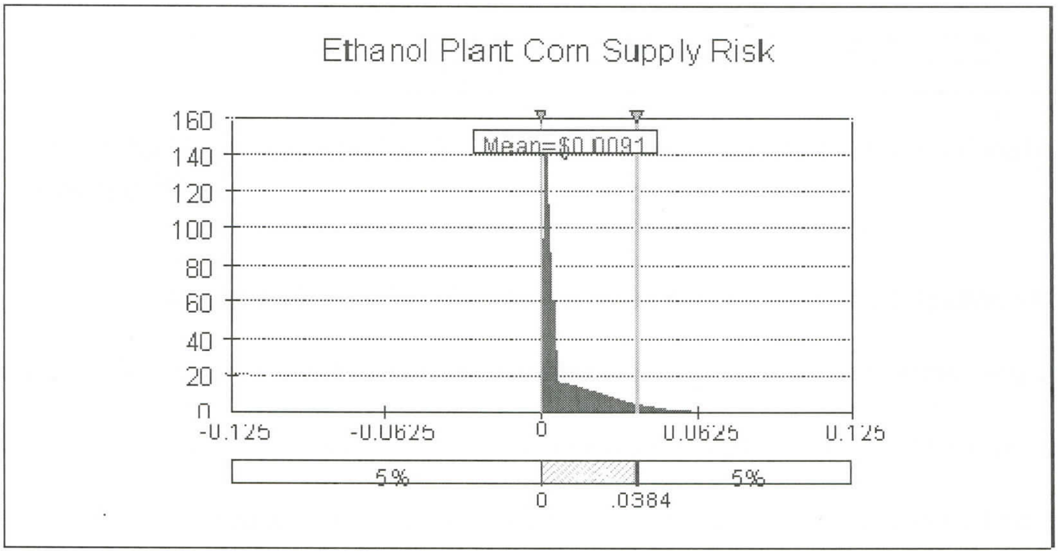

Figure 13. Corn Supply Risk Distribution for an Ethanol Plant Using 100% Corn as Feedstock where 70% Corn is Locally Available.

The largest component of the cost was the price of corn, followed by the cost of production. The largest component of income was the price of ethanol, followed by the price of DDGS.

The net profit distribution for this base scenario (Figure 14) showed that the plant expected a profitability from -$0.61/gallon to $0.52/gallon at a 90% of probability. The minimum and maximum expected profitabilities were -$1.39/gallon and $14.14/gallon with a standard deviation of $0.491/gallon.

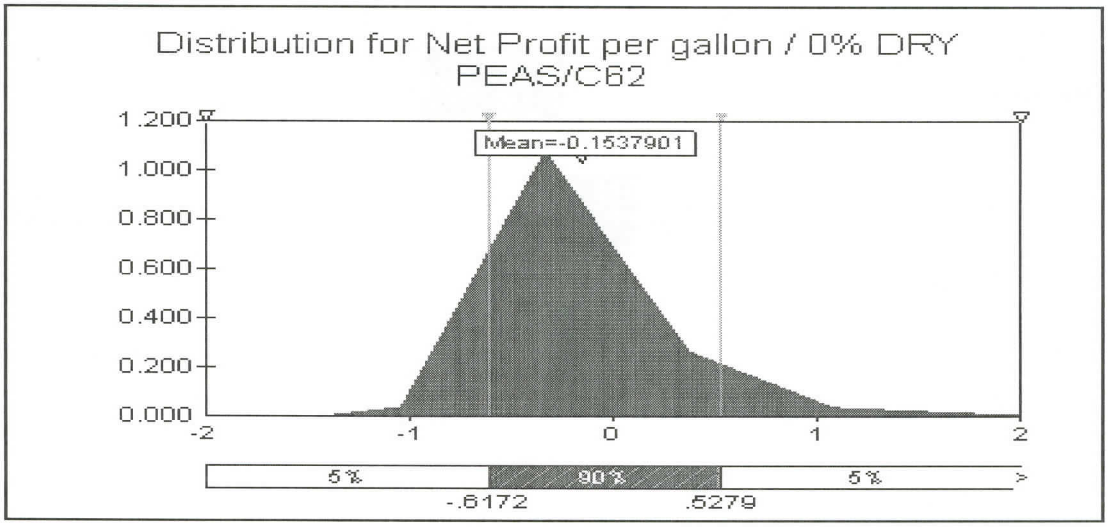

Figure 14. Net Profit Distribution for an Ethanol Plant Using 100% Corn as Feedstock: 70% Supply Risk.

The tornado graph (Figure 15) showed the expected change in profit/gallon of ethanol with the prices of input and output variables. The prices of ethanol and corn were critical for the financial success of the plant. These results were consistent with those of Eidman (2007), who suggested that ethanol plants of 60 mgy and 120 mgy would be profitable with corn prices of $3.90 /bushel and $4.25/bushel per gallon, respectively.

5.1.1. Sensitivity Analysis for an Ethanol Plant Using 100% Corn as Feedstock

A sensitivity analysis for the base scenario, an ethanol plant using 100% corn as feedstock, was conducted to estimate the change in the net profit/gallon due to ratio of corn supply risk and corn prices.

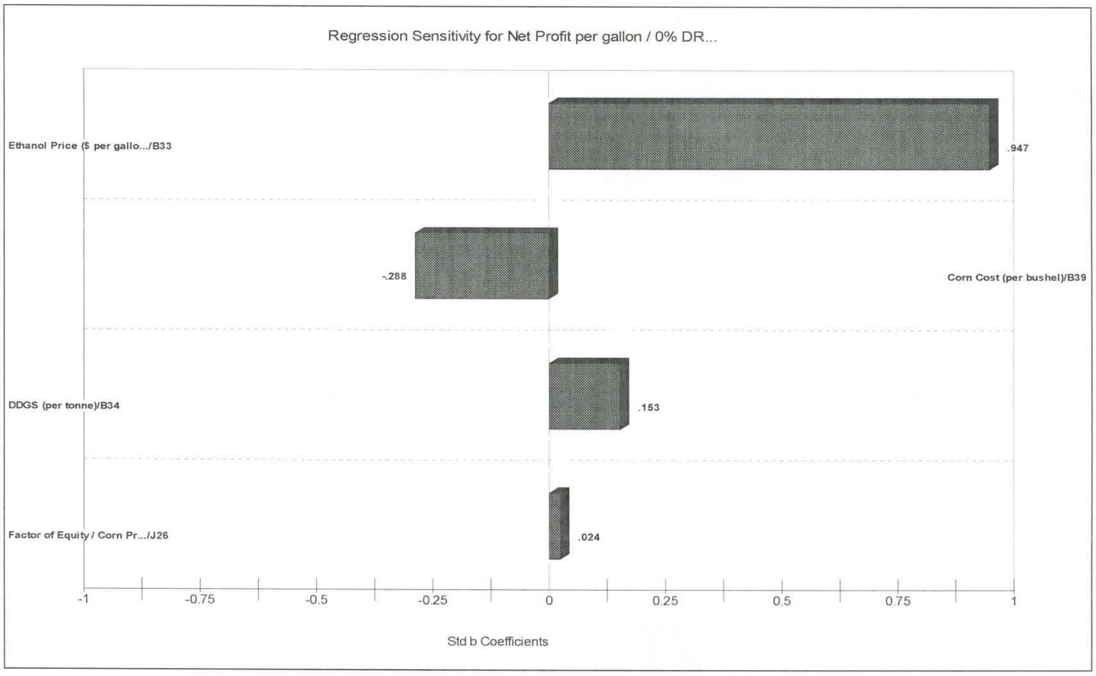

Figure 15. Tornado Graph for an Ethanol Plant Using 100% Corn as Feedstock.

Sensitivity Analysis of Corn Supply Risk: The sensitivity analysis was conducted to estimate the change in net profit/gallon with the amount of available corn for the plant. Corn supply risk of an ethanol plant increases when more ethanol is being produced from corn and when the number of ethanol plants increases. Simulation was conducted by changing the percentage of corn available locally to 50%. The increase of supply risk decreased the profit/gallon. The ethanol plant faced an expected supply risk of $0.02/bushel on-going basis because the local corn production in the surrounding region fell below the historical average.

