A STOCHASTIC SIMULATION OF THE NORTH DAKOTA ETHANOL PRODUCTION INCENTIVE

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Title

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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

MASTER OF SCIENCE

ABSTRACT

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The objective of this research is to determine the effect the North Dakota Ethanol Production Incentive has on ethanol plant survivability. This thesis uses a stochastic simulation to show the financial performance of an ethanol plant with and without subsidy support. Historical corn and ethanol prices are used to simulate market conditions a typical ethanol might face. Using the forecast prices, an ethanol plant balance sheet was created to show how a plant would perform in normal market conditions, as well as how the plant would perform with the Ethanol Production Incentive and also with alternative subsidy structures that were developed. The results showed the Ethanol Production Incentive was the most effective subsidy tested and it does appear to improve plant balance sheets to a certain extent during a downturn.

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When I began graduate school three years ago, I really had no inkling of the journey that lay before me. As I took more advanced courses and encountered challenges that I truly believed were beyond my abilities, the support of friends and family grew from something that was just a comfort to a very crucial factor in the completion of this paper. To these people I owe everything.

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This thesis has been a marathon experience and I will never forget the people who helped me reach the finish line.

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1. INTRODUCTION

1.1. Problem Statement

The modern ethanol industry began in the 1970s in the wake of the Arab oil embargo. The U.S. government passed the National Energy Act in 1978, part of which was the Energy Policy Act that launched the ethanol industry by subsidizing ethanol 40 cents per gallon. Since 1978, the federal ethanol subsidy has ranged between 40 and 60 cents per gallon. The federal subsidy today is 45 cents per gallon for corn-based ethanol and $1.01 per gallon for cellulosic-based ethanol (Jessup, 2009). Over the past 30 years, various acts of legislation have been passed that have led to an increased usage of ethanol in fuels. Farmers have been strong proponents of ethanol because the ethanol industry has strengthened demand for corn and support for commodity prices.

The ethanol industry has experienced major growth in recent years due to rising oil prices, favorable national legislation and improving technologies, making ethanol more competitive in the energy industry. Many of the major agricultural producing states have extensive support programs to encourage new ethanol plant construction, make ethanol more price competitive, and increase ethanol demand. Major questions have been raised with regard to the efficacy of these subsidies: how they are structured, how they impact the market, who benefits, and who potentially is adversely affected.

North Dakota's Ethanol Production Incentive is designed to support new ethanol plants during economic downturns. The program operates by linking subsidy payments to both corn and ethanol prices. An analysis of the Ethanol Production Incentive is necessary to help North Dakota determine whether its ethanol support programs reduce probability of plant closure.

The Ethanol Production Incentive, passed by the State of North Dakota to protect ethanol producers from high corn prices, resulted in the state making substantial payments to ethanol producers (State of North Dakota, 2007). Questions have been raised regarding whether this is the best use of the state's tax dollars, what kind of impact the subsidy is having on the state ethanol producers and whether there are viable alternatives to the current subsidy program.

1.2. Objectives and Hypothesis

The study examines the current Ethanol Production Incentive that North Dakota uses to support the ethanol industry. The research involves developing a model to demonstrate the impact of the current program using a Monte Carlo Simulation. The model is used to determine the most efficient structure for the Ethanol Production Incentive, that is, the program that has the most positive impact on plant survivability. It is expected that the North Dakota subsidy for ethanol producers has improved plant rate of return on equity and reduced plant risk of bankruptcy. It also is expected that the alternative subsidy structures may provide greater improvements either in plant survivability or lower program costs.

Table 1.1 shows historical payments to ethanol producers since the ethanol production incentive came into effect. These figures can be used with historical corn and ethanol prices to measure the accuracy of forecast subsidy payments. Figures are from Energy Outreach and Special Programs, North Dakota Department of Commerce.

1.3. Thesis Overview

The thesis is organized into six chapters, including the introduction in Chapter 1. Chapter 2 reviews literature regarding the history of ethanol production and the importance of subsidies to the ethanol industry. Chapter 3 describes the theoretical model. Chapter 4

Table 1.1. Historical Payments Made to Ethanol Producers since the Ethanol Production Incentive Came into Effect.

Plants in Operation After 1995										
	Q1: 10/07 - 12/07		Q2: 1/08-3/08		Q3: 4/08-6/08		Q4: 7/08-9/08		Q5: 10/08-12/08	
Plant	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION
A	$240,963.59	13,955,420	$660,557.56	13,742,529	$698,478.85	13,776,946	$768,949.01	14,601,560	$0.00	14,649,505
B	$227,339.43	13,166,376	$650,385.93	13,530,914	$722,274.64	13,266,162	$705,556.31	13,397,797	$0.00	13,444,300
C							$961,448.88	18,525,516		
D										
Total	**$468,303.02**	**27,121,796**	**$1,310,943.49**	**27,273,443**	**$1,420,753.49**	**27,043,108**	**$2,435,954.20**	**46,524,873**	**$0.00**	**28,093,805**

	Q6: 1/09 - 3/09		Total	
Plant	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION
A	$16,303.24	14,592,920	$2,385,252.25	85,318,880
B	$12,847.07	11,499,320	$2,318,403.38	78,304,869
C			$961,448.88	18,525,516
D	$13,359.83	11,958,289	$13,359.83	11,958,289
Total	**$42,510.14**	**38,050,529**	**$5,678,464.34**	**194,107,554**

Plants in Operation Prior to 1995										
	7/02-6/03		7/03-6/04		7/04-6/05		7/05-6/06		Totals	
Plant	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION	PAYMENT	PRODUCTION
E	$500,000.00	1,250,000	$300,000.00	750,000	$300,000.00	750,000	$450,000.00	1,125,000	$1,550,000.00	3,875,000
F	$750,000.00	1,875,000	$600,000.00	1,500,000	$600,005.00	1,550,226	$900,000.00	2,261,909	$2,850,005.00	7,187,135
Total	**$1,250,000.00**	**3,125,000**	**$900,000.00**	**2,250,000**	**$900,005.00**	**2,300,226**	**$1,350,000.00**	**3,386,909**	**$4,400,005.00**	**11,062,135**

Source: (Energy Outreach and Special Programs, 2009)

presents the empirical model and describes the data sources, prices, distributions and alternative subsidy structures. Chapter 5 reports the simulation results showing a plant with no subsidy and then the same plant with the different subsidies being tested. Chapter 6 discusses the results, limitations and recommendations for future study.

2. LITERATURE REVIEW

2.1. Brief History of Ethanol[1]

Ethanol was first used as a fuel in an engine developed by Samuel Morey in 1826. During the Civil War, ethanol was taxed as a liquor to help raise money for the war effort. In 1908, Henry Ford's first automobile, the Model T, was designed to be able to run on either ethanol or gasoline. In the 1920s, ethanol became popular as an additive in gasoline to prevent engine knocking. The first U.S. ethanol plant was built in the 1940s by the U.S. Army for fuel production. For the next three decades, virtually no commercial ethanol fuel was sold due to low gasoline prices.

Before government action, there was only a marginal market for domestically produced ethanol fuels. The cost of producing ethanol was greater than the price consumers were willing to pay. During the Arab oil embargo of the early 1970s, the U.S. government responded by passing the Energy Tax Act of 1978, which included an exemption of the 4 cents/gallon federal fuel excise tax on gasoline for fuel blended with at least 10% ethanol (Whipnet Technologies, 2007). In the late 1970s, ethanol usage increased as it was blended more with gasoline to reduce carbon monoxide emissions. To further promote environmentally friendly fuels, the Crude Oil Windfall Profit Tax Act and the Energy Security Act were signed into law in 1980. This legislation was designed to encourage energy conservation and domestic fuel development (Whipnet Technologies, 2007). In the 1980s, ethanol became more commonly used as an oxygenate for gasoline Ethyl Tertiary Butyl Ether (ETBE), a fuel made from ethanol and petroleum, to reduce carbon monoxide

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[1] Information from the first three paragraphs was taken from the Fuel–Testers ethanol fuel history page. Fuel-Testers 2008. Available at http://www.fuel-testers.com/ethanol_fuel_history.html. [Accessed September, 2008].

emissions and smog. These early subsidies and favorable legislation were critical in making the ethanol industry commercially viable.

The Clean Air Act Amendments of 1990 required winter usage of oxygenated fuels in areas where carbon monoxide levels were not meeting EPA emissions standards. It also mandated year-round use of oxygenates in areas that were the farthest from meeting EPA ozone standards. The 1992 Energy Policy Act legislation was signed into law to decrease national dependence on fuel imports by requiring some fleets to use alternative fuel vehicles. In 1999, several states banned the gasoline additive Methyl Tert-Butyl Ether (MTBE) when traces of it were found in drinking water. By 2004, MTBE was banned as a fuel additive in most of the country. The phasing out of MTBE left ETBE as the primary fuel oxygenate in the United States.

At the turn of the century, major U.S. auto manufacturers began selling Flexible Fuel Vehicles (FFVs), which can run on gasoline blends of up to 85% ethanol. The Energy Policy Act of 2005 was the first federal legislation that required the use of renewable fuels. It also included regulations to ensure gasoline sold in the United States contained a minimum volume of renewable fuel, setting a target of 7.5 billion gallons of renewable fuel production by 2012 (U.S. Department of the Interior, 2005).

The Renewable Fuel Standard Program (RFS) was signed into law in September 2006. This national-level renewable fuel program was intended to increase the blending of renewable fuels (ethanol) into automobile gasoline. The national Renewable Fuels Standard (RFS) mandated doubling the use of ethanol and biodiesel by 2012 from 2006 levels.

In December 2007, the Energy Independence and Security Act was passed; it included provisions which raised renewable fuel (ethanol) production requirements to 15 billion gallons by 2015 and 36 billion gallons by 2022 (of this, 21 billion gallons were required to come from cellulosic and other advanced biofuels). More recently, throughout 2007-2008 an increasing number of individual states began requiring at least 10% ethanol in gasoline. In 2008, ethanol production reached 9 billion gallons.

These legislative acts have served as a catalyst for the recent dramatic growth in the ethanol industry. An April 2007 poll found that 70% of the public thought ethanol was a "good idea" and agreed with the statement that ethanol made from corn is an American-made substitute for foreign oil that causes less air pollution (CBS News/New York Times Poll , 2007). The survey highlighted the strong public support ethanol has had in recent years; this support is another reason the government has promoted ethanol more aggressively.

Ethanol production in the United States has grown dramatically in recent years; however, at present that growth has slowed significantly. Today's ethanol industry is a direct result of subsidies and regulations, at both the federal and state levels, aimed at promoting ethanol use, especially corn ethanol. Without government support, the ethanol industry would not exist (Perrin, Fretes, & Sesmero, 2008).

According to a study published in the *Proceedings of the National Academy of Sciences*, ethanol and biodiesel generate more energy than is consumed to produce it (Hill, Nelson, Tilman, Polasky, & Tiffany, 2008). Ethanol yields produced 25% more energy than the energy invested in its production, while biodiesel yields 93% more energy than what is invested in its production. These figures take into account the energies needed to process the fuels and produce the crop, as well as the energy required for all the inputs used to help produce the crop. Another important result of the study was its determination that if the entire U.S. corn and soybean crop were used for the production of biofuels, it would only meet 12% of gasoline and 6% of diesel demand. These numbers show that from an energy output perspective, biofuels produce more energy than they take to produce, yet alone they cannot meet U.S. energy needs.

2.2. Implications of Subsidies in the Ethanol Industry

Until recently, the ethanol industry has experienced enormous growth. U.S. ethanol production climbed to 9 billion gallons in 2008, an increase of more than 2.5 billion gallons from 2007 (Renewable Fuels Association, 2009). The rapid expansion in U.S. ethanol production resulted from higher oil prices during the past several years along with the passage of the Energy Policy Act of 2005 and current biofuels programs already in place (Wescott, 2007). Over the past 20 years, improvements in technology and efficiency have led to a 30% decrease in production costs (Gallagher, Shapouri, & Brubaker, 2007). The improvements in technology have helped boost the overall profitability of the ethanol industry by giving plants more capacity to absorb volatile commodity prices and are a notable factor in the recent building boom in the industry. Another factor leading to greater growth has been recent high oil prices, which made ethanol much more competitive and spurred government action to boost the industry in order to decrease dependence on foreign energy sources.

With these improvements in technology and efficiency, some have questioned the need for the government to continue subsidizing the ethanol industry. There are several reasons the ethanol industry continues to rely on subsidies. While an ethanol plant's ability to generate a profit has improved, the federal ethanol subsidy remains crucial in keeping the price of ethanol competitive. The volatile prices of inputs, such as corn and energy, have also had a negative impact on the ethanol industry's economic performance. The State of North Dakota passed the April 2003 Ethanol Production Incentive for several reasons. One was to protect the local ethanol industry from volatile commodity prices. Rural development was another reason the state found it necessary to support the industry. A 50-million-gallon per year (MGY) ethanol plant consumes 18.2 million bushels of corn per year with feedstock accounting for two-thirds of overall operational spending (Urbanchuck, 2006). Construction of a 50 MGY plant generates $209 million (2005 dollar value) of new annual gross output for the local economy, while a 100 MGY plant will generate $406 million annually. At the state level, a 50 MGY ethanol plant adds $115 million annually to the economy as measured by gross state output (Urbanchuck, 2006). These numbers indicate that the state economy should grow because of the operations of the ethanol industry (Urbanchuck, 2006).

The bankruptcy of VeraSun Energy in October 2008 due to poor hedging choices and Glacier Energy looking for more investor contributions are two prime examples that reveal how the ethanol industry is still sensitive to market fluctuations. When corn prices are high and ethanol prices are low, even well-managed ethanol producers can struggle to remain profitable. The North Dakota Ethanol Production Incentive is designed for this type of situation; its success in helping plants survive adverse market conditions will determine whether it should be kept in its current form, significantly altered or simply repealed.

Arguments also have been made against subsidizing ethanol in any form, blaming the corn-based ethanol plants for driving up the price of commodities and contending that ethanol plants consume more energy than they produce. A study prepared by the Congressional Research Service showed that "U.S. ethanol production in 2006 consumed roughly 17% of the U.S. corn crop and the futures contract for March 2007 corn on the Chicago Board of Trade, rose from $2.50 per bushel in September 2006 to a contract high of over $4.16 per bushel in January 2007 (a rise of 66%)" (Yacobucci & Schnepf, 2007, pp. 4,7). With market data showing the biofuels sector would have been profitable during much of

2006 without being subsidized (Perrin, Fretes, & Sesmero, 2008), questions have been raised as to whether the continued subsidizing of ethanol production is necessary. These concerns are focused on possible side effects that could result from excessive federal incentives; incentives that have already led to the recent expansion of ethanol production capacity and growth in demand for corn to supply future ethanol production.