The risk increased the cost of hauling and decreased the net profit by $0.01/bushel. It was estimated that the net profit decreased by $0.01/bushel for 17% of increment in supply risk. The distribution of this scenario (Figure 16) showed that the plant corn supply risk was within $0.04/bushel. Figure 17 shows the net return distribution of the ethanol plant with a supply risk of 50%. The average profit/gallon of the plant was -$0.16, decreasing from -$0.15/gallon to -$0.16 with a reduction in the availability of corn in the surrounding counties. The plant expected a profit/gallon from -$0.6289 to $0.522 at a 90% of probability.

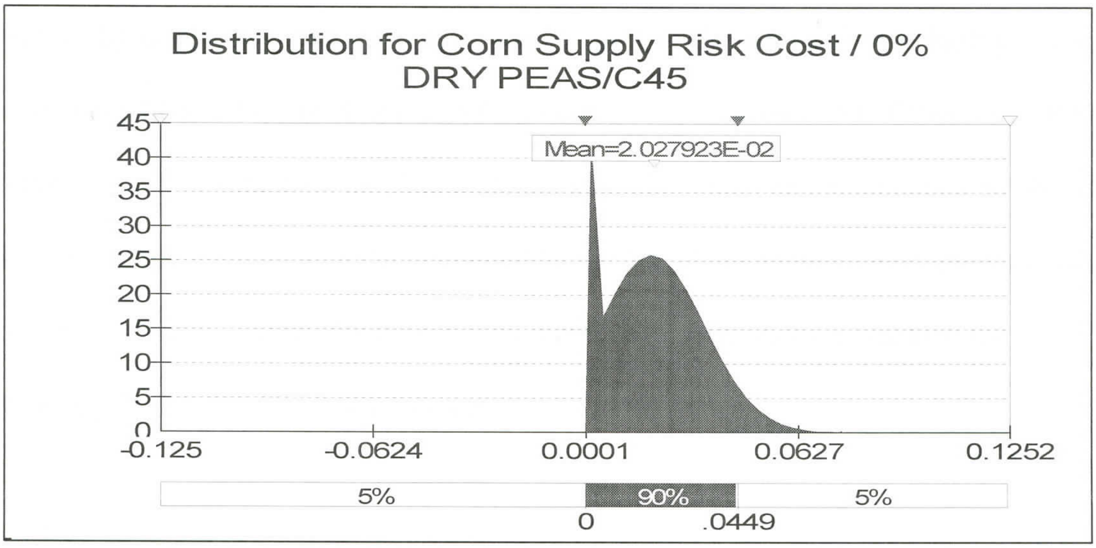

Figure 16. Corn Supply Risk Distribution for an Ethanol Plant Using 100% Corn as Feedstock where 50% Corn is Locally Available.

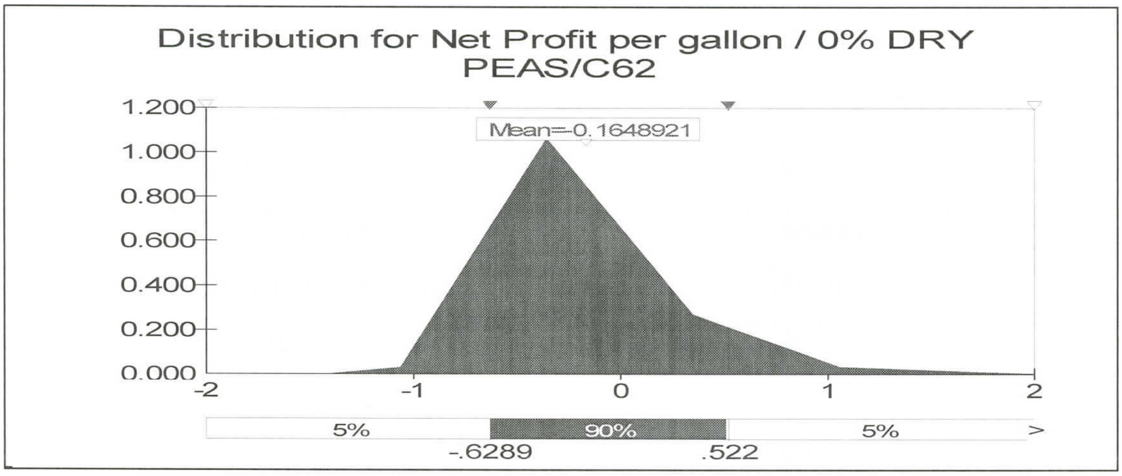

Figure 17. Net Profit Distribution for an Ethanol Plant Using 100% Corn as Feedstock: 50% Supply Risk.

Sensitivity Analysis of Corn Prices: Corn is the principal input for ethanol production, an increment in corn prices decreases the profitability of an ethanol plant. The corn price for this scenario was $3.60/bushel. The prices were varied from -40% to + 40%/bushel in the sensitivity analysis while other variables remained constant. Mean returns were higher for the lower corn prices. At the highest corn price the plant was economically unviable with a net loss of -$0.70/ gallon. The net profit was highly sensitive to corn prices (Table 5). The dropping of the corn prices by 40% to $2.16/bushel, improved the ethanol plant profitability to $0.412/gallon, and when corn prices increased by 40% to $5.04/bushel, the plant profitability declined to $-0.70/gallon. Breakeven corn price was near to $3.24/bushel. Approximately a 10% increase in corn prices, decreased the profitability by $0.14/gallon and vice versa.

Table 5. Ethanol Profit/Gallon: Corn Price Sensitivity for an Ethanol Plant Using 100% Corn as Feedstock

Corn Prices ($/bushel)	**Net Income($/gallon)**
$ 2.16 (Base -40%)	$0.412
$ 2.52 (Base -30%)	$0.273
$ 2.88 (Base -20%)	$0.134
$ 3.24 (Base -10%)	-$0.005
$ 3.60 (BASE)	**-$0.144**
$ 3.96 (Base + 10%)	-$0.283
$ 4.32 (Base +20%)	-$0.422
$ 4.68 (Base +30%)	-$0.561
$ 5.04 (Base + 40%)	-$0.700

5.2. Ethanol Plant Replacing 10% Corn with Dry Pea as Feedstock

The net profit model for an ethanol plant replacing 10% corn with dry pea as feedstock is presented in Table 6. The profitability of this model was lower than the profitability of the base scenario.

As it was mentioned before, corn supply risk is an important concern for an ethanol plant. In this case, it was also assumed that 70% of the corn grown locally was available. The distribution of the supply risk (Figure 18) showed that the supply risk per bushel decreased compared with the base scenario. The mean and maximum expected supply risks were $0.008/bushel and $$0.03, respectively.

Table 6. Net Profit Model for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock

Item	**Price/unit**	**Total**
Plant Capacity (gallon)		110,000,000.00
Raw Material		**10% DRY PEA**
Dry Pea (bushel)		5,967,305
Corn (bushel)		38,223,938
Output		
Ethanol (gallon)		110,000,000
DDGS (ton)		334,770
Dry Pea Meal (short ton)		32,173
Investment Cost		
Plant Investment Cost	$1.02	$102,000,000.00
Additional Equipment Cost for Dry Pea Plant		$28,000,000.00
Total Investment		**$130,000,000.00**
Debt Equity Assumptions		
Factor of Equity		0.4
Factor of Debt		0.6
Initial Debt		$78,000,000.00
Interest Rate		0.07
Interest Cost/Year		$5,460,000.00
Gross Revenue		

Table 6. (Continued)

Item	Price/unit	Total
Ethanol Price ($/gallon)	$1.38	$152,463,971.35
DDGS ($/ton)	$112.84	$37,776,111.38
Dry Pea Meal ($/short ton)	$284.46	$9,151,867.23
Gross Revenue		$199,391,949.97
Gross Revenue ($/gallon)		**$1.81**
Input Cost		
Corn Cost ($/bushel)	$3.60	$137,606,177.61
Dry Pea Cost ($/bushel)	$8.60	$ 51,291,764.64
Gross Cost of Input		$188,897,942.25
Input Cost ($/gallon)		**$1.72**
Operating Expenses ($/gallon)		
Corn Supply Risk Cost		$0.000
Electricity Cost		$0.035
Additional Electricity Cost for Dry Pea Equipment		$0.010
Fuels		$0.110
Water		$0.002
Denaturant		$0.034
Enzyme		$0.037
Yeast		$0.005
Chemicals		$0.023
Labor		$0.048
Maintenance		**$0.047**
Total Variable Cost ($/gallon)		**$0.350**
Fixed Cost ($/gallon)		
Depreciation (15 years/gallon / @10 %)		$0.12
Interest (@7%)		$0.05
Total Fixed Cost ($/gallon)		**$0.17**
Net Profit ($/gallon)		-$0.42