Another point of contention over the ethanol industry is the effect ethanol plants have on the economy and the environment beyond the resources they consume. Structural concerns such as upgrading refinery infrastructure, as well as changes needed in engine design to accommodate larger proportions of ethanol in fuel are a direct result of increased ethanol use (Yacobucci & Schnepf, 2007). The environmental ramifications of increased biofuels production are another point to consider. Concerns exist over using food to produce fuel and whether the energy benefit from a fuel produced by natural gas and farm machinery is efficient enough to be justified. Another concern is land use change. According to Searchinger, if increased biofuels usage boosts demand for corn and pushes commodity prices higher, it would accelerate forest and grassland conversion to farmland even if surplus farmland exists elsewhere. The results of that study showed that if corn ethanol production was completely emission-free except for land-use change, overall greenhouse gas emissions would still be projected to increase over a 30-year period (Searchinger, et al., 2008).

A 2006 study by Swenson and Eathington examined the actual impact that new plant construction has on the local economy. They found that local job creation was exaggerated by assuming increased demand for corn would boost farming jobs. In reality, a surplus of corn still exists and increased efficiency continues to reduce the manpower needed for corn production. They noted local job creation was dependent on how much of the plant was actually owned locally (Swenson & Eathington, 2006). Another issue is the variable levels of sulfur in dried distillers grains (DDGS), which can be used as livestock feed. Highly variable sulfur levels in DDGS, however, can affect animal performance and health (Lane, 2007). Issues such as the quality of DDGS are highly relevant as DDGS are an important source of income to ethanol producers. Water usage has been another issue of contention, with many local towns, farmers and livestock operations concerned about the quantity of water that ethanol producers consume.

Before deciding whether or not the government ethanol subsidies should be ended or drastically reduced, the impact of doing so must be examined. A 2007 study by Kruse et al. simulated the impact if the 51 cents per gallon ethanol tax credit, the 54 cents per gallon ethanol import tariff, and the $1.00 per gallon biodiesel tax credit were permitted to expire. The study used a stochastic model to analyze the impact of the removal of the above subsidies but left the Renewable Fuel Standard mandating a minimum use of ethanol in place. Their results showed that future growth in biofuels is greatly reliant on the federal tax credits and the import tariff. They project ethanol production would contract by 30% and biodiesel production by more than half (this includes the recent capacity growth). Their results showed net returns would fall so dramatically that a large number of plants would close due to an inability to cover operating costs (Kruse, Westhoff, Meyer, & Thompson, 2007).

Another study by Perrin et al. examined the technical efficiency of the corn ethanol industry and its economic viablility. They examined seven average dry grind ethanol plants and found that from 2006 through 2007, average ethanol prices were 66 cents per gallon above the plant shutdown level (over variable operating costs). They also figured about 35 cents per gallon for interest and depreciation, and concluded net operating returns from the sample period would be large enough to encourage continued new plant construction. However, recent market volatility,the failure of Verasun, and the financial difficulties of other large ethanol producers have shown that the federal subsidy may not be sufficient. The study also found plants are vulnerable to the volitile prices of corn and when using more recent corn prices from July, 2008, the same plants would be 16 cents per gallon over shutdown level. Furthermore, without the federal 51 cents per gallon subsidy, operating revenues would drop to about 36 cents per gallon, leading to a large number of plants shutting down. (Perrin, Fretes, & Sesmero, 2008). This illustrates how crucial the federal 51 cents per gallon subsidy is to the ethanol industry.

A major political objective of ethanol subsidies is to benefit corn producers. The ability of seed producers and corn processors to take relatively large shares of the subsidy benefits when they can leverage market power is extremely relevant to the policy debate (Saitone, Sexton, & Sexton, 2007). When the seed companies and ethanol processors have oligopoly market power, the absolute benefits and share of benefits of the subsidy attained by farmers is sharply reduced. (Saitone, Sexton, & Sexton, 2007). Thus, much of the subsidy intended for corn producers is instead directed toward other players in ethanol production.

Another study regarding the impact of government support by Du et al. examines the net welfare change caused by the U.S. ethanol subsidy. Their findings were unusual because the first fundamental theorem of welfare economics would imply that the market-distorting ethanol subsidy should not be welfare enhancing and their results directly conflict with the theorem. (Du, Hayes, & Baker, 2008). The reason for this is that markets for agricultural commodities were not competitive prior to large-scale ethanol production due to farm subsidies (Du, Hayes, & Baker, 2008). Their results show the ethanol subsidy alone is market distorting, but the subsidy actually reduces the distortion from farm subsidies in agricultural commodity markets, with the combined effect being a reduction of net market distortion.

Another aspect of subsidies that should be examined is whether the subsidy is fixed or variable. The federal government currently has a 51 cents per gallon ethanol blended with gasoline credit. A 2006 study by Quear & Tyner developed a variable subsidy to compare with the fixed subsidy currently in place. They used a Tiffany-Eidman profit model to examine the efficiency of the subsidies and estimate government costs and producer risk. The study found that a variable rate subsidy cost the government 37% less than the current program and reduced producer risk by 21% compared with the current subisdy (Quear & Tyner, 2006).

Another study conducted in 2007 by Taheripour & Tyner used production functions, probable values of supply and demand elasticities, substitution elasticities, and market shares. They concluded that with a competitve market and no fuel standard, the share of the ethaonl subsidy between ethanol and gasoline producers depends on their supply elasticities and the elasticity of substitution between ethanol and gasoline (Taheripour & Tyner, 2007). This implies that when supply elasticity of corn decreases, farmers receive a larger share of the subsidy,but they also found that with the fuel standard and limited ethanol production capacity, producers should receive the entirety of the ethanol subsidy (Taheripour & Tyner, 2007). The study also showed ethanol production boosts demand for corn and in the longer term will push up demand for land as farmers try to increase output from a limited supply of land (Taheripour & Tyner, 2007).

More recently, ethanol producers have been faced with increasingly difficult market conditions. When cost-cutting measures and investment are no longer sufficient to keep the plant profitable, ethanol producers are faced with the choice of continuing to operate at a loss or shutting down. An important lesson from elementary microeconomics is that a firm should be shut down if operating revenues are less than variable costs (McDonald & Siegel, 1985). A plant in Grafton, North D akota, made that choice and shut down temporarily to wait for corn prices to fall or ethanol prices to rise (Shirek, 2007). Another plant in Pratt, Kansas , also suspended operations due to high corn prices but continued to employ the staff and used the downtime to undertake large maintence projects (Holmseth, 2008).

To help reduce the likelihood of ethanol plants closing from high corn and ethanol price gaps, North Dakota passed legislation creating the Ethanol Production Incentive , which is designed to ease the financial burden of high corn prices and low ethanol prices. This legislation includes payments for increased ethanol production at existing plants, as well as payments for higher corn prices.

> If the average quarterly price per bushel of corn is above one dollar and eighty cents, for each one cent by which the quarterly price is above one dollar and eighty cents, the Office of Renewable Energy and Energy Efficiency shall add to the amount payable under this section one-tenth of one cent times the number of gallons of ethanol produced by the eligible facility during the quarter. (State of North Dakota, 2007)

The legislation also has a mechanism to reduce the payment when ethanol passes a certain price per gallon. It states:

> If the average quarterly rack price per gallon of ethanol is above one dollar and thirty cents, for each one cent by which the average quarterly rack price is above one dollar and thirty cents, the Office of Renewable Energy and Energy Efficiency shall subtract from the amount payable under this section, two-tenths of one cent

times the number of gallons of ethanol produced by the eligible facility during the quarter. (State of North Dakota, 2007)

The legislation also limits subsidy payments for no longer than a 10-year period and no more than 10 million dollars total (State of North Dakota, 2007). Annual subsidy payments are capped at $1.6 million.The legislation also created the Ethanol Production Incentive Fund for the subsidy program.

3. THEORETICAL MODEL

This chapter develops a stochastic simulation model of a typical corn-based ethanol plant. The model is used to evaluate the impact of the Ethanol Production Incentive and whether it could be structured to be more effective at reducing the probability of plant bankruptcy. The stochastic profit model includes all economic sources of revenue as well as all fixed and variable costs from the production of ethanol.

With the high price volatility of inputs and outputs, it is difficult for ethanol producers to generate a return on their investment. Ethanol producers must carefully manage their margins in this sometimes adverse economic environment. As the price of corn changes, the subsidy payments made by the State of North Dakota also have fluctuated, and it is important to measure the effect the varying levels of these payouts are having on local ethanol producers. The standard net profit model for a profit maximizing business is:

$$(1)\quad \pi = TR - TC$$

Where π is profit, TR is total revenue and TC is total cost. TR is comprised of quantity of ethanol output multiplied by price, DDGS output multiplied by price, and revenue from subsidy payments. Total cost consists of fixed costs, such as depreciation of equipment and buildings, interest on borrowing, as well as variable costs, which are calculated by multiplying the cost of producing a single unit by the total output.

3.1. Production Function

To determine the impact of the current North Dakota state ethanol subsidy, a production function will be used to model an average North Dakota ethanol plant. The costs will be broken down into corn and miscellaneous inputs. This allows the impact of changing corn and energy prices on an ethanol plant's total cost to be measured. Output will be defined as ethanol and DDGS. A subsidy payment also will be included on the output side to account for the North Dakota Ethanol Production Incentive. The total subsidy payment is the payment per gallon multiplied by ethanol output, which is a function of corn and miscellaneous inputs. Ethanol revenue is price of ethanol multiplied by ethanol output. f'(x) is composed of both positive and negative variables.

The marginal rate of substitution is zero because the analysis assumes a fixed proportion production function. In this case, each unit of output requires a specific amount of each input, which leaves changing the level of output as the only method of adjusting to changes in cost of inputs.

We can now set up the profit function as shown below:

$$(2)\ \pi = P_1 f(x_1, x_2 | x_1) + P_2 g(x_1, x_2 | x_1) + S_1 f(x_1, x_2 | x_1) - x_1 w_1 - x_2 w_2$$

Where:

π is annual profit in dollars for a 50-million-gallon per year ethanol plant

P_1 is the price of ethanol in dollars per gallon

P_2 is the price of DDGS in dollars per ton

S_1 is the ethanol subsidy payment in dollars per gallon

$f(x_1, x_2 | x_1)$represents the quantity of ethanol output per gallon as a function of inputs x_1 and x_2(given x_1)

$g(x_1, x_2 | x_1)$ represents the quantity of DDGS output per ton as a function of input x_1 and x_2(given x_1)

x_1 is the quantity of corn in bushels

w_1 is the price of corn in dollars per bushel

x_2 is the quantity of miscellaneous inputs per gallon of ethanol produced

w_2 is the dollar value of miscellaneous inputs per gallon of ethanol produced

First Order Conditions

Taking the derivative of the profit function with respect to x_1 (quantity of corn) provides the marginal physical product of corn by employing one more unit of input as shown in Equation 3.

$$(3)\ \frac{d\pi}{dx_1} = 0 \ \leftrightarrow\ s_1 \frac{df(x_1,x_2|x_1)}{dx_1} = w_1 \ - \ p_1 \frac{df(x_1,x_2|x_1)}{dx_1} - p_2 \frac{dg(x_1,x_2|x_1)}{dx_1}$$

Let $f_{x1} = \frac{df(x_1,x_2|x_1)}{dx_1} \qquad g_{x1} = \frac{dg(x_1,x_2|x_1)}{dx_1}$

$$(4)\ \frac{d\pi}{dx_1} = 0 \ \leftrightarrow\ s_1 = \frac{w_1}{f_{x1}} - p_1 - p_2 \frac{g_{x1}}{f_{x1}}$$

To evaluate this expression, consider the sign of each individual term:

$\frac{w_1}{f_{x1}}$: w_1 (corn price) will be positive since corn prices are always greater than zero. f_{x1} will be positive as the firm will operate at the point on its production possibilities curve before diminishing marginal returns. Since both the numerator and denominator are positive, the entire term is positive.

$-p_1$: P_1 (ethanol price) will be negative with respect to S_1. As ethanol price increases, the subsidy payment will decrease which indicates an inverse relationship.

$-p_2 \frac{g_{x1}}{f_{x1}}$: P_2 (DDGS price) will be negative with respect to S_1 and as DDGS price increases the subsidy payment decreases, indicating an inverse relationship. $g(x_1)$ and $f(x_1)$ will be consistently negative as the firm will operate at the point on its production possibilities curve before diminishing marginal returns and with the negative sign they both will have an inverse relationship with subsidy payment.

The equation shows the direct relationship between the subsidy payment per gallon and the price of corn. The equation also shows an inverse relationship between subsidy payment and price of ethanol and DDGS. However, whether f'(x) is positive or negative is indeterminate because it is not known which absolute value is larger. As a result, the impact of the subsidy cannot be determined a priori.

Taking the derivative of the profit function with respect to x_2 (quantity of miscellaneous inputs) provides the marginal physical product of miscellaneous inputs by employing one more unit of input as shown in Equation 5. Profit is comprised of revenue generated by output of ethanol and DDGS, minus the cost of miscellaneous inputs. The equation shows a direct relationship between miscellaneous inputs and output, where a change in cost of miscellaneous inputs could change the optimal quantity of output.

$$(5)\ \frac{d\pi}{dx_2} = 0 \ \leftrightarrow \ s_1 \frac{df(x_1,x_2|x_1)}{dx_2} = w_2 - p_1 \frac{df(x_1,x_2|x_1)}{dx_2} - p_2 \frac{dg(x_1,x_2|x_1)}{dx_2}$$

Let $f_{x2} = \frac{df(x_1,x_2|x_1)}{dx_2} \qquad g_{x2} = \frac{dg(x_1,x_2|x_1)}{dx_2}$

$$(6)\ \frac{d\pi}{dx_2} = 0 \ \leftrightarrow \ s_1 = \frac{w_2}{f_{x2}} - p_1 - p_2 \frac{g_{x2}}{f_{x2}}$$

To evaluate this expression, consider the sign of each individual term:

$\frac{w_2}{f_{x2}}$: w_2 (cost of miscellaneous inputs will be positive since costs are always greater than zero. f_{x2} will be positive as the firm will operate at the point on its production possibilities curve before diminishing marginal returns. Since both the numerator and denominator are positive, the entire term is positive.

$-p_1$: P_1 (ethanol price) will be negative with respect to S_1. As ethanol price increases, the subsidy payment will decrease, which indicates an inverse relationship.

$-p_2 \frac{g_{x2}}{f_{x2}}$: P_2 (DDGS price) will be negative with respect to S_1 and as DDGS price increases the subsidy payment decreases, indicating an inverse relationship. $g(x_2)$ and $f(x_2)$ will be consistently negative as the firm will operate at the point on its production possibilities curve before diminishing marginal returns. The negative sign indicates they both will have an inverse relationship with subsidy payment.

Output is determined by factors such as corn and ethanol prices. The difference in price of the inputs and outputs in turn determine profitability. Miscellaneous inputs are a less significant factor for profitability and risk of bankruptcy because many miscellaneous inputs are fixed or can change by only a small degree. With the relationship of $f'(x)$ being indeterminate, the actual effect cannot be determined a priori.

The first order conditions taken with respect to x_1 and x_2 suggest that the total subsidy payment has an impact in determining plant output as well as reducing risk in adverse economic conditions. This follows the intent of the legislation, which is designed to increase support as marginal cost rises and marginal revenue falls. With respect to x_1, as the gap between marginal cost and marginal revenue grows, the total subsidy payment will also increase. This will boost marginal revenue and lead to higher output and profitability than market conditions would otherwise dictate. Equation 7 below takes the derivative of the profit function with respect to S_1 (ethanol subsidy payment per gallon of ethanol produced). The result suggests that if the subsidy increases, ethanol production will increase as well.

$$(7)\ \frac{d\pi}{ds_1} = f(x_1, x_2|x_1) > 0$$

The marginal rate of substitution is zero because the analysis used a fixed proportion production function. In this case, each unit of output requires a specific amount of each input.

3.2. Industry Supply Curve

The industry supply curve will show the relationship between the price of ethanol and the quantity supplied by producers. This can be formulated by finding the individual supply curves of the ethanol producers in North Dakota and then horizontal summing to determine the industry supply curve. To find an individual producer's supply curve in the long run, the marginal costs above the average total cost represents the firm's long-run supply curve (average variable cost and average total cost being the same in the long-run). The sum of the quantities all firms are willing to produce at a given price reveals the industry supply curve, as shown in Figure 3.1, where S_1 is supply without subsidy, S_2 is supply with subsidy, and P is price, Q is quantity and D is demand.

Figure 3.1 illustrates how the subsidy shifts the supply curve from S_1 to S_2. The amount of the subsidy is shown by the vertical distance (P1 – P2). The subsidy shifts the market equilibrium price from P_1 to P_2 and the production equilibrium quantity from Q_1 to Q_2 (McCain, 1998). The end result is a higher output quantity at a lower price.

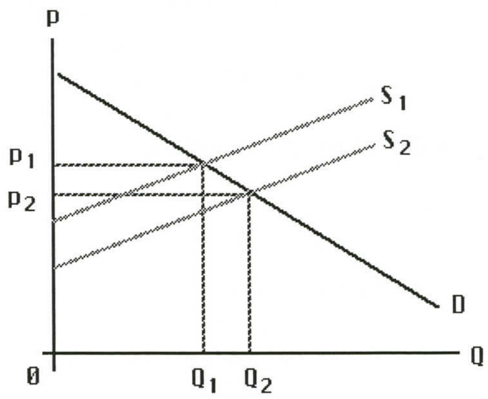

Figure 3.1. Ethanol Industry Supply Curve.
Sources: (McCain, 1998)

4. DATA SOURCES, METHODS AND SIMULATION PROCEDURES

A model was developed in the previous chapter to evaluate the impact of subsidy on the profitability of ethanol production (Equation 2). Using this model, the effect of the ethanol production subsidy can be examined and ways to improve it can be explored. In this chapter, an empirical Monte Carlo simulation model is developed, tested and evaluated with monthly corn and ethanol price data. The model is a spreadsheet designed to stochastically evaluate plant profitability with and without the Ethanol Production Incentive. The model also tests two alternative structures for the Ethanol Production Incentive. The stochastic element simulates corn and ethanol prices and uses survey data for the fixed costs of production. BestFit (Palisade Corporation, 2009) is used to fit the corn and ethanol distributions using the Anderson-Darling (A-D), Kolmogorov-Smirnov (K-S) and Chi-square (C-S) tests. The forecast prices are then used to project plant profitability, profitability with the Ethanol Production Incentive and profitability with the alternative subsidy structures. Stand alone plant rate of return on equity and probability of bankruptcy are calculated. The analysis compares the impact of different subsidies on plant rate of return on equity and probability of bankruptcy.

To determine the impact of the Ethanol Production Incentive on plant risk of bankruptcy, the outcome for two hypotheses is simulated. The null hypothesis is that the state ethanol subsidy will have no impact on plant risk of bankruptcy. The alternative hypothesis is that the state subsidy does have an impact on plant risk of bankruptcy.

4.1. Analytical Model

The empirical model developed in this chapter is based on Monte Carol simulation and tests the theoretical constructs proposed in the previous chapter. "Monte Carlo simulation is a computerized mathematical technique that allows people to account for risk in quantitative analysis and decision making" (Palisade Corporation, 2009). Plant profitability is simulated with a stochastic model using the Monte Carlo method. Historical data sets are used to generate probability distributions for corn and ethanol prices, which are then used to model future values. This was done in an Excel spreadsheet that was first set up to calculate plant income using historical data. When completed, dynamic and static variables are defined. Dynamic variables in the simulation are defined as corn price and ethanol price. These variables were selected both for their importance to plant profitability as well as for their significance in calculating the Ethanol Production Incentive payment. All other variables are left static because of their lesser impact on plant profitability and the dramatic increase in model complexity that would result by making all variables dynamic. Static variables include price of DDGS, cost of electricity, natural gas, additional natural gas drying for 60% of DDGS, labor and management. All of the simulations are before interest and taxes.

4.2. Data Sources

This section describes the sources of data used to calibrate the simulation model. Several sources of data are available, including Hofstrand (2008) and Ellinger (2007) but ultimately data from a study investigating the efficiency of Midwest ethanol plants (Perrin, Fretes, & Sesmero, 2008) were selected. The study by Ellinger offers greater detail for plant operational cost data: it projects the balance sheet of plant finances for several years and includes details such as income per bushel of corn consumed and income per gallon of ethanol produced. Furthermore, the study includes the predicted breakeven prices of ethanol and corn. However, the data are highly dependent on assumptions such as plant size (100 million gallons), per gallon total building cost at $1.80 per gallon, 50% equity financing, and a sweep factor of 25%. Another study by Hofstrand at Iowa State University also was considered, which calculates returns per gallon of ethanol produced, as well as profitability, revenue and costs. Like Ellinger, this study calculates the breakeven point for corn and ethanol price. However, the study is dependent on assumptions such as year built (2007), specific capacity (100 million gallons), 50% lender financing, a plant operating at 120 percent of nameplate capacity, and input costs typical for an Iowa corn ethanol facility.

Both of these studies attempt to model the profitability of one ethanol plant in a specific geographic area, with the former study based on a plant in Illinois and the latter study focused on a plant in Iowa. Inputs and costs of both locations vary from that of North Dakota. In Perrin's study, seven dry-grind ethanol plants throughout the Midwest were surveyed. None of the plants were in North Dakota; however, the averages of the data taken are more likely to reduce error. The studies by Hofstrand and Ellinger both model a single plant in a single state, versus Perrin's study that uses data from Iowa, Michigan, Minnesota, Missouri, Nebraska, South Dakota and Wisconsin (see Table 4.1). Another advantage of Perrin's study that should be emphasized is that it uses actual survey data, versus the other studies, which were more dependent on assumptions and projected figures. The survey period for Perrin's study began in the third quarter of 2006 and lasted until the fourth quarter of 2007 (six consecutive quarters).

Table 4.1. Ethanol Plant Costs.

Variable Cost per gallon	**Perrin**	**Hofstrand**	**Ellinger**
Cost of Corn	$0.93	$1.24	$1.05
Cost of Electricity	$0.03	$0.06	$0.37
Cost of Natural Gas	$0.25	$0.28	
Natural Gas 60% DDGS dry	$0.12		
Labor and Management	$0.05	$0.03	$0.03
Other	$0.19	$0.20	$0.20
Total	**$1.57**	**$1.80**	**$1.64**

Sources: Perrin (2008), Hofstrand (2008), and Ellinger (2007)

The goal of Perrin's study was to estimate the cost function of a representative Midwest ethanol plant. Both variable and fixed costs were estimated. A critical measure of ethanol plant performance is corn cost per gallon of ethanol produced.

Perrin's study found corn costs to be 93 cents per gallon. Ellinger provided a seven-year projection with a combined energy (thermal and electric) cost of 37 cents per gallon. Perrin also factored in cost of additional natural gas for drying 60% of DDGS at 12 cents per gallon of ethanol produced. Neither Ellinger nor Hoftstrand had a separate figure for this factor. Table 4.2 contains the costs and the figures used in calculating the subsidy.

The payment threshold is specified in state legislation: When the price per bushel of corn is over $1.80, the state will pay one-tenth of a cent for each cent over the threshold. The deduction threshold is specified as follows: When the price per gallon of ethanol is over $1.30, the state will deduct from the payment two-tenths of a cent for each cent over the threshold.

Representative fixed costs were not surveyed in Perrin's study; however, it included a combined estimated cost of 35 cents per gallon for interest and depreciation. These were higher than either Hofstrand or Ellinger's studies indicated, as shown in Table 4.3. The Midwest ethanol plants surveyed produced 2.86 gallons of ethanol per bushel of corn. They also produced 14.9 pounds of DDGS per bushel of corn. Using the aforementioned statistics, the cost per gallon of ethanol can be calculated along with plant profit or loss per gallon. The ethanol production incentive also is factored in separately to show the difference between plant profit with and without subsidy.

In years with net losses, both the net loss and principle payment reduce plant equity. Principle payments were calculated using the principle payment function in Excel. Inputs

Table 4.2. Total Plant Costs.

Item	Price
Feedstock	
Ethanol per bu of Corn (gal/bu)	2.87
Corn needed for production (bu)	17,421,602
Total DDGS extracted (tons)	128,484.00
DDGS (revenue per gallon)	$0.23
Miscellaneous Input Costs (per gallon)	
Electricity	$0.03
Natural gas (MMBTU)	$0.19
additional drying for 60% of DDGS	$0.04
Labor and Management	$0.05
Depreciation and Interest	$0.35
Other	$0.19
Total Miscellaneous Input Costs (per gallon)	$0.85

Sources: Perrin (2008)

Table 4.3. Interest and Depreciation Costs.

Fixed Costs per Gallon	Perrin	Hofstrand	Ellinger
Interest		$0.07	$0.12
Depreciation		$0.11	$0.08
Total	**$0.35**	**$0.18**	**$0.20**

Sources: Perrin (2008), Hofstrand (2008), and Ellinger (2007)

used included the interest rate on debt (15%), period (annual), nper (15), and annual loan balance ($45 million). Total equity was calculated by adding annual net income to starting equity.

In the simulation, miscellaneous costs are static while costs of corn and price of ethanol are dynamic. Costs were calculated on a per gallon basis and categorized as the cost of corn and miscellaneous costs. Cost of corn per gallon was calculated using a cost function coefficient (Perrin, Fretes, & Sesmero, 2008). Miscellaneous costs per gallon include electricity, natural gas, drying for 60% of DDGS, labor and management, and other expenses, as shown in Table 4.2. Revenue is comprised of ethanol price, DDGS sales, plus the subsidy payment, if applicable.

Operating cost less interest and taxes was calculated by multiplying operating cost per gallon by total plant capacity. Mean operating costs were $1.24 per gallon, which compares with $1.29 per gallon from Perrin et. al. (2008), 97 cents per gallon from Shapouri and Gallagher (2008), 92 cents from Kwiatkowski and McAloon (2006), and $1.31 from Eidman (2007). Interest was calculated using the interest payment function in Excel. Total operating cost was calculated by taking the sum of operating cost less interest and taxes.

The rate of return on equity was calculated by dividing net income by average equity (Brigham, Gapenski, & Ehrhardt, 1999). Rate of return on equity was calculated for ten years and then the average was taken for the 10-year average rate of return on equity. Plant equity was examined to determine the 10-year average rate of return on equity for the plant, as well as to evaluate the possibility of bankruptcy.

Risk of bankruptcy was calculated each year for 10 years. If equity was positive, the spreadsheet cell value was zero, meaning not bankrupt. If equity was negative, the spreadsheet cell value was one for bankruptcy. Negative equity automatically reset equity the next year back to starting equity and assumes new ownership. The 10-year risk of bankruptcy was calculated by taking the mean of the risk of bankruptcy cells for all 10 years. This was done to show the percent chance of plant bankruptcy, both with and without the different subsidies.

4.3. Price Data

Corn price data were obtained from the National Agricultural Statistics Service (NASS), which conducts agricultural market research and collects agricultural statistics for the

United States Department of Agriculture (USDA). Ethanol price data were obtained from the Nebraska Energy Office. The Nebraska Ethanol Board supplied the ethanol price data.

Corn price was simulated with monthly data from January 1988 to December 2008 (United States Department of Agriculture, 2007). The mean price of corn was $2.32 per bushel with a standard deviation of 72 cents per bushel. The median price was $2.17 per bushel. The highest price was $6.33 per bushel while the lowest price was $1.46 per bushel. Price data were used from the USDA source (through NASS) for North Dakota. The data, as graphed below in Figure 4.1, show the average corn price over the past 20 years.

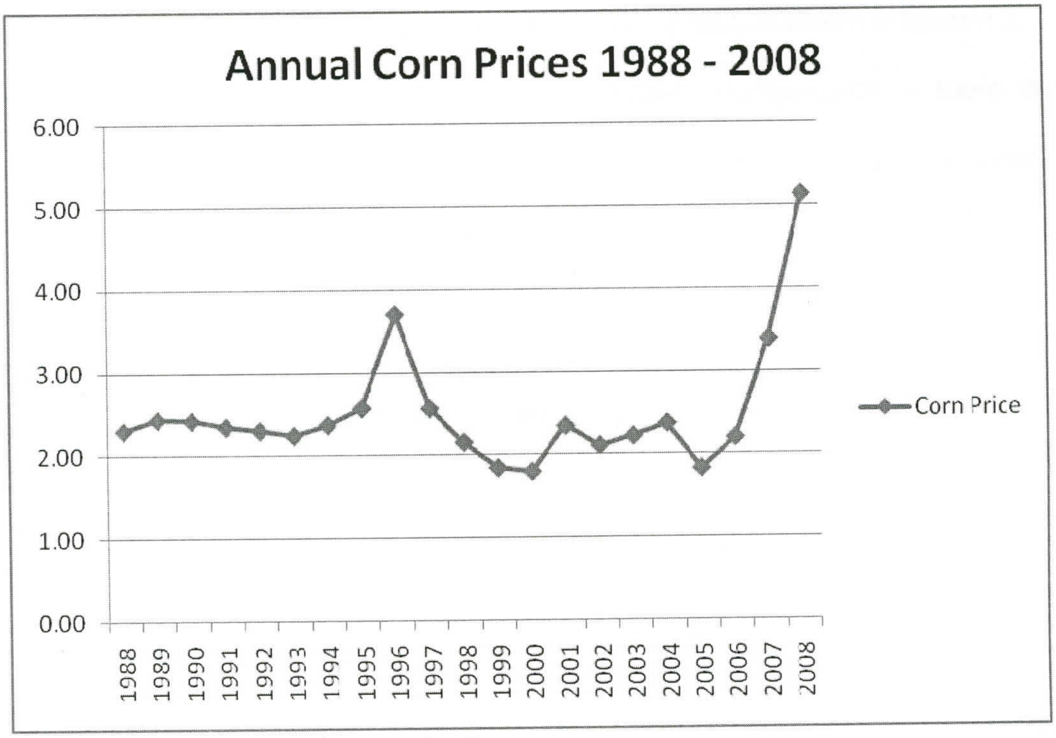

Figure 4.1. Annual Corn Price Data.
Source: NASS, USDA

From 2005 to 2008, the price of corn in the United States more than doubled. There are many factors that are pushing prices higher. Some of the major factors include the increased demand for corn used in ethanol production, reduced global supplies from poor harvests, the low value of the dollar, increased consumption by emerging economies, and higher input costs (Capehart & Richardson, 2008). With the rising corn prices, ethanol producers have been impacted significantly as their input costs have increased dramatically. While the size of the recent price spike is unusual, it is important to include it in the study, as price spikes in the future are possible. As the world population continues to grow and the amount of arable land decreases, it is likely that there will be more surges in demand in the future. According to a study by McPhail & Babcock (2008), the expansion of ethanol production will increase the prices of corn. More recently, however, corn prices have eased back to historical prices.