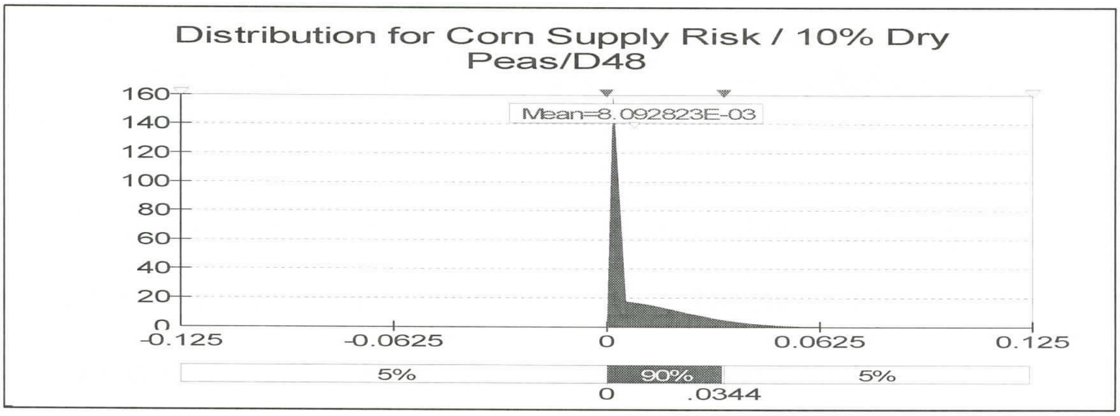

Figure 18. Corn Supply Risk Distribution for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock where 70% Corn is Locally Available.

The mean profitability for this plant was -$0.43/gallon with a negative profitability in the present price ratios of corn, ethanol, and dry peas of $3.5/bushel, $1.38/gallon, and $8.08/bushel, respectively.

The largest components of the cost were the corn price, the dry pea price, and the investment cost. The largest components of income were the ethanol price, the DDGS price, and the dry pea meal price.

The net profit distribution for this scenario (Figure 19) showed that the plant expected a profitability from $0.91/gallon to $0.27/gallon. The expected standard deviation was $0.52/gallon at 90% probability.

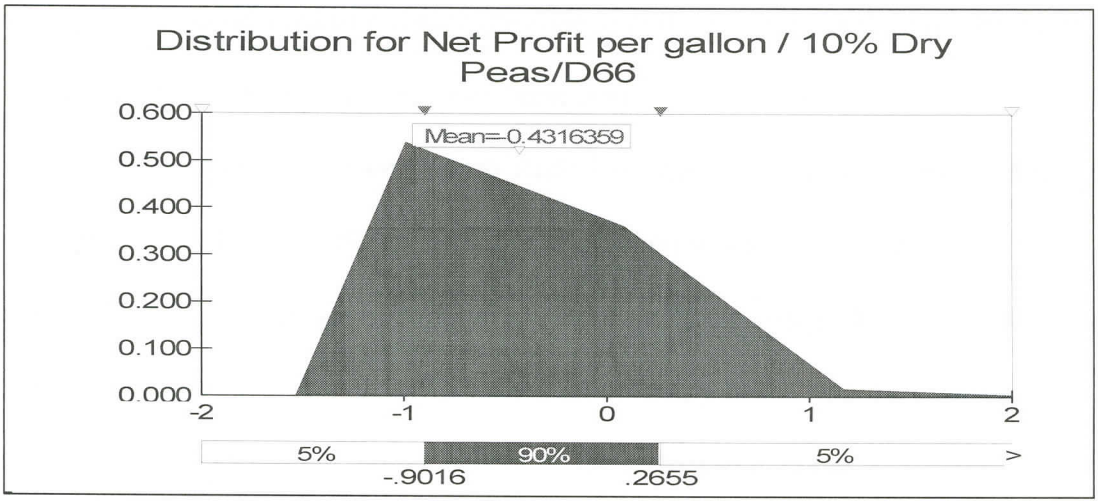

Figure 19. Net Profit Distribution for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock: 70% Supply Risk.

The tornado graph (Figure 20) showed the expected change in profit/gallon of ethanol with the prices of the input and output variables. The impact of the rise of corn price on net profit was reduced by $0.05/gallon for this scenario.

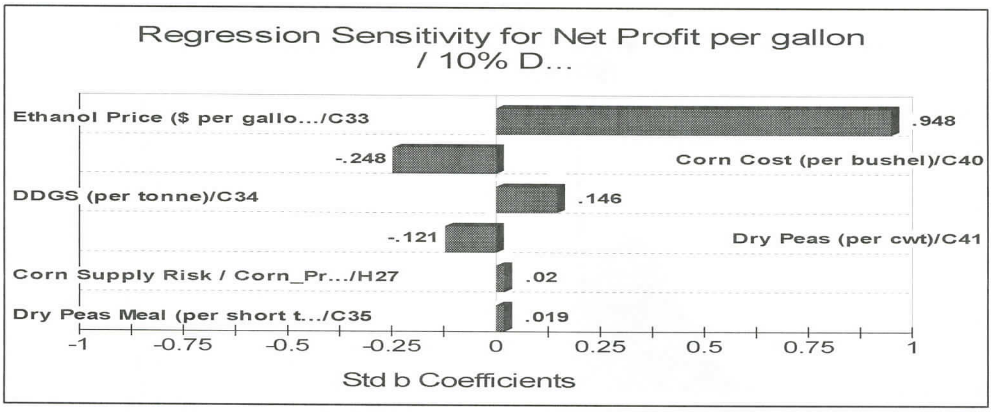

Figure 20. Tornado Graph for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock.

5.2.1. Sensitivity Analysis for an Ethanol Plant Replacing 10% Corn with Dry Pea

A sensitivity analysis for the second scenario, an ethanol plant replacing 10% corn with dry pea, was conducted to estimate the change in the net profit/gallon due to the ratio of corn supply risk, corn prices, and investment cost.

Sensitivity Analysis of Corn Supply Risk: The sensitivity analysis was conducted to estimate the change in net profit/gallon for ethanol plant when the corn supply risk increases to 50%. The increase of supply risk decreased the profit/gallon. The ethanol plant faced an expected supply risk of $0.02/bushel, an on-going basis, because local corn production in the surrounding region fell below the historical average.

The increased risk was due to the uncertainty in the hauling cost. The hauling cost risk was $0.017/bushel. It was estimated that the net profit decreased by $0.02/bushel for a 20% increment in the supply risk. The distribution of this supply risk (Figure 21) showed that the plant had a maximum corn supply risk of $0.04/bushel. Figure 22 displays the net return distribution of the plant with a supply risk of 50%. The average profit/gallon of the plant was -$0.44, expecting a profit/gallon from -$0.91 to $0.21 at a 90% of probability.

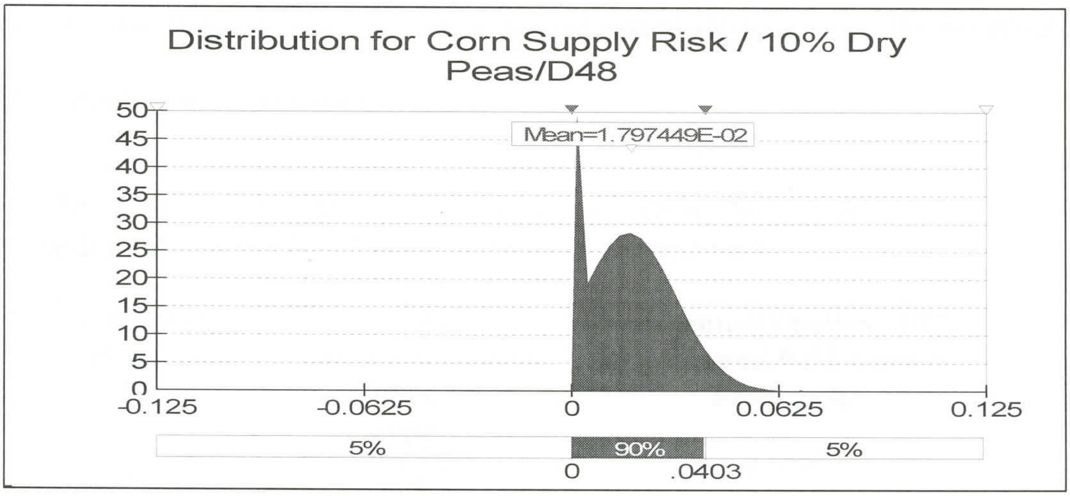

Figure 21. Corn Supply Risk Distribution for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock where 50% Corn is Locally Available.

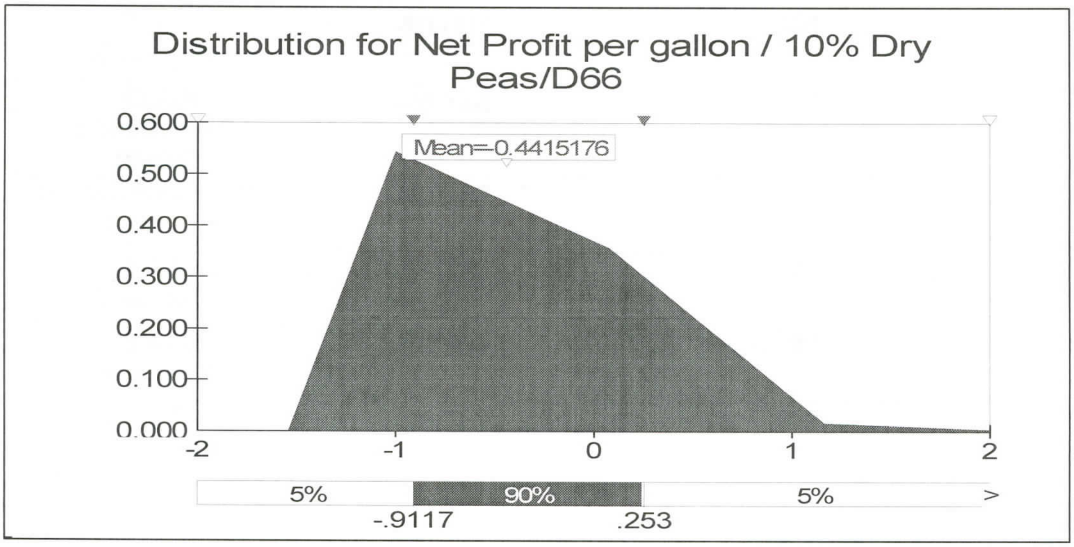

Figure 22. Net Profit Distribution for an Ethanol Plant Partially Replacing 10% with Corn Dry Pea as Feedstock: 50% Supply Risk.

Sensitivity Analysis of Corn Prices: Corn is the principal input for ethanol production, an increment in corn prices decreases the profitability of an ethanol plant. The corn price for this scenario was \$3.60/bushel. The prices were varied from -40% to + 40%/bushel in the sensitivity analysis while other variables remained constant as in the base scenario. Mean returns were higher for the lower corn prices. At the highest corn price, the plant was economically unviable with a net loss of -$0.93/gallon. The net profit was highly sensitive to corn prices (Table 7).

Table 7. Ethanol Profit/Gallon: Corn Price Sensitivity for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock

Corn Prices ($/bushel)	**Net Income($/gallon) 100% Corn Feedstock**	**Net Income($/gallon) 10% Dry Pea and 90% Corn as Feedstock**
$ 2.16 (Base -40%)	$0.412	0.068
$ 2.52 (Base -30%)	$0.273	-0.056
$ 2.88 (Base -20%)	$0.134	**-0.181**
$ 3.24 (Base -10%)	-$0.005	-0.306
CORN $ 3.6/BUSHEL (BASE)	**-$0.144**	-0.431
$ 3.96 (Base + 10%)	-$0.283	-0.556
$ 4.32 (Base +20%)	-$0.422	-0.681
$ 4.68 (Base +30%)	-$0.561	-0.806
$ 5.04 (Base + 40%)	-$0.700	-0.932

The dropping of the corn prices by 40% to $2.16/bushel, improved the ethanol plant profitability to $0.06/gallon, and when corn prices increased by 40% to $5.04/bushel, the plant profitability declined to $-0.93/gallon. Breakeven corn price was near to $2.16/bushel. Approximately a 10% increase in corn price, decreased the profitability by $0.12/gallon and vice versa. At present corn/dry pea price ratio, corn price would have to rise to $4.45 (Base +20%) for pea to become breakeven with corn.

Figure 23 shows the effect of the change in corn and dry pea prices. The current corn and dry pea price ratio was 0.45. The analysis showed that as corn price increased by 10%, the ratio changed by 0.04. The analysis suggested that for every 10% change in prices, the net profit changed by $0.12/gallon.

PRICE RATIO TO PROFITABILITY ANALYSIS			
	INITIAL PRICE	CORN INCREASES 10%	PEAS INCREASE 10%
CORN	$3.60	$3.96	$3.60
PEAS	$8.08	$8.08	$8.89
NEW RATIO	0.45	0.490	0.405
% CHANGE		0.045	0.041
10% DRY PEAS			
For every 4% change in price ratio, net profit chages by $0.12/gallon.			
10% change in corn price is 4% change in ratio			
10% change in dry peas price is 4% change in ratio.			

Figure 23. Price Ratio Analysis for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock.

Sensitivity Analysis of Investment Cost: Investment cost is the second principal input for the ethanol plant replacing 10% corn with dry pea as feedstock. It was expected that with the advancement in technology, equipment with higher capacities will be available to reduce the investment cost.

The decrease in investment cost, increased the profitability of the ethanol plant. The estimated investment cost for dry pea equipment for this scenario was $28 million and the prices varied from present to -90% by sensitivity analysis while other variables remained constant. Mean returns were higher for the lower equipment cost when the investment cost decreased by 90%.

Sensitivity analysis results suggested that the investment did not have a high impact on the net profit of the plant. At the lowest investment cost (-90%) the plant was economically unviable with a net loss of -$0.39/gallon. It was observed that the investment cost was not highly sensitive. For every 10% drop in investment cost the profitability decreased by $0.003. The net profit/gallon sensitivity analysis results are summarized in the Table 8. Ethanol plant replacing 10% corn with dry pea was not profitable in the present price ratio. The corn price needs to increase by about 25% from the current prices before the plant profits could be comparable to a plant using 100% corn as its feedstock.

Table 8. Ethanol Profit/Gallon: Investment Cost Sensitivity for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock

Investment Cost	**Net Income($/gallon)**
Base -90%	-0.399
Base -80%	-0.402
Base -70%	-0.406
Base -60%	-0.409
Base -50%	-0.413
Base -40%	-0.417
Base -30%	-0.420
Base -20%	-0.424
Base -10%	-0.428
Base ($28Million)	-0.431

Sensitivity Analysis of Correlation Testing: The variables in the base scenario were assumed to be independent. However, a correlation analysis was conducted to estimate the change in net profit for the ethanol plant with a scenario where corn, DDGS, and dry pea prices were correlated. Historical correlation among the annual average prices of corn, dry pea, ethanol, DDGS, dry pea meal, and production data of corn was calculated for the period mentioned above . The prices of dry pea, corn, and DDGS were correlated at 5% significance level, while other variables were not correlated. The correlation matrix is presented in Table 9.

Table 9. Correlation Among Dry Pea, DDGS, and Corn Prices

Variable	Corn Price	DDGS Price	Dry Pea Price
Corn Price	1	0.92** (0.000)	0.79** (0.002)
DDGS Price		1	0.82** (0.001)
Dry Pea Price			1

** Significant at the 5% level.
The figures within the parentheses show the P-value.

Sensitivity analysis was conducted including the correlation among the variables and using Risk Corrmat in @Risk (Palisade Corporation, 2007). It was found that the value of the distribution remained the same for other variables. Results showed an improved net profit of -$0.44/gallon. The net profit distribution of this ethanol plant (Figure 24) showed that the mean profit was -$0.44/gallon at a 90% probability of profit/gallon variability from -$0.956 to $0.284. The average profit increased by $0.02/gallon compared to the base model. Therefore it can be concluded that the correlation among the variables did not have a significant impact.