Ethanol price was simulated using ethanol price monthly data, as shown in Figure 4.2 below, were used from January 1988 to December 2008 (Nebraska Energy Office, 2009). The mean price of ethanol was $1.45 per gallon with a standard deviation of 49 cents per gallon. The median price was $1.26 per gallon and the highest price was $3.58 per gallon, while the lowest price was 90 cents per gallon.

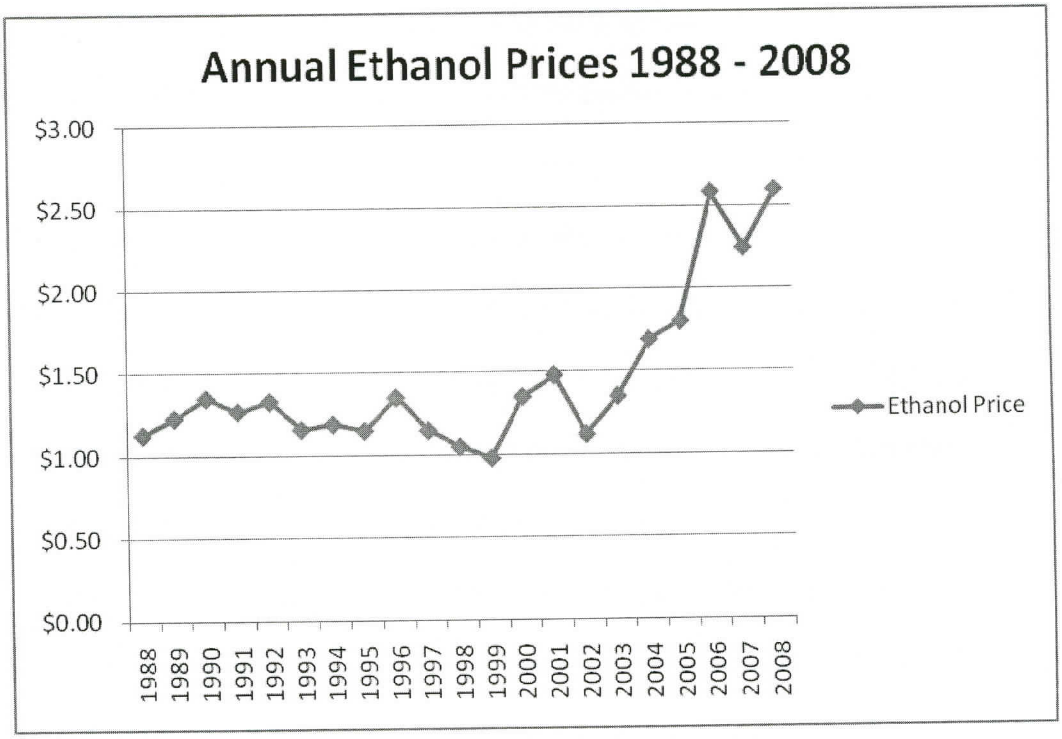

Figure 4.2. Annual Ethanol Price Data.
Source: Nebraska Energy Office

Since 2002, ethanol prices have steadily increased. Federal legislation such as the Energy Policy Act of 2005, Renewable Fuel Standard Program of 2006, and the Energy Independence and Security Act of 2007 all boosted demand for renewable fuels. At the same time, gas prices, which are positively correlated with ethanol prices at the national level, have experienced a dramatic increase, making ethanol more attractive as an alternative and leading to higher demand and higher prices. More recently, as the price of gasoline has retreated so has the price of ethanol, with both falling to levels closer to 2005 prices. The data are collected in Nebraska, and while Nebraska rack prices will not be identical to that of North Dakota, local historical data does not exist due to the relatively late beginning and small scale of the ethanol industry in North Dakota.

4.4. Data Distribution

The model was designed to show the effect that the Ethanol Production Incentive has on plant rate of return on equity and plant shutdown point. The model was then used to explore ways the subsidy could be changed to be more effective. The data distributions were used by @Risk (Palisade Corporation, 2009)to predict future prices. Using the production function developed earlier with survey data from Perrin's study, it is possible to model ethanol plant return on equity, subsidy payments and risk of bankruptcy. Using monthly data from January 1988 to December 2008, @Risk was used to test each set of data for the best distributional fit using the Chi-squared (C-S), Anderson-Darling (A-D), and Kolmogorov-Smirnov (K-S) tests. Once the best distributional fits were found for both corn and ethanol, they were used to forecast prices.

The Risk Loglogistic distribution fitted the corn prices with the A-D, and K-S distribution statistics. Risk Loglogistic was fitted first with A-D and K-S, and a close second in C-S. This was done using the BestFit distribution (Palisade Corporation, 2009). The A-D and K-S distributions are more applicable to continuous data, whereas C-S was derived to test binned data. As a result, the Loglogistic density function was chosen to model the distribution of corn prices. Loglogistic parameters are defined by gamma, beta, and alpha, which are the location parameter, shape parameter, and scale parameter, respectively. For Loglogistic corn price, the gamma was 1.30, beta was .84, and alpha was 2.92. The p-value was .1704.

The Risk Loglogistic distribution fitted the ethanol prices with the A-D and K-S distribution statistics. Risk Loglogistic was fitted first with A-D and K-S, and a close second in C-S using BestFit Distribution (Palisade Corporation, 2009). As a result of the distributional fit tests, Risk Loglogistic was chosen to simulate ethanol price. For Loglogistic ethanol price, the gamma was .89, beta was .41, and alpha was 2.21. The p-value for ethanol price was .0001.

The shapes of the two distributions are similar; both are skewed towards the left with tails unbound to the right. On the national level there is strong evidence that corn and ethanol prices are correlated. Using the historical corn and ethanol prices, a correlation coefficient of .41 was imposed on the simulated prices.

4.5. Alternative Subsidy Structures and Sensitivities

Along with examining the current Ethanol Production Incentive, the model also was used to test two alternative structures for the subsidy to determine if the changes would improve the subsidy's effectiveness.

One alternative subsidy is to base the payment on the historical price margin between corn and ethanol. Using the historical data collected earlier, the average margin between corn price per bushel and ethanol price per gallon was calculated at 87 cents. This was set as the new payment threshold and kept the one-tenth of a cent payment for each cent over the set price. The subsidy deduction was eliminated; all other aspects of the subsidy (time limit, payment limits) were left unchanged. In the study, this is referred to as the margin subsidy.

The second alternative subsidy takes the rolling average of the most recent three years of corn and ethanol prices and uses the average as the subsidy thresholds for payments and deductions. The subsidy payment was increased to one-half cent for each cent over the threshold in order for the subsidy to have a significant impact. All other aspects of the subsidy were unchanged. In the study, this is referred to as the three-year rolling average subsidy.

The sensitivities used DDGS as a dynamic variable, which was applied to the base model and the three-year rolling average alternative subsidy model. This variable was made dynamic to improve the accuracy of the simulation.

4.6. Statistical Significance

The following formulas are used to prove that the results of the different subsidy structures are statistically significant from the base mode (Mendenhall, Beaver, & Beaver, Introduction to Probability and Statistics, 2006):

H_o : Any difference is due to random error.
H_a : Difference is a result of systemic differences.

To find the total sample variance (s^2), the number of observations in the base model minus one is multiplied by base model population variance. This is repeated for the subsidy model and the two calculated figures are summed. The summed total is then divided by base model observations plus subsidy model observations minus two.

$$s^2 = \frac{(N_1 - 1)\,\sigma_1^{\,2} + (N_2 - 1)\,\sigma_2^{\,2}}{N_1 + N_2 - 2}$$

To find the calculated t-value for statistical significance, the average risk of bankruptcy in the base model is found and then subtracted from the average risk of bankruptcy in the subsidy model. The calculated figure is then divided by the square root of sample variance multiplied by one divided the number of base model observations plus one divided by subsidy model observations.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(s^2 (\frac{1}{n1} + \frac{1}{n2}))}}$$

Where:

N_1 is number of observations from the base model

N_2 is number of observations from the subsidy model

$\sigma_1{}^2$ is the population variance of the base model

$\sigma_2{}^2$ is the population variance of the subsidy model

$\bar{x}_1$ is the average risk of bankruptcy of the base model

$\bar{x}_2$ is the average risk of bankruptcy of the subsidy model

s^2 is the total sample variance

5. RESULTS AND SENSITIVITIES

Results of the stochastic simulation model developed to evaluate North Dakota's ethanol production incentive are presented in this chapter. The model simulates plant profit per gallon with and without the North Dakota Ethanol Production Incentive. The simulation was run for 10,000 iterations in @Risk. The rate of return on equity for a 50-million-gallon per year ethanol plant was determined with and without the ethanol production incentive in the context of both risky input and output prices to determine the impact of the ethanol production incentive on plant viability. In summary, the incentive was found to decrease plant vulnerability to high market prices of corn. The subsidy accomplished this by increasing support when the price of corn was high and decreasing support as ethanol price increased. Finally, alternative subsidy structures were examined that provide greater financial assistance to plants while minimizing public sector burden.

5.1. Chapter Overview

The base rate of return on equity for the simulated ethanol plant is 6.41%, as shown below in Table 5.1. In the base model, mean prices paid for corn and received for ethanol are $2.29 per bushel and $1.44 per gallon, respectively. These prices were randomly drawn from Loglogistic distributions using historical data. Results of this statistical estimation are presented in section 5.2.

The rate of return with the Ethanol Production Incentive increases to -0.04% (Table 5.1). The Ethanol Production Incentive is presented in section 5.3. Then, margin based subsidy is

Table 5.1. Simulated Ethanol Plant's Return on Equity.

	Rate of Return	Net Income
No Subsidy	-6.41%	$1,277,668
With Subsidy	-0.04%	$1,996,609

tested and presented in section 5.4. The three-year rolling average subsidy is presented in section 5.5.

5.2. Ethanol Plant Simulation: Base Model

This section discusses the base model that includes forecast prices for corn and ethanol, as well as the forecast for net income, the rate of return on equity, and the probability of bankruptcy for an unsubsidized ethanol plant.

5.2.1. Corn price forecast. Corn prices in the base model were based on USDA data collected from 1988 through 2008. @risk calculated the BestFit simulated distribution as RiskLoglogistic (1.29, 0.835, 2.91), shown in Figure 5.1. At a 90% probability, corn price is expected to fall in a range from $1.61 per bushel to $3.54 per bushel, with a mean price of $2.29 per bushel. The minimum and maximum expected prices were $1.32 per bushel and $7.97 per bushel with a standard deviation of 68 cents per bushel. Perrin's projected corn price was $3.04, and studies by Shapouri and Kwiatkowski estimated corn price at $2.23 and $2.20, respectively. The distribution is positively skewed and unbound to the right, which implies higher prices are increasingly unlikely. A correlation of .45 was found between historical corn and ethanol prices and was imposed on the probability distributions for both. Potential price spikes could be caused by infrequent events, such as unfavorable growing conditions and crop failures. In most years though, prevailing prices hover around the mean closest to the left-hand side of the distribution. This implies that ethanol plants can plan under normal circumstances for corn prices to fall inside the expected price range, which can be used to estimate the future cost of corn, as well as subsidy payments.

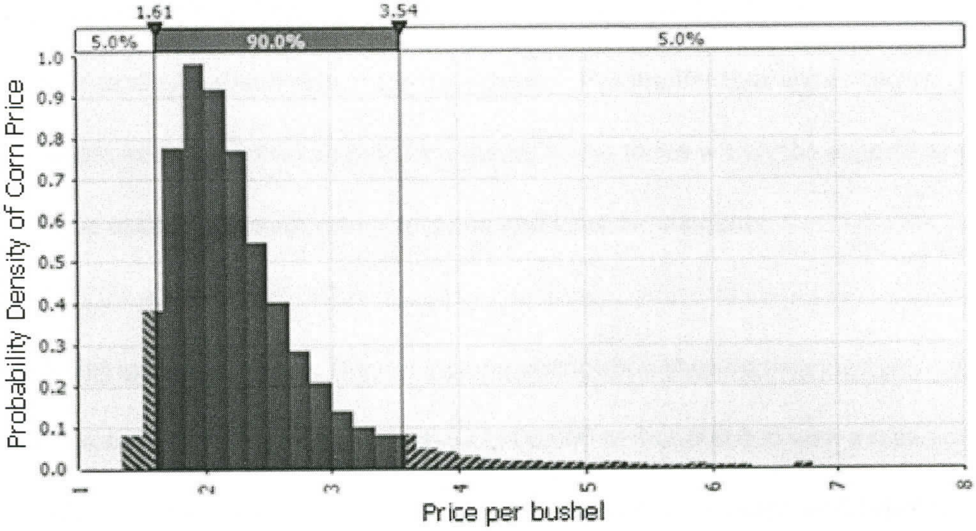

Figure 5.1. Corn Price Probability Distribution.