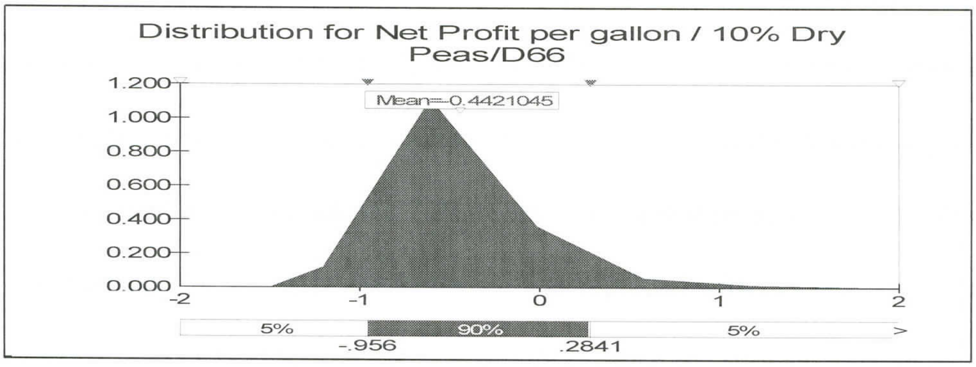

Figure 24. Net Profit Distribution with Correlation Analysis for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock.

Sensitivity Analysis of Mean Prices: In the base model, the mean prices of dry pea, corn, and dry pea meal were increased to account the average mean prices. The mean prices were not increased during the sensitivity analysis. The net profit distribution of the plant (Figure 25) showed a positive profitability of $0.22/gallons, which was higher than for the base model.

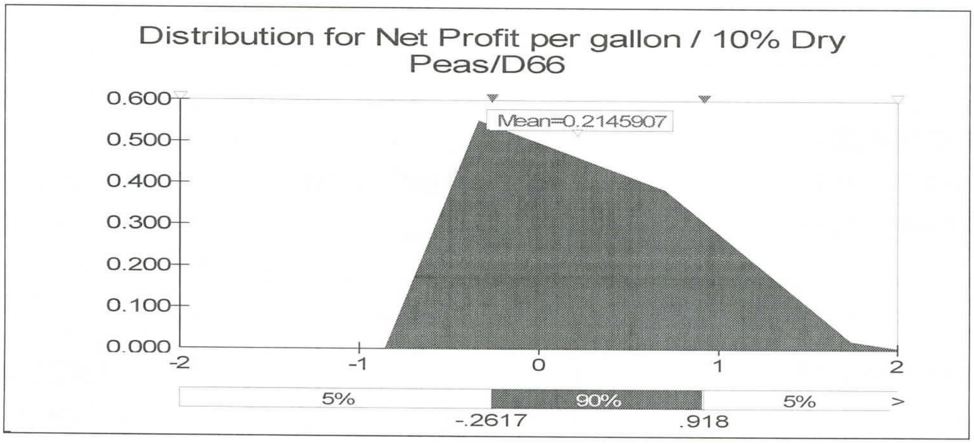

Figure 25. Net Profit Distribution for an Ethanol Plant Partially Replacing 10% Corn with Dry Pea as Feedstock Using Mean Prices.

5.3. Ethanol Plant Replacing 30% Corn with Dry Pea as Feedstock

The net profit model for an ethanol plant replacing 30% corn with dry pea as feedstock is presented in Table 10. The results showed that this scenario was unviable due to the high investment cost of dry pea fractionation equipment and the soaring dry pea prices. It was assumed in the model that 70% of the corn grown locally was available. The supply risk per bushel decreased when 30% corn was replaced with dry pea compared with the base scenario. The distribution of the risk supply (Figure 26) showed a mean of $0.003/bushel with a maximum of $0.02. The risk was reduced by about $0.006/bushel compared to the ethanol plant with 100% corn as feedstock.

Table 10. Net Profit Model for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock

Item	Prices/unit	Total
Plant Capacity (gallon)		110,000,000.00
Raw Material		**30% DRY PEA**
Dry Pea (bushel)		17,900,000
Corn (bushel)		29,729,730
Output		
Ethanol (gallon)		110,000,000
DDGS (ton)		330,050
Dry Pea Meal (short ton)		96,519
Investment Cost		
Plant Investment Cost	$1.02	$102,000,000.00
Additional Equipment Cost for Dry Pea Plant		$86,000,000.00
Total Investment		**$188,000,000.00**
Debt Equity Assumptions		
Factor of Equity		0.4
Factor of Debt		0.6
Initial Debt		$112,800,000.00
Interest Rate		0.07
Interest Cost/Year		$7,896,000.00
Gross Revenue		
Ethanol Price ($/gallon)	$1.38	$152,463,971.00
DDGS ($/ton)	$112.84	$37,776,518.00
Dry Pea Meal ($/short ton)	$284.46	$27,455,602.00
Gross Revenue		$217,163,091.00
Gross Revenue ($/gallon)		**$1.97**
Input Cost		
Corn Cost ($/bushel)	$3.60	$90,972,972.97
Dry Pea Cost ($/bushel)	$8.60	$153,858,825.88
Gross Cost of Input		$244,831,798.85
Input Cost ($/gallon)		**$2.23**
Operating Expenses ($/gallon)		
Corn Supply Risk Cost		$0.000
Electricity Cost		$0.035
Additional Electricity Cost for Dry Pea Equipment		$0.030
Fuels		$0.110
Water		$0.002
Denaturant		$0.034
Enzyme		$0.037

Table 10. (Continued)

Item	Prices/unit	Total
Yeast		$0.005
Chemicals		$0.023
Labor		$0.048
Maintenance		$0.047
Total Variable Cost ($/gallon)		**$0.371**
Fixed Cost ($/gallon)		
Depreciation (15 years/gallon / @10 %)		$0.17
Interest (@7%)		$0.07
Total Fixed Cost ($/gallon)		**$0.24**
Net Profit ($/gallon)		-$0.87

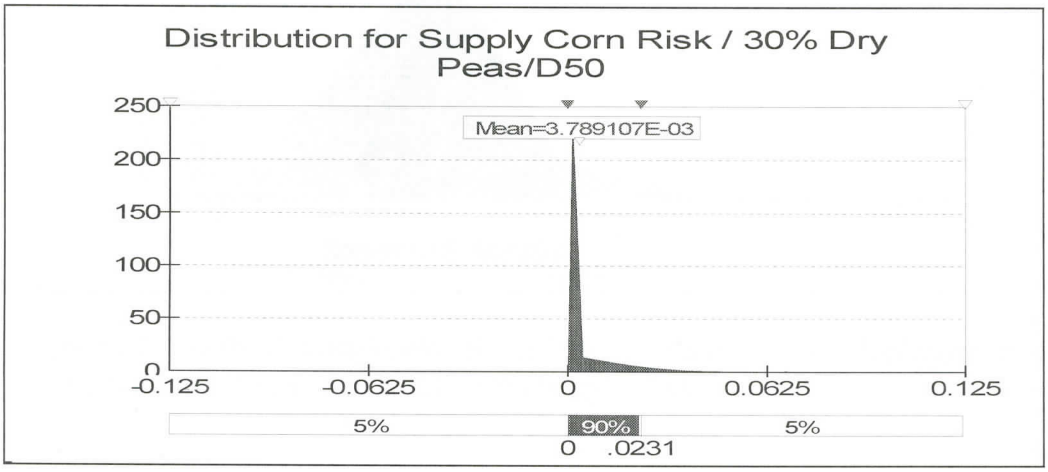

Figure 26. Corn Supply Risk Distribution for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock where 70% Corn is Locally Available.

The mean profitability for this ethanol plant was -$0.86/gallon. The results showed a negative profitability in the present ratios of corn, ethanol, and dry peas of $3.5/bushel, $1.38/gallon, and $8.08/bushel, respectively.

The largest components of the cost were the corn price, the dry pea price, and the investment cost. The largest components of income were the ethanol price, the DDGS price, and the dry pea meal price.

The net profit distribution for this scenario (Figure 27) showed that the plant expected a profitability from -\$1.44/gallon to -\$0.12/gallon with an standard deviation of \$0.52/gallon at a 90% probability. The tornado graph (Figure 28) showed the expected change in profit/gallon of ethanol with the prices of the input and output variables.