5.2.2. Ethanol price forecast. Ethanol prices in the base model were based on 1988-2008 data from the Nebraska Energy Office. @risk calculated the BestFit simulated distribution as RiskLoglogistic (0.88, 0.41, 2.21), shown below. At 90% probability, ethanol price is expected to fall in a range from 99 cents per gallon to $2.37 per gallon, with a mean price of $1.44 per gallon. The minimum and maximum expected prices are 88 cents per gallon and $5.37 per gallon with a standard deviation of 51 cents per gallon. Figure 5.2 shows the distribution is positively skewed and unbound to the right, which implies higher

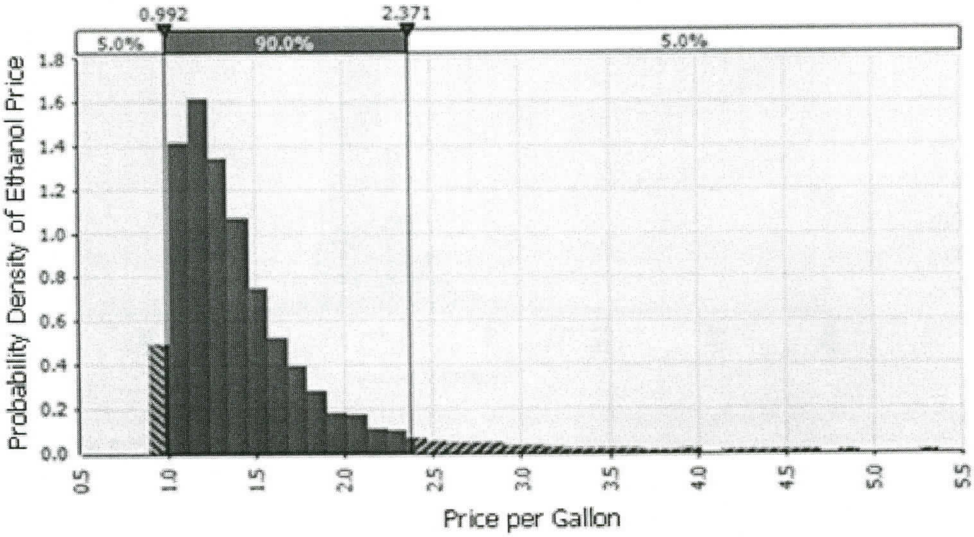

Figure 5.2. Ethanol Price Probability Distribution.

prices are increasingly unlikely. In most years though, prevailing prices hover around the mean closer to the left-hand side of the distribution. This implies that under normal circumstances ethanol plants can plan for ethanol prices to fall within the expected range, which can be used to estimate future revenue and subsidy payments.

5.2.3. Net income forecast. The net income distribution showed expected plant income at 90% of probability falling at a range of -$22,600,000 to $42,800,000 with a mean of $1,277,668. The minimum and maximum expected income is projected at -$110,470,542 and $193,080,398 with a standard deviation of $23,632,561. Net income is before interest and taxes. Perrin's study had plant return over operating cost at $33,150,000 (taking return over operating costs per gallon times 50 million gallons). The net income distribution, shown in Figure 5.3, follows the corn and ethanol price distributions as positively skewed and unbound. In the same way, the tails also reflect this with most scenarios showing net income hovering near the mean at the left-hand side of the distribution and with the

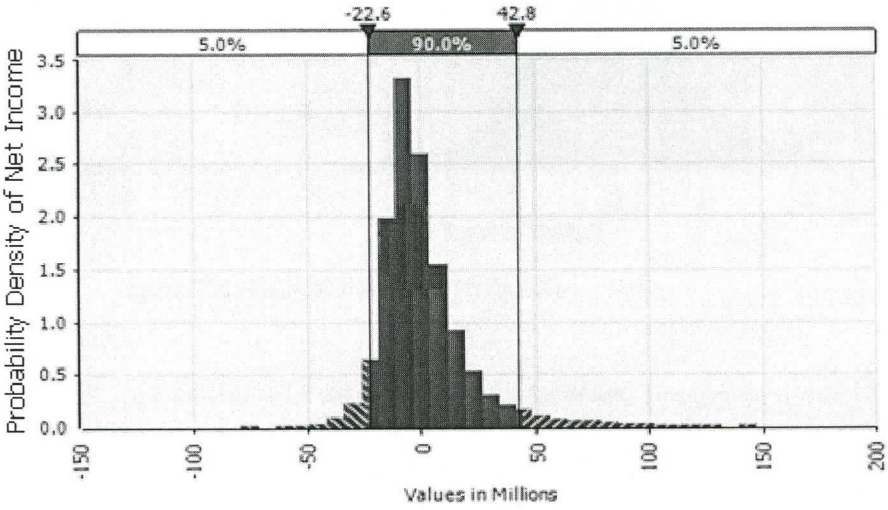

Figure 5.3. Net Income Distribution.

outlying levels of income increasingly unlikely. The tails of the net income distribution reflect the influence corn and ethanol price have on net income, with the tails of the net income distribution similar to that of corn and ethanol.

5.2.4. Rate of return on equity forecast. The rate of return on equity was calculated by taking the net income and dividing by average equity (Brigham, Gapenski, & Ehrhardt, 1999). The rate of return on equity distribution shows the expected rate of return at 90% probability, falling from -67% to 64.5% (Figure 5.4). The minimum and maximum rates of return are projected at -254.79% and 136.41% with a standard deviation of 40.82%. The mean rate of return is -6.41%.

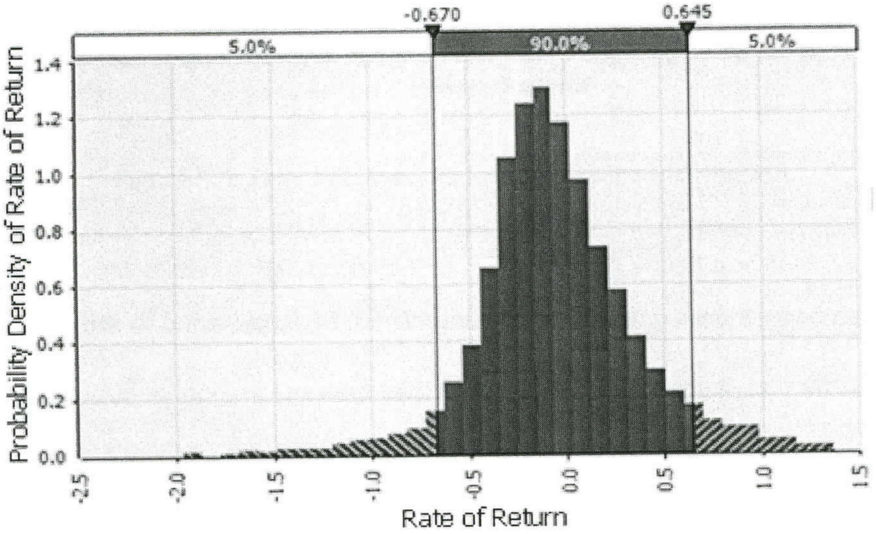

Figure 5.4. Rate of Return Distribution.

5.2.5. Ten-year rate of return on equity forecast. The ten-year rate of return on equity was calculated by taking the net income and dividing by the average equity (Brigham, Gapenski, & Ehrhardt, 1999). The rate of return on equity distribution shows the expected rate of return at 90% probability falling from -.2% to 0% (Figure 5.5). The minimum and maximum rate of return are projected from -1981.46% and .3456% with a standard deviation of 26.11%. The mean rate of return is -1.26%. The 10-year rate of return is a measurement to show the return an investor could expect on investment. Taken along with risk of bankruptcy, it shows the level of investor risk versus expected return.

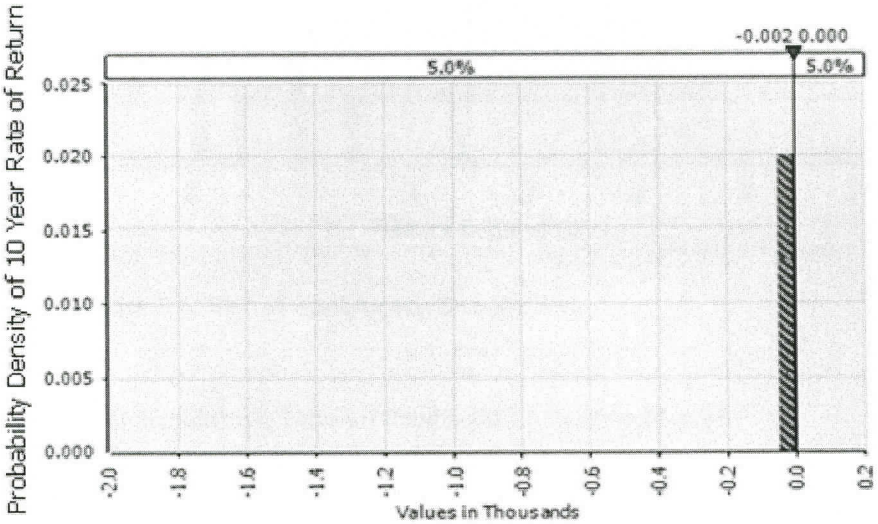

Figure 5.5. Ten-Year Average Rate of Return Distribution.

5.2.6. Risk of bankruptcy. In the simulation, bankruptcy occurs when equity reaches zero. If bankruptcy occurs, the next year begins with equity at $45,000,000 (original starting equity) and assumes a new owner purchases the plant. The risk of bankruptcy is determined by taking the average of the number of times equity reaches zero over ten years (Figure 5.6). At 90% probability, the risk of bankruptcy falls between 0% and 50%, with a mean probability of 10.64%. The standard deviation is 14.76%.

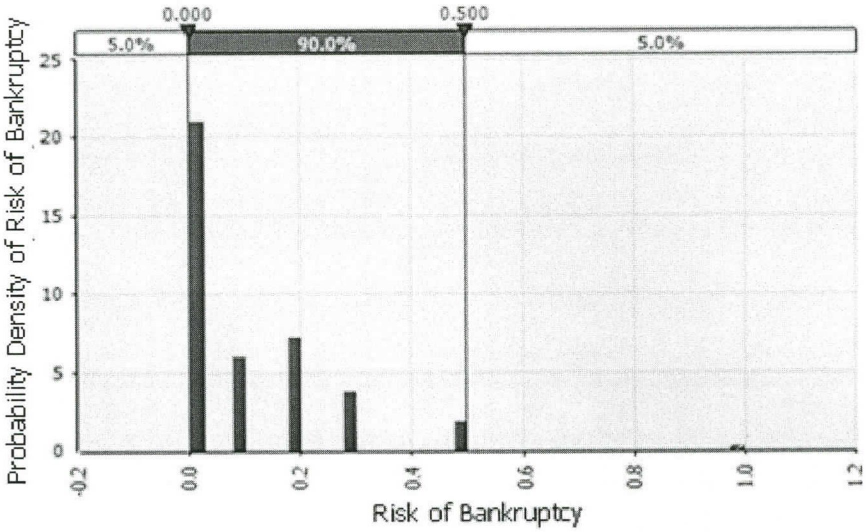

Figure 5.6. Risk of Bankruptcy Distribution.

5.3. Ethanol Plant Simulation: Ethanol Production Incentive Model

This section covers the Ethanol Production Incentive model using the same results for corn and ethanol prices. It includes the subsidy payment per gallon, net income with subsidy payment, and rate of return with the subsidy.

5.3.1. Ethanol production incentive subsidy payment per gallon forecast. The total Ethanol Production Incentive payment (per gallon) was calculated using the forecast corn and ethanol prices. At 90% probability, the subsidy payment is expected to fall in a range of zero cents per gallon to 17.4 cents per gallon, with a mean payment of 5.17 cents per gallon (Figure 5.7). The minimum and maximum expected payments are zero cents per gallon and 61.78 cents per gallon, with a standard deviation of 6.54 cents per gallon.

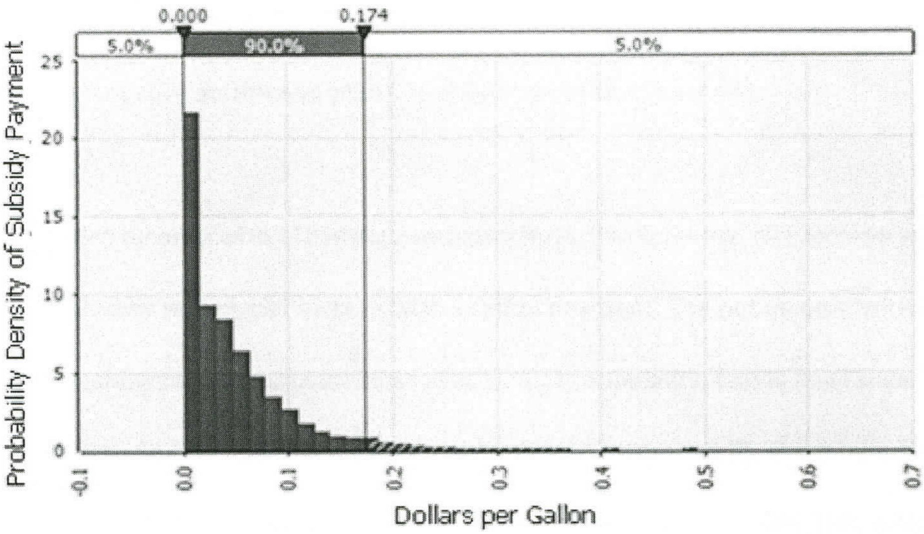

Figure 5.7. EPI Subsidy Payment per Gallon Distribution.

5.3.2. Total ethanol production incentive payment forecast. The total subsidy payment to the plant was calculated by multiplying the subsidy payment per gallon by plant capacity. At 90% probability, the subsidy payment falls in a range of $0 to $1.6 million with a mean payment of $718,941 per firm and a standard deviation of $718,094 (Figure 5.8). The subsidy payment softens the impact of downturns when there are high corn prices and low

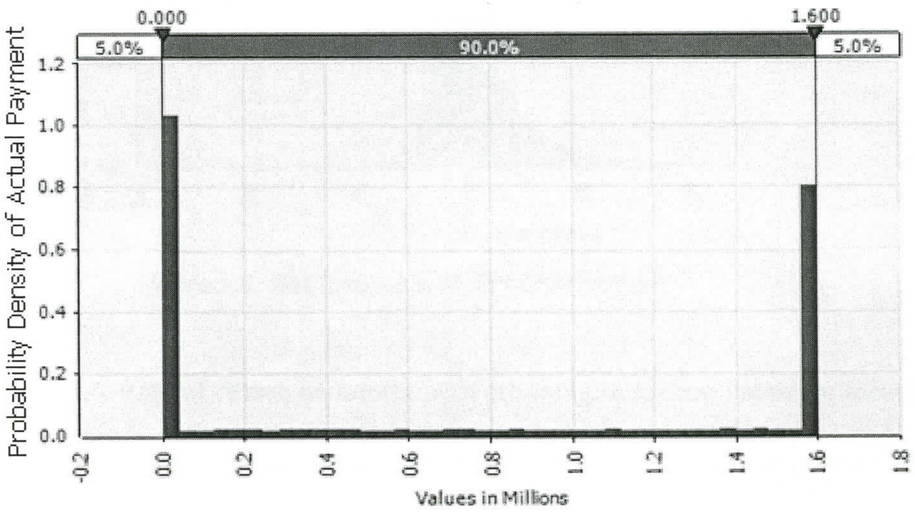

Figure 5.8. EPI Subsidy Payment Distribution.

ethanol prices, decreasing the size of the losses incurred. The subsidy appears to moderately improve an ethanol plant's ability to weather downturns.