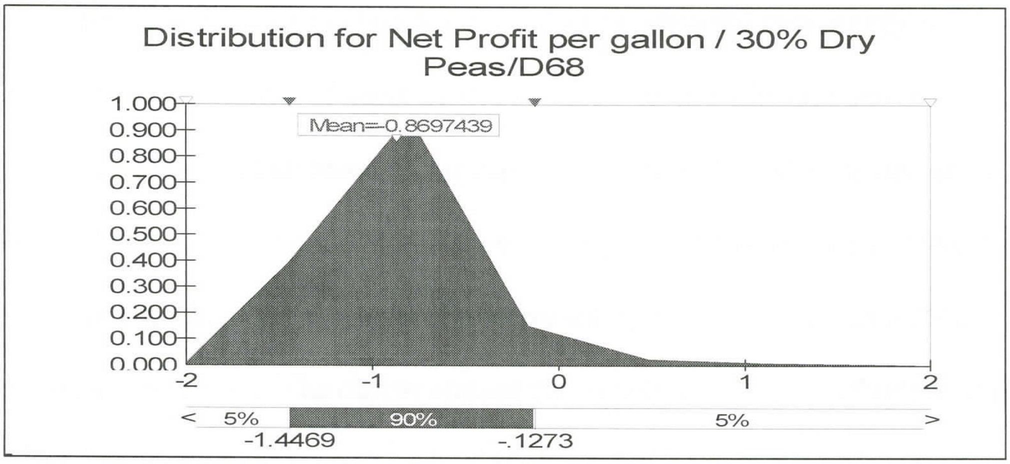

Figure 27. Net Profit Distribution for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock: 70% Supply Risk.

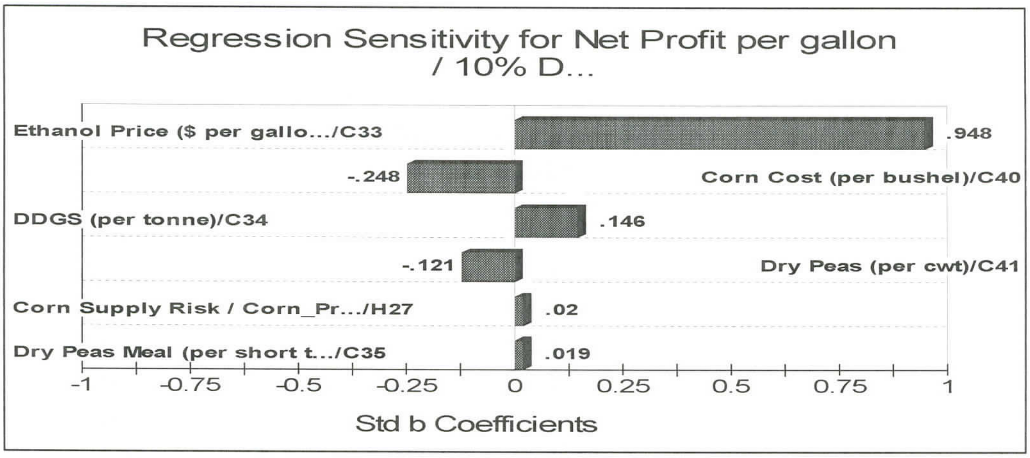

Figure 28. Tornado Graph for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock.

5.3.1. Sensitivity Analysis for an Ethanol Plant Replacing 30% Corn with Dry Pea

A sensitivity analysis for the third scenario, an ethanol plant replacing 30% corn with dry peas, was conducted to estimate the change in the net profit/gallon due to the ratio of corn supply risk, corn prices, and investment cost.

Sensitivity Analysis of Corn Supply Risk: The sensitivity analysis was conducted to estimate the change in net profit/gallon for ethanol plant when the corn supply risk increases to 50%. The increase of supply risk decreased the profit/gallon and increased the hauling cost. The ethanol plant faced an expected supply risk of $0.009/bushel, an on going basis, because local corn production in the surrounding region fell below the historical average. It was estimated that the net profit decreased by $0.005/bushel for a 20% increment in the supply risk. The distribution of this supply risk (Figure 29) showed that the plant had a maximum corn supply risk of $0.02/bushel. Figure 30 displays the net return distribution of the plant with a supply risk of 50%. The average profit/gallon of the plant was -$0.87, expecting a profit/gallon from -$1.44 to $0.13 at a 90% of probability.

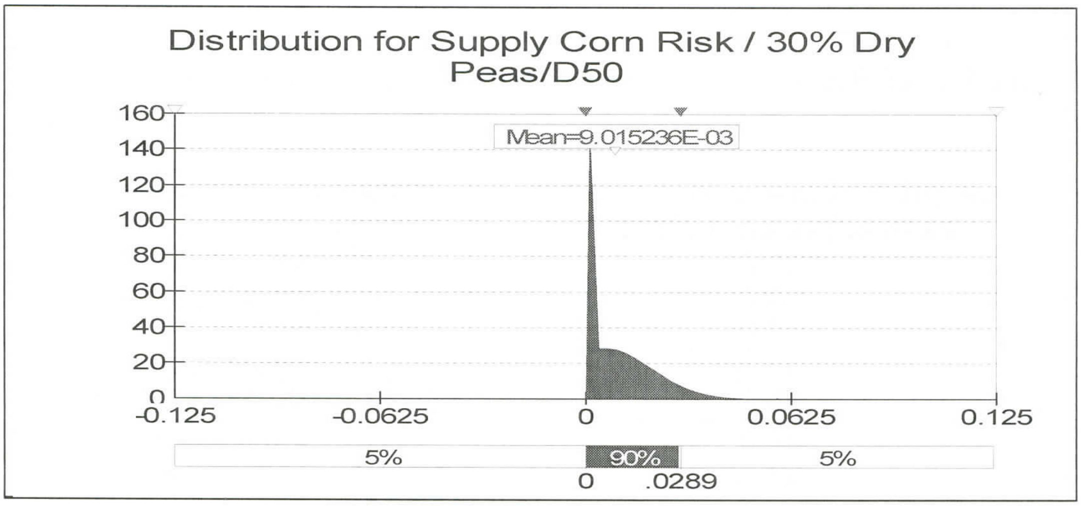

Figure 29. Corn Supply Risk Distribution for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock where 50% Corn is Locally Available.

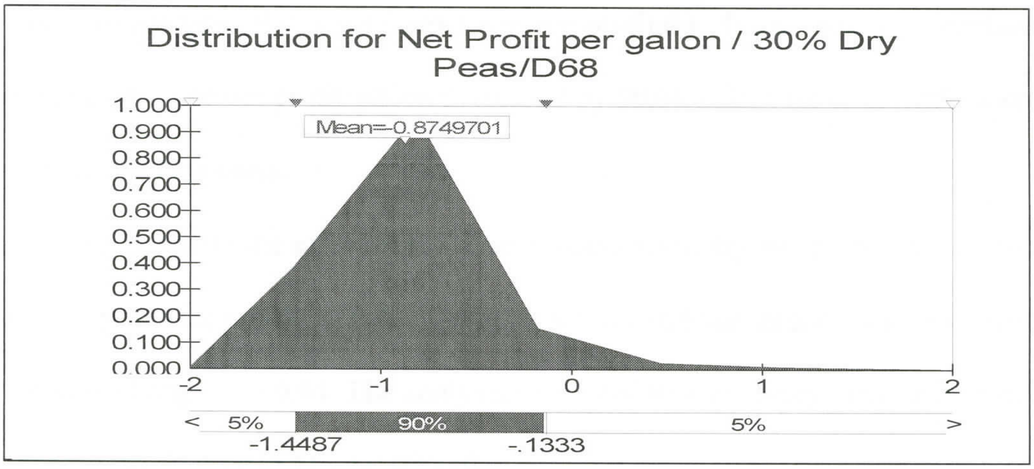

Figure 30. Net Profit Distribution for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock: 50% Supply Risk.

Sensitivity Analysis of Corn Prices: Corn is the principal input for ethanol production, an increment in corn price decreases the profitability of an ethanol plant. The corn price for this scenario was $3.60/bushel, and it was varied from -40%-40%/bushel. Mean returns were higher for the lower corn prices; however the plant was unviable even if the corn prices fell by 40%. The net profit was highly sensitive to the corn prices (Table 11).

Table 11. Ethanol Profit/Gallon: Corn Price Sensitivity for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock

Corn Prices ($/bushel)	Net Income($/gallon) 30% Dry Pea and 70% Corn as Feedstock
$ 2.16 (Base -40%)	-0.538
$ 2.52 (Base -30%)	-0.621
$ 2.88 (Base -20%)	-0.704
$ 3.24 (Base -10%)	-0.787
CORN $ 3.6/BUSHEL (BASE)	-0.869
$ 3.96 (Base + 10%)	-0.952
$ 4.32 (Base +20%)	-1.035
$ 4.68 (Base +30%)	-1.117
$ 5.04 (Base + 40%)	-1.200

For this scenario, the ethanol plant was not profitable due to the high investment and dry pea costs. The net profit/gallon decreased by $0.08/gallon for every 10% increase in corn price and vice versa.

Figure 31 shows the effect of the change in corn and dry pea prices. The current corn and dry pea price ratio was 0.45. The analysis showed that as corn price increased by 10%, the ratio changed by 0.04. The analysis suggested that for every 10% change in prices, the net profit changed by $0.08/gallon.

PRICE RATIO TO PROFITABILITY ANALYSIS			
	INITIAL PRICE	CORN INCREASES 10%	PEAS INCREASE 10%
CORN	$3.60	$3.96	$3.60
PEAS	$8.08	$8.08	$8.89
NEW RATIO	0.45	0.490	0.405
% CHANGE		0.045	0.041
10% DRY PEAS			
For every 4% change in price ratio, net profit chages by $0.12/gallon.			
10% change in corn price is 4% change in ratio			
10% change in dry peas price is 4% change in ratio.			

Figure 31. Price Ratio Analysis for an Ethanol Plant Partially Replacing 30% Corn with Dry Pea as Feedstock.

Sensitivity Analysis of Investment Cost: Investment: cost is the second principal input for ethanol plant replacing 30% corn with dry pea as feedstock. It was expected that with the advancement in technology, equipment with higher capacities will be available to reduce the investment cost.

The decrease in the investment cost, increased the profitability of the ethanol plant. The estimated investment cost for dry pea equipment for this scenario was $86 million and the prices varied from present to -90%. Mean returns were higher for the lower equipment cost when the investment cost decreased by 90%.

Sensitivity analysis results suggested that the investment did not have a high impact on the net profit of the plant. At the lowest investment cost (-90%) the plant was economically unviable with a net loss of -$0.76/gallon. It was observed that the investment cost was not highly sensitive. For every 10% drop in investment cost the profitability decreased by $0.01. The net profit/gallon sensitivity analysis results are summarized in Table 12.

Table 12. Ethanol Profit/Gallon: Investment Cost Sensitivity for an Ethanol Plant Replacing 30% Corn with Dry Pea as Feedstock

Investment Cost	Net Income($/gallon)
Base -90%	-0.769
Base -80%	-0.780
Base -70%	-0.792
Base -60%	-0.803
Base -50%	-0.814
Base -40%	-0.825
Base -30%	-0.836
Base -20%	-0.847
Base -10%	-0.858
Base ($ 86 Million)	**-0.869**

Ethanol plant replacing 30% corn with dry pea as feedstock was unviable in the present price ratio of corn and dry pea. The present investment cost and dry pea cost were very high making the plant unviable.

5.4. Summary

A simulation model of a 100 million gallon ethanol plant located in central North Dakota was constructed to evaluate the profitability of replacing 10% and 30% corn with dry pea as feedstock. It was assumed that 70% of corn required by the plant would be sourced within a 60 mile radius of the plant. Prevailing prices of corn, dry pea, ethanol, DDGS, and dry pea meal were used for the analysis. However, a premium was added to these corn and dry pea prices in response to the impact of a new plant on local corn basis in the region. The model also considered the supply risk of corn. When corn production in the 60 mile ratio of the plant fell below the historical levels, corn was transported from eastern North Dakota which incurred in an additional cost of $0.20/bushel. The cost of fractionation equipment necessary to process the pea was estimated in $20 million and $86 million for 10% and 30% dry pea plants respectively.

Results showed that the ethanol plants replacing 10% and 30% corn with dry pea as feedstock were economically unfeasible in the present price ratios. The profitability was sensitive to the change in corn price, resulting in a low profit. The ethanol plant replacing 10% corn with dry peas had a net income/gallon of $-0.143. Corn price would have to rise more than 20% before this plant would be breakeven. The profitability improved only marginally, when alternative scenarios with decreasing investment cost of dry pea fractionation equipment were evaluated.

6. CONCLUSIONS AND STUDY LIMITATIONS

A large expansion of ethanol production is underway in the United States. Starch from corn has been the principal raw material for the production of ethanol in the United States. Due to the rapid increase of ethanol production in United State, demand and price of corn has increased since 2004.

A small change in the corn price has a high impact on the production cost of ethanol. The profit/gallon decreases by $0.035 for every dollar increase in the price of corn/bushel, assuming that the price of DDGS is $71.43 (Eidman, 2007). Additionally, North Dakota is facing a challenge to increase the production of corn as the existing plants were expected to consume the crop produced in 2006, as indicated by Roger Johnson, Agriculture Commissioner (February 1, 2007; Senate Bill 2391). Therefore, it is expected that new ethanol plants will have to import corn from other states, further increasing the transportation cost.

The expansion of the corn industry in North Dakota may also be constrained due to the limited availability of corn varieties tailored to the arid and northern climate. Lack of moisture and frost are two perils that have historically reduced corn yields in the state and new drought resistant corn varieties are needed to increase the production further. Due to rising demand and uncertainty about availability of corn in North Dakota, there was a need to consider alternative crops for the production of ethanol. Previous studies suggested that dry pea can partially replaces corn in ethanol production (Wilhelmi et.al, 2007).

The objective of this research was to develop an economic stochastic model for a typical 100 million gallon per year (mgy) Midwestern ethanol plant to evaluate the profitability and risk of using dry pea as a partial replacement of corn feedstock in the proportions of 10% and 30%. This study applied the results from the developed engineering and fermentation process models for an ethanol plant partially replacing corn with dry pea conducted by Wilhelmi et al. (2007) and Pryor (2007).

6.1. Procedure and Data

A stochastic profit model was developed to evaluate the profitability and risk of using dry pea as partial replacement of corn as feedstock. The first option evaluated the profitability of producing ethanol from 100% corn as feedstock. In the second option, 10% of the corn feedstock was replaced by dry pea. In the third option, 30% of the corn feedstock was replaced by dry pea. The major components of risk in the model were the uncertainty and variability in raw material prices and availability of corn in the region. More specifically, risk was a result of variability in prices of ethanol, prices of DDDS, prices and availability of corn around Jamestown, ND, and prices of dry pea.

The location of this new plant was assumed to be Jamestown, North Dakota. Jamestown, ND due to availability of corn from the surrounding region. It was also assumed that the plant would source 70% of its corn supply needs within the 60 miles radius of the plant. The balance corn was expected to be hauled in from Fargo, ND about 100 miles away from Jamestown, ND. Data for estimating the profitability of the ethanol plant was collected from diverse technical reports and other published sources. The fixed and variable cost of production of a 100 million gallon ethanol plant producing ethanol from 100% corn as feedstock was estimated following recommendations of Dale and Tyner (2006). However, cost of production for the ethanol plant partially replacing corn with dry pea was estimated following the recommendation of Wilhelmi et al. (2007).

Statistical distribution functions of the random variables were determined using BestFit (Palisade Corporation, 2007), which estimates parameters for each possible distribution using maximum likelihood estimators based on the historical data. Prices of ethanol and DDGS were calculated from 1982-2006, prices of corn were calculated from 1985 to 2006, price of dry pea were calculated from 1995 to 2006, and corn produced in North Dakota were calculated from 1998 to 2006. Present mean prices and historical standard deviation of prices were used for the distribution due to increase in the average prices of corn, dry pea and dry pea meal.

6.2. Results

Results showed that the ethanol plant 10% and 30% failed to cover the cost of production at present corn prices. The ethanol plant profitability was quite sensitive to changing corn prices.

The replacement of 10% of the plant's corn feedstock with dry pea resulted in lower profits. Net income/gallon of ethanol produced declined to $-0.472. Corn price have to rise more than 20% before peas would be breakeven. Alternative scenarios with increasing investment cost discounts of dry pea fractionation equipment improved profitability only marginally. The results also suggested that in present price ratio the 30% dry pea plant was not economically feasible.

6.3. Limitations of the Study

In this study, a model to evaluate the profitability of an ethanol plant partially replacing corn with dry pea was developed. Due to limited data indicating the starch and protein content of dry pea in North Dakota, the model had limitation in calculating the ethanol output from dry pea (Wilhelmi et al., 2007). Further laboratory experiments needs to be conducted to estimate the chemical composition in dry pea in the state and for estimating the probable change in the ethanol output. It is also recommended to improve the process model as it does not calculate the influence of increase or decrease in protein and fiber contents of dry pea.

The study was limited by the availability of price data of ethanol, DDGS, and dry pea meal. Due to limited production of ethanol in the state, there was no data available on point of consumption of the ethanol and DDGS. Also as ethanol industry works with contracts between the buyer and seller, the information was not available. Therefore future research may be conducted to estimate the average distance and the cost of transportation of the finished products.