5.3.3. Net Income with ethanol production incentive forecast. Net income with subsidy was calculated by adding net income with subsidy payment. The net income with subsidy distribution shows expected plant income at 90% of probability, falling in a range of -$21,000,000 to $42,800,000 with a mean of $1,996,609 (Figure 5.9). The minimum and maximum expected income is projected at -$108,870,542 and $193,080,398, with a standard deviation of $23,254,606. The distribution is positively skewed and unbound. The subsidy increased the left parameter by $1,600,000 and increased the mean level of income. This shows the subsidy's impact on increasing overall plant net income.

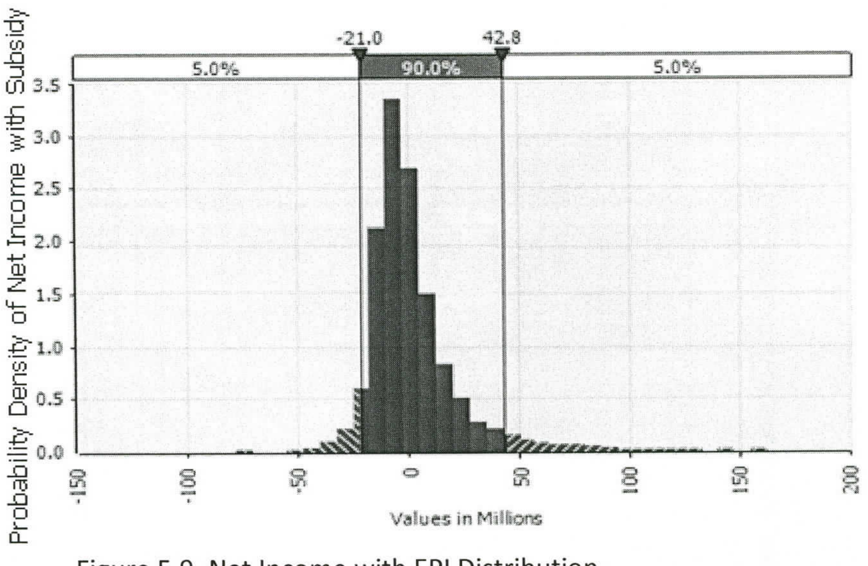

Figure 5.9. Net Income with EPI Distribution.

5.3.4. Rate of return on equity with ethanol production incentive forecast. The rate of return distribution shows the expected rate of return at 90% probability, falling from -60.8% to 64.5% with a standard deviation of 39.17% (Figure 5.10). The mean rate of return was -.04%.

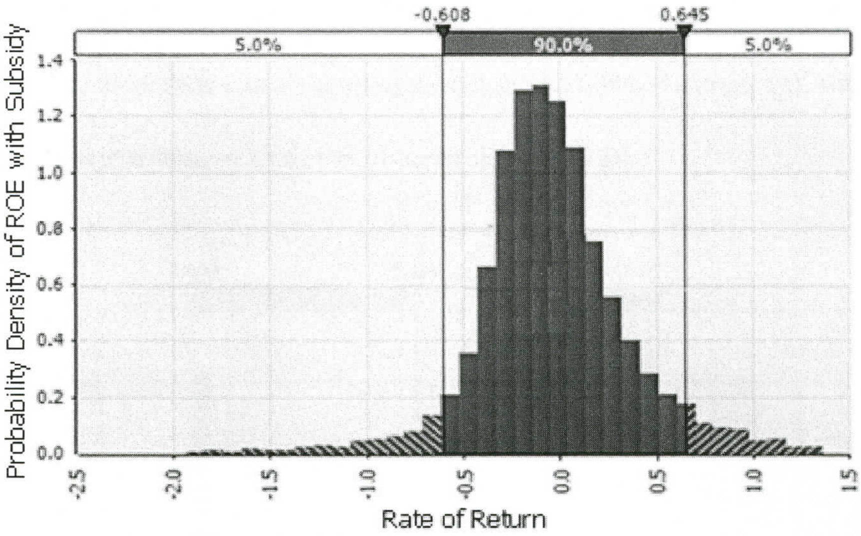

Figure 5.10. Rate of Return with EPI Distribution.

5.3.5. Ten-year rate of return with ethanol production incentive forecast. The rate of return distribution shows the expected rate of return at 90% probability, falling from -270% to 20% with a standard deviation of 38.70% (Figure 5.11). The mean rate of return is given as -.92%.

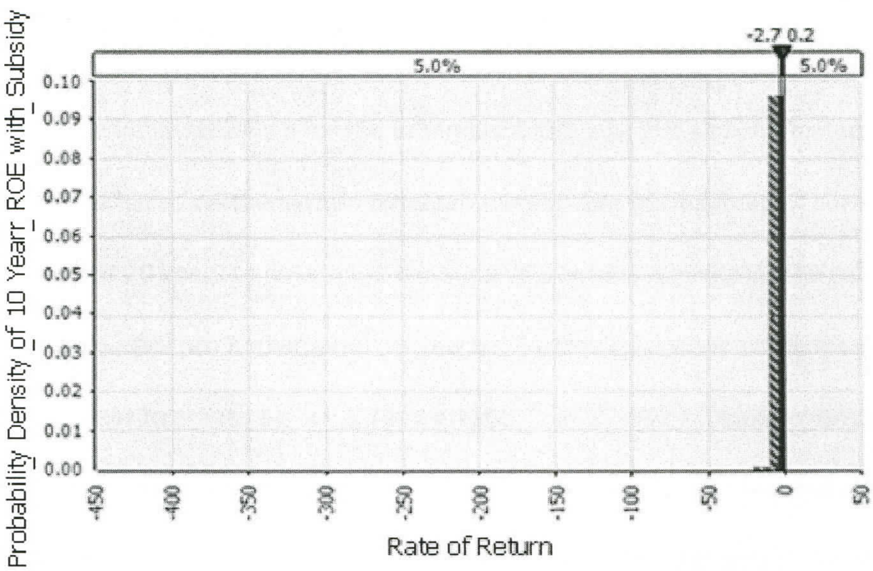

Figure 5.11. Ten-Year Average Rate of Return with EPI Distribution.

5.3.6. Risk of bankruptcy with ethanol production incentive. The risk of bankruptcy is determined by taking the average of the number of times equity reaches zero over 10 years.

At 90% probability, the risk of bankruptcy falls between 0% and 40%, with a mean probability of 10.08% and a standard deviation of 14.29% (Figure 5.12). The ethanol production incentive reduces risk of bankruptcy by .56%.

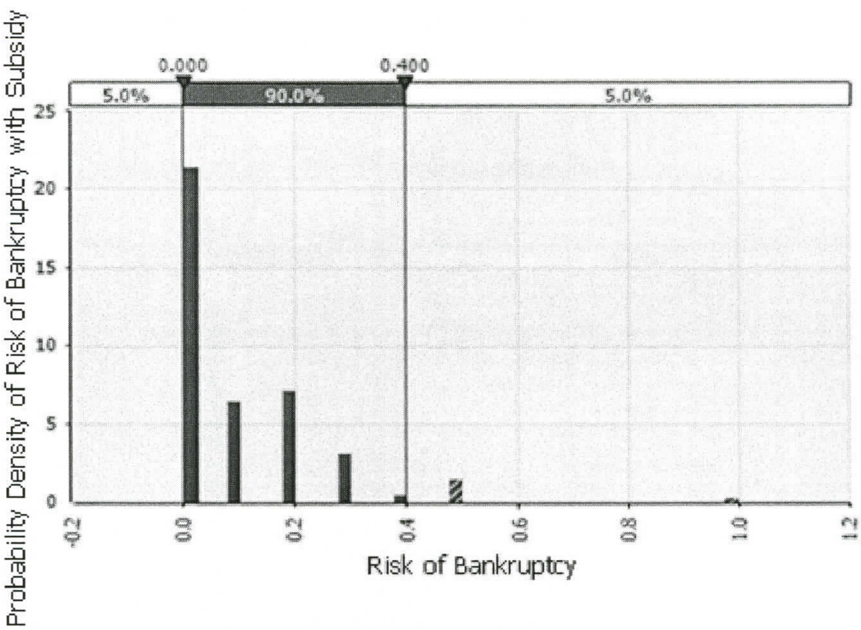

Figure 5.12. Risk of Bankruptcy with EPI Distribution

5.4. Ethanol Plant Simulation: Margin Subsidy

An alternative structure for the ethanol subsidy was created and tested. The new scheme was based on the margin between the average price spread of corn and ethanol from the last 20 years to determine the subsidy payment threshold. The calculated average margin between corn and ethanol price was 87 cents. Payments are made when the price of corn increases to create a price spread greater than 87 cents. The payment per one cent over the threshold for corn price was left at one-tenth of a cent. The deduction for ethanol price was removed. This alternative structure was examined to determine if the ethanol subsidy could be administered more efficiently and thus reduce taxpayer cost.

5.4.1. Margin subsidy payment per gallon forecast. The total margin subsidy payment per gallon was calculated using the forecast corn and ethanol prices. At 90% probability, the subsidy payment under the margin scheme is expected to range from zero cents per gallon to 10.8 cents per gallon, with a mean payment of two cents per gallon (Figure 5.13). The minimum and maximum expected payments are zero cents per gallon and 59 cents per gallon, with a standard deviation of 4.6 cents per gallon.

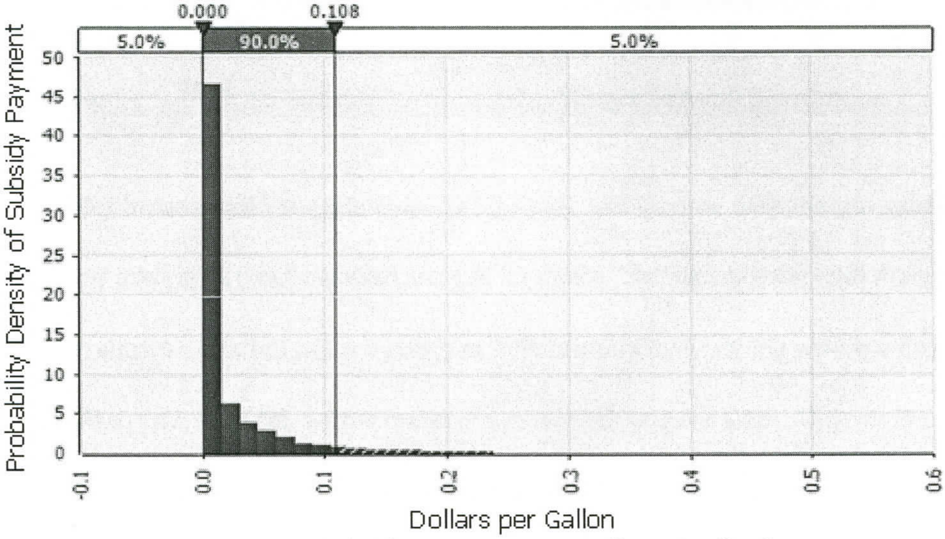

Figure 5.13. Margin Subsidy Payment per Gallon Distribution

5.4.2. Total margin subsidy payment forecast. The total margin subsidy payment was calculated by multiplying the subsidy payment per gallon by plant capacity. At 90% probability, the margin average subsidy payment is expected to range from zero dollars to $1,600,000, with a mean payment of $487,894 and a standard deviation of $668,180 (Figure 5.14). The margin average subsidy payment softens the impact of downturns when there are high corn prices and low ethanol prices, decreasing the losses incurred. The margin subsidy appears to moderately increase an ethanol plant's ability to weather downturns but to a lesser extent than the EPI. The margin average subsidy has less of an impact but has a correspondingly lower cost as well.

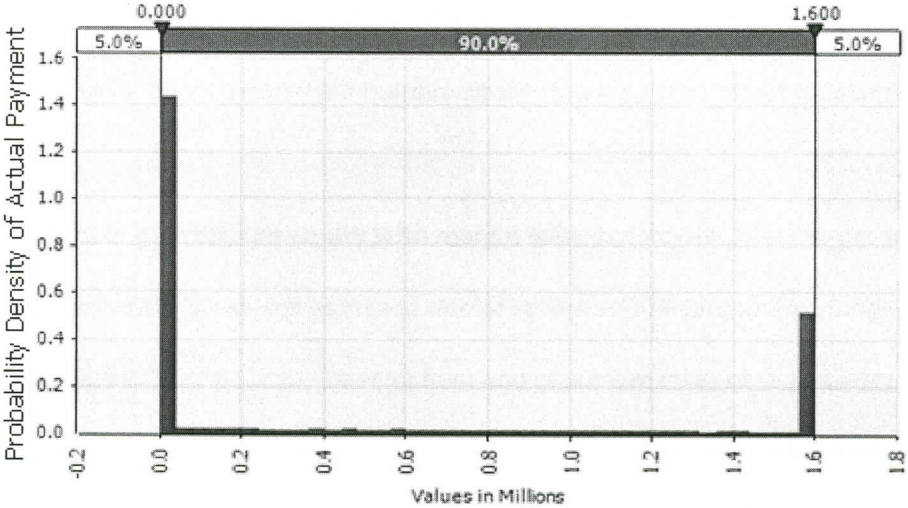

Figure 5.14. Total Subsidy Payment with Margin Subsidy Distribution

5.4.3. Net income with margin subsidy forecast. Net income with margin subsidy was calculated by adding net income with subsidy payment. The net income with margin subsidy distribution shows expected plant income at 90% probability of falling within a range of -$21,000,000 to $42,900,000, with a mean of $1,765,563 (Figure 5.15). The minimum and maximum expected incomes are projected at -$108,870,542 and $193,080,398, with a standard deviation of $23,346,001. The distribution is positively skewed and unbound. The

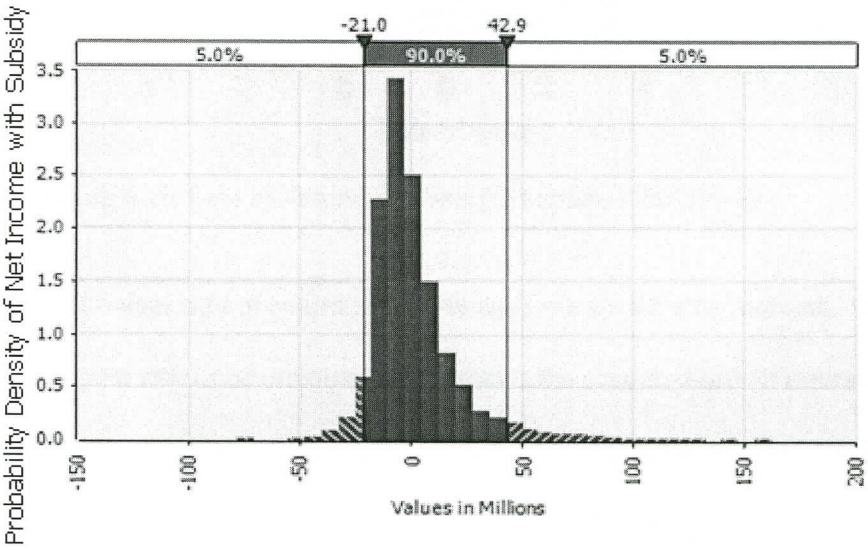

Figure 5.15. Net Income with Margin Subsidy Distribution.

margin average subsidy increased the left parameter by $1,600,000 and increased the mean level of income. This indicates the margin subsidy has a positive effect on plant net income.