In the process model it is expected that lysine content in the DDGS may increase thereby increasing the value of DDGS. However the expected percentage increase was not calculated as part of the process model. Therefore experiments need to be conducted before a firm assumption can be made which may result in higher returns for DDGS.

In the process model, it is suggested that dry pea hull would be another product coming out of the air classification. However it is not added in the economic feasibility model.

REFERENCES

BBI International, 2003. The Ethanol Plant Development Handbook, 4th edition, BBI International, Salida, CO.

Bryan and Bryan International, 2001. Dumas Texas Area Ethanol Feasibility Study. Unpublished, Bryan and Bryan International, Salida, CO.

Clean Fuel Development Coalition (CFDC), 2006. Ethanol Fact Book, Online available at: http://www.cleanfuelsdc.org/info/ethanol.html. Accessed on July 2007.

Cochran, M.J., Richardson, J.W., and Nixon, C., 1990. Economic and Financial Simulation for Small Business: A Discussion of the Small Business Economic, Risk, and Tax Simulator. Simulation, 54(4):177-188.

Coltrain, D., 2004. Economic Issue with Ethanol: Revisited. Unpublished, Kansas State University, Manhattan, KS.

Dale, T.R., and Tyner, W.E. 2006. Economic and Technical Analysis of Ethanol Dry Milling: Model Description. Unpublished, Purdue University, West Lafayette, IN.

Davidson, D., 2007. ND Experimenting Ethanol Boom. DTN News, February 27, 2007.

Eidman, R.V., 2007. Economic Parameters for Corn Ethanol and Biodiesel Production. Unpublished, University of Minnesota, Minneapolis, MN.

Gregoire, T., 2007. Pro Crop: Field Selection for Field Pea in Crop Rotations. Unpublished, North Dakota State University Extension Service, Fargo, ND.

Haugen, R., 2007. Preliminary Research on Field Pea Acres, Production, Agronomic Considerations and Sources of Information. Unpublished, North Dakota State University, Fargo, ND.

Iverson, J., 2007. Personal Communication. Iverson Farms.

Jorion, P., 2001. Value at Risk: The New Benchmark for Managing Financial Risk, McGraw Hill, New York, NY.

Lardy, G., 2007. Personal Communication. North Dakota State University.

Linsmeier, T., and Person N., 2000. An Introduction to Value at Risk. Financial Analytics Journal, 56:47-67, March-April.

McConnell, R.C., and Brue S., 2006. Economics, 17th edition, McGraw Hill/Irvin, New York, NY.

McKay, K., Schatz, B., and Enders, G., 2003. Field Pea Production. North Dakota State University Extension Service Bulletin, No. A-1166 (Revised), March.

McNew, K., and Griffith, D., 2000. Locating an Ethanol Plant: What will be the Impact on Corn Prices. Unpublished, Montana State University, Bozeman, MT.

McPhee, K., 2003. Dry Pea Production and Breeding: a Mini Review. Food, Agriculture and Environment, 1(1):64-69.

Nebraska State Government Energy Office, 2007. Energy Statistics: Ethanol Price Database. Online Available at: http://www.neo.ne.gov/statshtml/137.html. Accessed on July 2007.

Nichols, N., Dien, B.S., Wu, Y.V., and Cotta, M.A., 2005. Ethanol Fermentation of Starch from Field Peas. Cereal Chemistry, AACC International, Inc 82(5):554-558.

Oelke, E.A., Oplinger, E.S., Hanson., C. V., Davis, D.W., Putnam, D. H., Fuller, E. I., and Rosen C. J., 1991. Dry Field Pea. North Dakota State University Extension Service Alternative Field Crops Manual, No.1-11, April.

Outlaw, J.L., Anderson, D.P., Klose, S.L., Richardson, J., Herbst, B.K., Waller, M., Raulston, J., Sneary, S., Gill, R. 2003. An Economic Examination of Potential Ethanol Production Ethanol Production in Texas. Unpublished, Texas A&M University, College Station, TX.

Palisade Corporation, 2007. @ Risk 4.5- Professional Version Software.

Pouliquen, L.Y., 1970. Risk Analysis in Project Appraisal. World Bank Staff Occasional Papers, International Bank of Reconstruction and Development.

Price, G.P., 2002. Commodity Spotlight: Will the Farm Act get Pulses Racing? U.S. Department of Agriculture, ERS, Agriculture Outlook, Washington D.C., November.

Pryor, S., 2007. Synergy of Using Field Peas as an Ethanol Feedstock. Unpublished, North Dakota State University.

Renewable Fuels Association (RFA), 2006. Ethanol Industry Outlook. Online available at: www.ethnaolrfa.org. Accessed on July 2007.

---. 2007. Ethanol Industry Outlook. Online available at: www.ethanolrfa.org. Accessed on July 2007.

Reutlinger, S., 1970. Techniques of Project Appraisal under Uncertainty. World Bank Staff Occasional Papers, International Bank of Reconstruction and Development.

Ribera, L. A., Outlaw, J., Richardson, J.L., Silva, J.D., Bryant, H. 2007. Mitigating the Fuel and Feed Effects of Increased Ethanol Production Utilizing Sugarcane. Unpublished, Texas A & M University, College Station, TX.

Richardson, J.W., Herbst, B.K., Outlaw, J.L., Anderson, D.P., Klose, S.L., Gill II, R.C. 2006. Risk Assessment in Economic Feasibility Analysis: The Case of Ethanol Production in Texas. Texas A & M University, Agriculture and Food Policy Center, AFPC Research Report 06-03, September.

Richardson, J.W., and Mapp, H.P. Jr., 1976. Use of Probabilistic Cash Flows in Analyzing Investment under Conditions of Risk and Uncertainty. Southern Journal of Agri Economics, 8:19-24.

Rowe Jr, W.J., 1977. Some Further Comments on Input Classifications. Scandinavian Journal of Economics, 79(20):488-489.

Sakamoto, O., 2004. The Financial Feasibility Analysis of Municipal Solid Waste to Ethanol Conversion. Unpublished thesis, Michigan State University, East Lansing, MI.

Scholz, T.F., 2007. Personal Communication. Dry Pea and Lentil Council.

Senate Bill 2391, 2007. Johnson Backs Renewable Energy Standard. North Dakota Department of Agriculture, February.

Skrypetz, S., 2006. Dry Pea: Situation and Outlook. Agriculture and Agri-Food Canada Market Analysis Division, Bi-weekly Bulletin No. 19(2), February.

Smith, V.H. and Jimmerson, J., 2005. Dry Pea. Montana State University Agricultural Marketing Policy Centre, Briefing No. 57, November.

Tiffany, D.G., and Eidman, V.R., 2003. Factors Associated with Success of Fuel Ethanol Producers. Unpublished, University of Minnesota, Minneapolis, MN.

U.S. Department of Energy (USDOE). 2007. Energy Efficiency and Renewable Fuels, Alternative Fuels Department. Online available at: http://www.eere.energy.gov/afdc/altfuel/ ethanol.html. Accessed on July 2007.

United States Department of Agriculture (USDA). 2007. The Economic Feasibility of Ethanol Production from Sugar in United States, Washington D.C., July.

United States Department of Agriculture, National Agricultural Statistics Service (USDA, NASS). 2007. Quick Statistics: Agricultural Statistics Database 2007. Online available at: http://www.nass.usda.gov/QuickStats/PullData_UNITED STATES.jsp. Accessed on July 2007.

United States Department of Agriculture, Economic Research Services (USDA,ERS), 2007. Quick Statistics: Custom Query 2007. Online available at: http://www.ers.usda.gov/Data/Feedgrains. Accessed on July 2007.

Westcott, P.C., 2007. Ethanol Expansion in the United States, How will the Agricultural Sector Adjust? U.S. Department of Agriculture, ERS, FDS-07D-01, Washington D.C., May.

Whims J., 2004. Corn Based Ethanol Costs and Margins Attachment. Unpublished, Kansas State University, Manhattan, KS.

Wilhelmi, A., Wiesenborn, D.P., Gustafson, C.R., Pryor, S.W. 2007. Model for Mechanical Fractionation of Field Pea to Supplement a Dry Grind Corn Ethanol Plant. Presented on ASABE /CSBE North Central Intersectional Conference, Fargo, ND. October 12-13.

Wisner, R., 2001. Reduced Crop Estimate Offset by Reduced Demand. Iowa State University Agriculture Experiment. Station Economics Information, 1805, January.