5.4.4. Rate of return on equity with margin subsidy forecast. The margin subsidy rate of return distribution shows the expected rate of return at 90% probability, ranging from -60.8% to 64.5% (Figure 5.16). The minimum and maximum rates of return are projected at -241% and 136.41%, with a standard deviation of 39.34%. The mean rate of return is -4.91%. This is an improvement over the unsubsidized rate of return but not a large enough change to generate a positive rate of return.

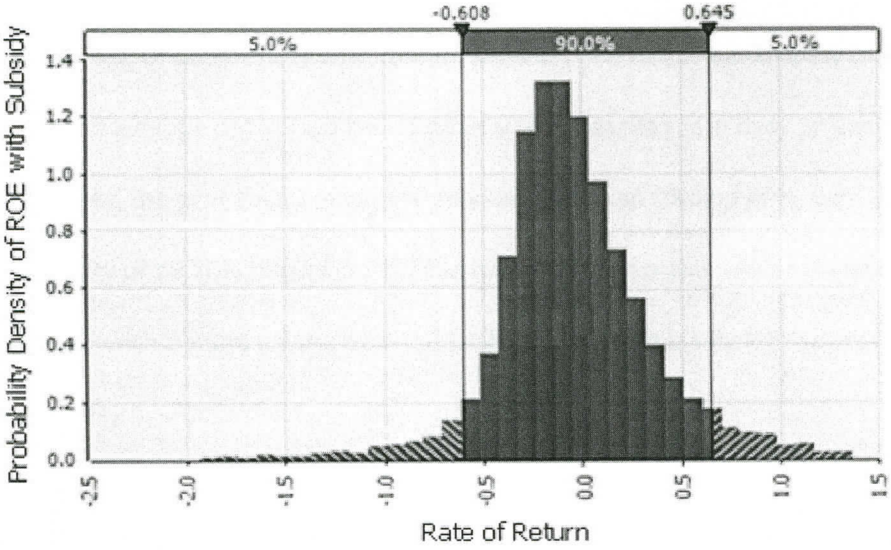

Figure 5.16. Rate of Return with Margin Subsidy Distribution.

5.4.5. Ten-year rate of return on equity with margin subsidy forecast. The margin subsidy 10-year rate of return distribution shows the expected rate of return at 90% probability, ranging from -270% to 20% (Figure 5.17). The minimum and maximum rate of return are projected at -409.92% and .3456%, with a standard deviation of 8.53%. The mean rate of return is -.98%. This is a 28% improvement over the unsubsidized rate of return.

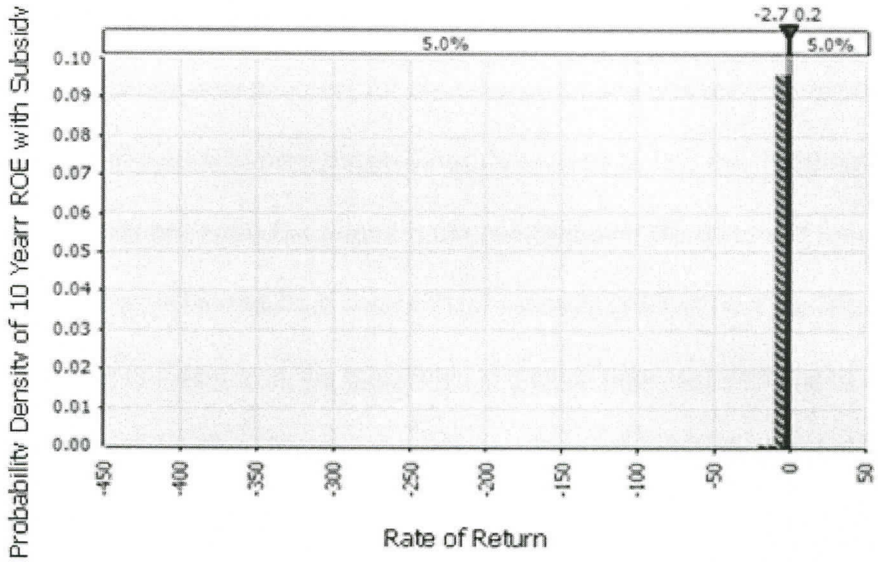

Figure 5.17. Ten-Year Average Rate of Return with Margin Subsidy Distribution.

5.4.6. Risk of bankruptcy with margin subsidy. The risk of bankruptcy is determined by taking the average of the number of times equity reaches zero over 10 years. At 90% probability, the probability of bankruptcy falls between 0% and 40%, with a mean probability of 10.20% (Figure 5.18). The minimum and maximum probabilities are 0% and100% with a standard deviation of 14.31%. The margin subsidy reduces probability of bankruptcy by .42%.

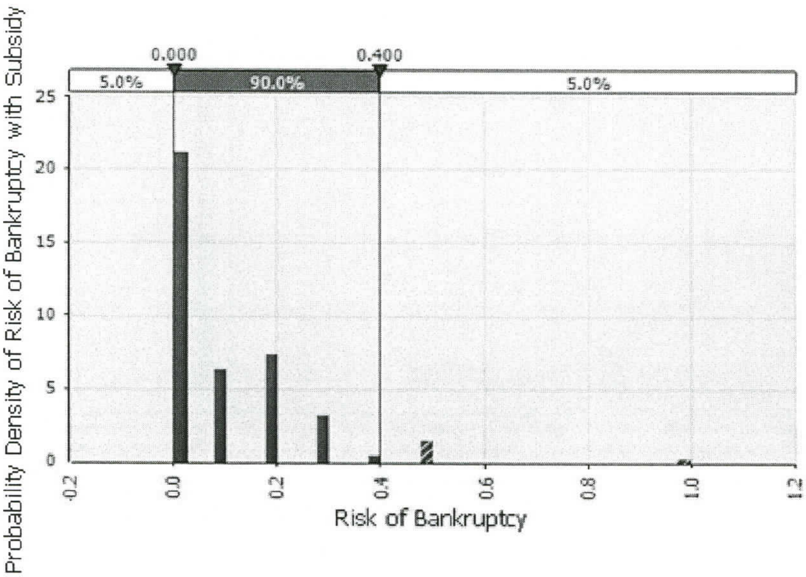

Figure 5.18. Risk of Bankruptcy with Margin Subsidy Distribution.

5.5. Ethanol Plant Simulation: Three-Year Rolling Average Subsidy.

A second alternative structure for the ethanol subsidy was tested using the average price of corn and ethanol from the previous three years to find the threshold for the average subsidy payment. The payment per one cent over the threshold for corn price was changed to one-half a cent from one-tenth of a cent in order to have significant results. The deduction per one cent over the threshold for ethanol price was unchanged at two-tenths of a cent. The alternative structure was used to change the subsidy threshold to reflect current prices.

5.5.1. Three-year rolling average subsidy payment per gallon forecast. The total three-year rolling average subsidy payment per gallon was calculated using the forecast corn and ethanol prices. At 90% probability, the three-year rolling average subsidy payment is expected to fall in a range of zero cents per gallon to 13.7 cents per gallon, with a mean payment of three cents per gallon (Figure 5.19). The minimum and maximum expected payments are zero cents per gallon and $2.35 per gallon, with a standard deviation of 16 cents per gallon.

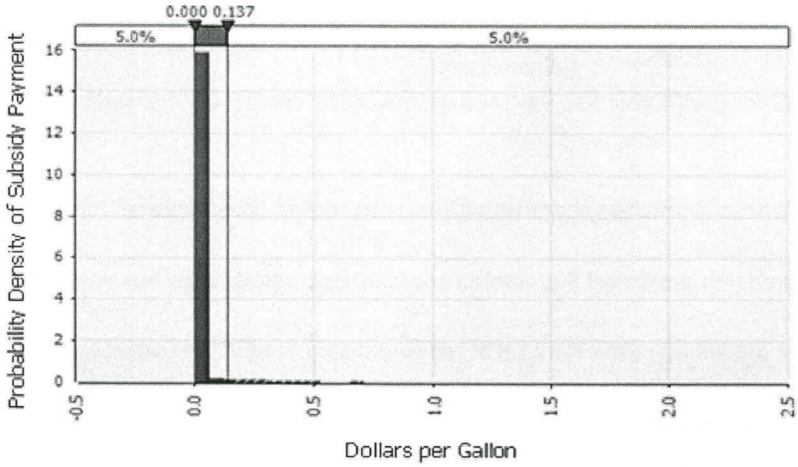

Figure 5.19. Three-Year Rolling Average Subsidy Payment per Gallon Distribution.

5.5.2. Total three-year rolling average subsidy payment forecast. The total three-year rolling average subsidy payment was calculated by multiplying the subsidy payment per gallon by plant capacity. At 90% probability, the three-year rolling average subsidy payment is expected to fall in a range of $0 to $1,600,000, with a mean payment of $107,384 (Figure 5.20). The minimum and maximum expected payments are $0 and $1,600,000, with a standard deviation of $397,671. The subsidy payment may increase an ethanol plant's ability to weather downturns but the impact would be far less than the other subsidy structures tested. Compared to the other subsidies, the relatively small three-year rolling average payment would have a near negligible effect on net income, which would result in a negligible effect on risk of bankruptcy.

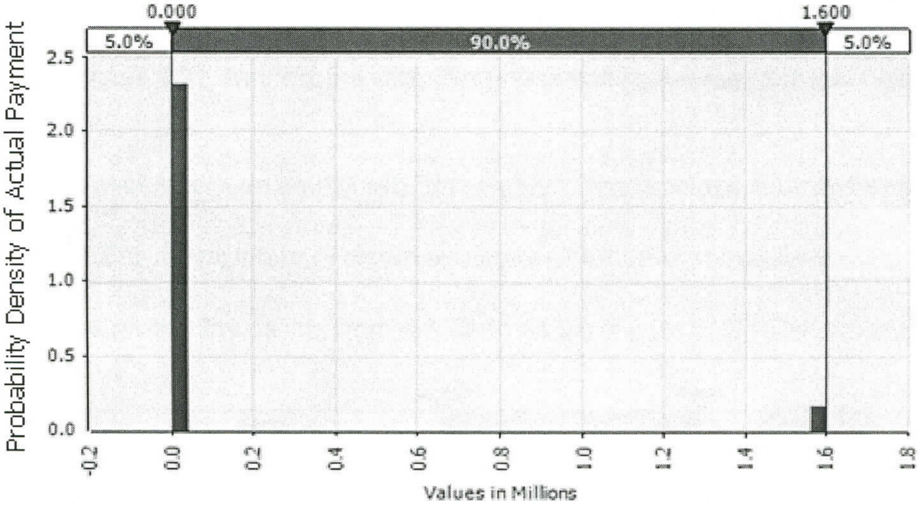

Figure 5.20. Three-Year Rolling Average Subsidy Payment Distribution.

5.5.3. Net income with three-year rolling average subsidy forecast. Net income with the three-year rolling average subsidy was calculated by taking net income and adding it to the subsidy payment. The net income with three-year rolling average subsidy distribution shows expected plant income at 90% of probability, falling at a range of -$22,000,000 to $42,900,000, with a mean of $1,385,053 (Figure 5.21). The minimum and maximum expected incomes are projected at $108,870,542 and $193,080,398, with a standard deviation of$23,582,909. The distribution is positively skewed and unbound. The subsidy increased the mean level of income but did not affect the left parameter. This shows the relatively minor impact the subsidy has on plant's net income.

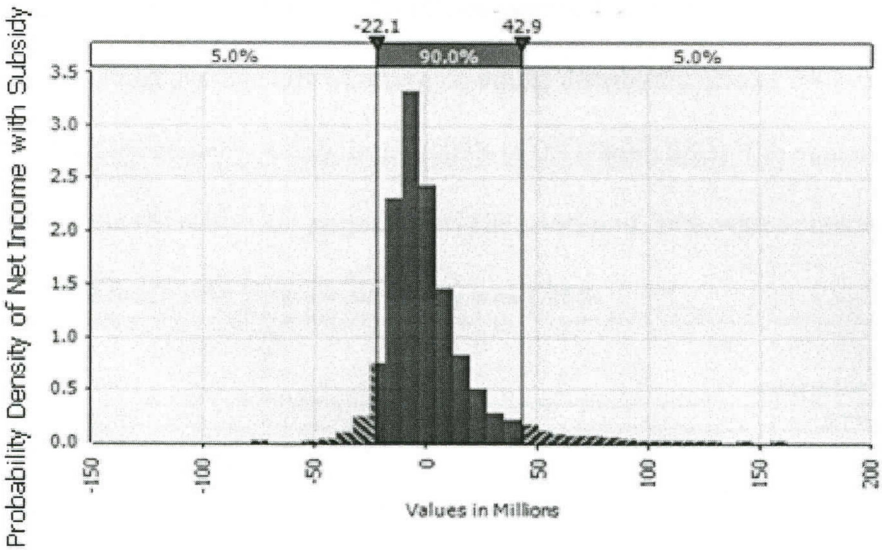

Figure 5.21. Net Income with Three-Year Rolling Average Subsidy Distribution.

5.5.4. Rate of return on equity with three-year rolling average subsidy forecast. The three-year rolling average rate of return on equity distribution shows the expected rate of return at 90% probability, falling from -65.2% to 64.5% (Figure 5.22). The minimum and

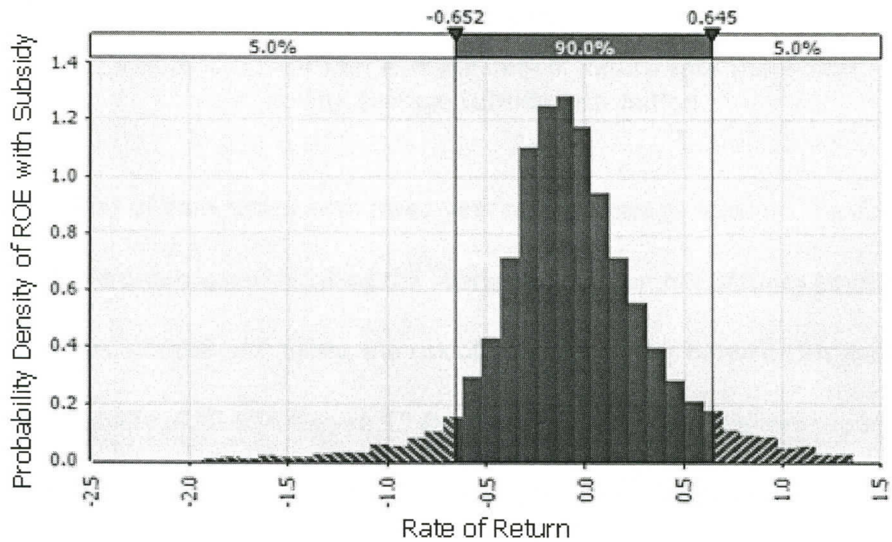

Figure 5.22. Rate of Return with Three-Year Rolling Average Subsidy Distribution.

maximum rates of return are projected at -241.93% and 136.41%, with a standard deviation of 40.31%. The mean rate of return on equity was -6.08%.

5.5.5. Ten-year rate of return with three-year rolling average subsidy forecast. The three-year rolling average rate of return on equity distribution shows the expected rate of return at 90% probability, falling from -.003% to 0% (Figure 5.23). The minimum and maximum rates of return are projected at -1981.46% and .34%, with a standard deviation of 26.09%. The mean rate of return on equity was 1.26%.

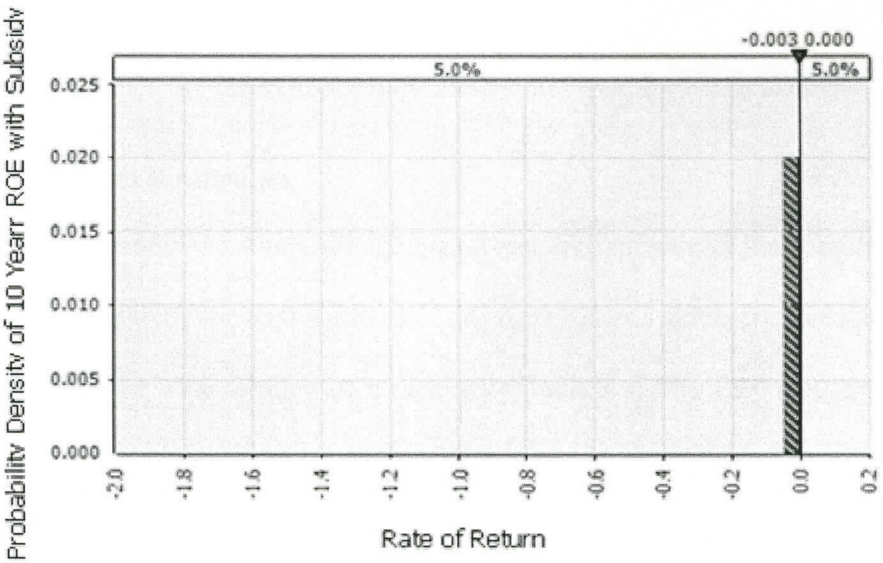

Figure 5.23. Ten-Year Average Rate of Return with Three-Year Rolling Average Subsidy Distribution.

5.5.6. Risk of bankruptcy with three-year rolling average subsidy. The risk of bankruptcy is determined by taking the average of the number of times equity reaches zero over 10 years. At 90% probability, the risk of bankruptcy falls between 0% and 40%, with a mean probability of 10.59% (Figure 5.24). The minimum and maximum probabilities are 0% and 100%, with a standard deviation of 14.64%. The three-year rolling average subsidy reduces probability of bankruptcy by .05%.

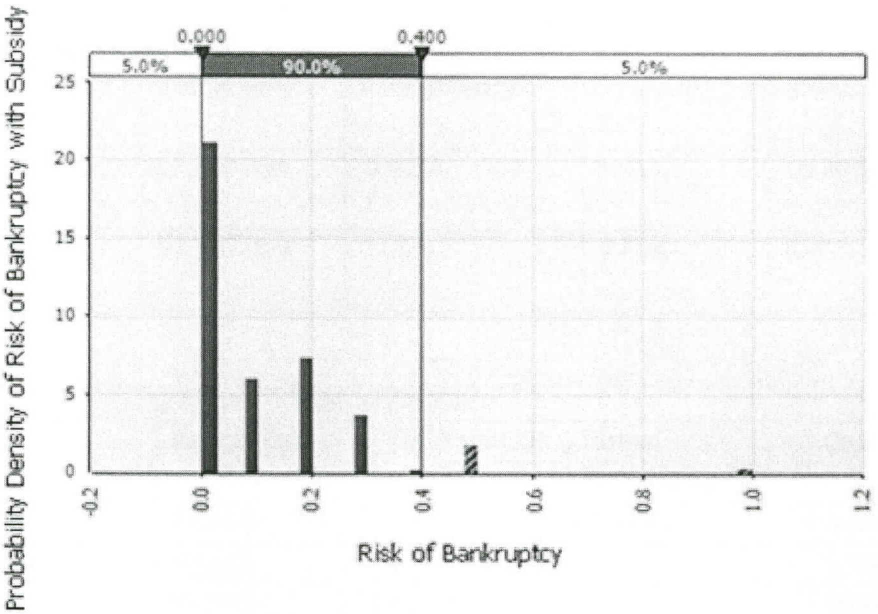

Figure 5.24. Risk of Bankrupcty with Three-Year Rolling Average Subsidy.

5.6. Summary and Sensitivities

The base model results show negative returns with or without the subsidy (Table 5.2). The DDGS sensitivity shows the impact of adding DDGS as a stochastic variable in the base model and in the 2006 through 2008 sensitivity (Table 5.3). The 2006 through 2008 sensitivity table shows the relatively insignificant impact the subsidies have when there are favorable market conditions (Table 5.4). The information in Table 5.2 is from figures in Appendix A. Information in Table 5.3 is from figures in Appendix B. Information for Table 5.4 is from figures in Appendix C.

Table 5.2. Base Model Results.

	Rate of Return	Ten-Year ROE	Risk of Bankruptcy	Cost of Subsidy
No Subsidy	-6.41%	-126.12%	10.64%	None
Current EPI	-4.31%	-92.76%	10.08%	$718,491
Margin Subsidy	-4.91%	-98.32%	10.20%	$487,894
Three-Year Average	-6.08%	-126.20%	10.59%	$107,385

Table 5.3. DDGS Sensitivity.

	Net Income	Rate of Return	Ten-Year ROE	Risk of Bankruptcy
Base Model	$1,277,668	-1.32%	1.98%	10.40%
2006-2008 Data	$3,145,059	0.05%	4.60%	8.45%

Table 5.4. Sensitivity between 2006 and 2008.

	Rate of Return	Ten-Year ROE	Risk of Bankruptcy	Cost of Subsidy
No Subsidy	47.56%	3.36%	2.18%	None
Current EPI	48.43%	4.02%	2.07%	$365,203
Margin Subsidy	48.84%	4.05%	2.07%	$669,187
Three-Year Average	48.86%	4.32%	2.07%	$719,231

The results demonstrate the impact the Ethanol Production Incentive has on plant feasibility in North Dakota. The Ethanol Production Incentive, in its current form, generates the best rate of return to ethanol plants of the three subsidies tested in the base model. However, the margin-based subsidy also gives ethanol producers an improved rate of return at a lower cost to the taxpayer and could be a considered a viable alternative. The three-year rolling average subsidy does not have a statistically insignificant impact.

The 2006 through 2008 sensitivity shows very different subsidy payouts and impact. In this sensitivity the Ethanol Production Incentive is the lowest cost subsidy structure and has an insignificant impact on risk of bankruptcy. The margin subsidy has a much higher subsidy payout but an insignificant impact on risk of bankruptcy. The three-year rolling average subsidy has the highest payout, but again a very minor impact on bankruptcy. With the improved economic conditions, ethanol plants should be receiving minimal assistance. The

Ethanol Production Incentive has the smallest payout, although even so, the payout is likely unnecessary and has an extremely small impact.

5.7. Statistical Significance

A t-distribution is used to determine if the generated results are significant from zero. For each subsidy, S^2 is calculated by taking the base model variance squared and multiplying it by number of observations minus one. This is then added to the subsidy model variance squared, which is multiplied by number of observations minus one. The calculated number is then divided by the combined observations of the base and subsidy models minus two.

The t-value is calculated by taking the 10-year average risk of bankruptcy for the base model and subtracting the 10-year average risk of bankruptcy of the subsidy. The calculated number is then divided by the square root of S^2 times one divided by number of observations of the base model plus one divided by number of observations from the subsidy model. This gives the calculated t-value for each subsidy.

EPI Subsidy

$$S^2 = \frac{(10 - 1)(.1746)2 + (10 - 1)(.1429)2}{(10 + 10) - 2}$$

$$S^2 = \frac{(9)(.0305) + (9)(.0204)}{18}$$

$$S^2 = \frac{.2745 + .1836}{18}$$

$$= .0255$$

$$t = \frac{10.64 - 10.08}{\sqrt{(.0255(1/10 + 1/10))}}$$

$$t = \frac{.56}{.0714}$$

$= 7.8431$ $\quad$ t_{crit} (99^{th} percentile) $= 3.25$

Reject H_o, the results are significant. This indicates that at the 99th percentile the results are statistically significant from zero, showing the subsidy had a statistically significant effect.

Margin Subsidy

$$S^2 = \frac{(10-1)(.1746)^2 + (10-1)(.1431)^2}{(10+10)-2}$$

$$S^2 = \frac{(9)(.0305) + (9)(.0205)}{18}$$

$$S^2 = \frac{.2745 + .1843}{18}$$

$$= .0255$$

$$t = \frac{10.64 - 10.20}{\sqrt{(.0255(1/10 + 1/10))}}$$

$$t = \frac{.44}{.0714}$$

$= 6.1625$ $\quad t_{crit}$ (99th percentile) = 3.25

Reject H_o, the results are significant. This indicates that at the 99th percentile the results are statistically significant from zero, showing the subsidy had a statistically significant effect.

Three-Year Average Subsidy

$$S^2 = \frac{(10-1)(.1746)2 + (10-1)(.1464)2}{(10+10)-2}$$

$$S^2 = \frac{(9)(.0305) + (9)(.0214)}{18}$$

$$S^2 = \frac{.2745 + .1929}{18}$$

$$= .0260$$

$$t = \frac{10.64 - 10.59}{\sqrt{(.0260(1/10 + 1/10))}}$$

$$t = \frac{.05}{.0721}$$

$= .6935$ $\qquad t_{crit}$ (99^{th} percentile) = 1.38

Do not reject H_o, the results are not significant. This indicates that at the 99^{th} percentile the results are not statistically significant from zero, showing the subsidy did not have a statistically significant effect.

6. CONCLUSIONS

The ethanol industry in North Dakota faces continued exposure to variable market prices of corn and ethanol. While corn prices have decreased from record highs, the price still remains volatile, as does the price of ethanol. The North Dakota state legislature enacted the Ethanol Production Incentive to improve survivability of ethanol plants faced with high corn prices and low ethanol prices. A stochastic simulation of the current subsidies was conducted to help the state of North Dakota determine how to structure its ethanol support programs to minimize plant risk of bankruptcy. In addition, two modifications of the existing subsidy were evaluated to find the most effective means of implementation.

6.1. Procedure

A stochastic model was developed using an ethanol plant production function to simulate the impact of different ethanol subsidies on plant rate of return on equity and plant risk of bankruptcy. The current Ethanol Production Incentive was tested first using the parameters detailed by the state legislation. Then, alternative structures for the subsidy were tested. The first alternative was a margin-based subsidy payment, which used the historical average margin between the price of corn and ethanol and then compared it with current price margins to determine the subsidy payment. The second alternative involved updating the current Ethanol Production Incentive price thresholds for payments and deductions to reflect current prices. Once the simulation was completed, the cost and impact of each subsidy was compared to determine which would have the greatest impact on risk of bankruptcy while minimizing costs.

The fixed and variable costs of production used in estimating plant costs were taken from "Efficiency in Midwest Corn Ethanol Plants" (Perrin, Fretes, & Sesmero, 2008). BestFit was used to estimate distribution parameters using historical data. Data for corn prices from

1988 through 2008 were taken from the USDA National Agricultural Statistics Service. Data for ethanol prices from 1988 to 2008 were taken from the Nebraska Energy Office.

6.2. Results

The stated purpose of the Ethanol Production Incentive is to help new ethanol plants preserve cash flows as price margins shrink. Without any subsidy, there was a 10.64% chance of bankruptcy in the plant's first 10 years of operation in the base model. The Ethanol Production Incentive reduced the risk of bankruptcy by .56% or 5% of the total probability of bankruptcy. The margin-based subsidy reduced the risk of bankruptcy by 10.20% or 4% of the total probability of going bankrupt. The three-year rolling average based subsidy reduced the risk of bankruptcy by 10.59% or 0.5% of the total risk of bankruptcy. From the perspective of protecting ethanol plants during downturns, the current Ethanol Production Incentive is the most effective method, followed closely by the margin-based subsidy.

In the 2006 through 2008 sensitivity, the results change significantly. The risk of bankruptcy without a subsidy drops to 2.18%, a significant decrease. The Ethanol Production Incentive reduces risk of bankruptcy to 2.07% or 5% of the total probability of bankruptcy. The margin-subsidy reduces the risk of bankruptcy to 2.07% or 87% of the total probability of bankruptcy. The three-year rolling average subsidy also has the same impact with a much higher payout. In this sensitivity, any subsidy should be minimizing or stopping payouts, as the risk of bankruptcy is already extremely low.

The rate of return on equity was another measure used to find the impact of the different support programs. The Ethanol Production Incentive improves plant rate of return on equity over 32% from a return of -6.41% to -4.31%. The margin-based subsidy improves the rate of return on equity to -4.91%. The three-year rolling average subsidy was the least effective, increasing rate of return on equity to -6.08%. From the rate of return on equity standpoint, the Ethanol Production Incentive and margin-based subsidy gave the greatest improvement, while the three-year rolling average subsidy was not effective. Overall, the three versions of the subsidy notably improve plant rate of return on equity.

In the 2006 through 2008 sensitivity, there is a major change in plant rate of return. Without any subsidy, rate of return rises to 47.56%. The three subsidies increase rate of return by around 1%, which has a limited effect on the much larger plant rate of return.

The cost of the ethanol support programs is another significant factor in determining which program is best for the State of North Dakota. The current Ethanol Production Incentive offers the greatest improvement in both rate of return on equity and probability of bankruptcy, but it is also the most costly, with an average annual payment of $718,491. The margin-based subsidy offers comparable results to the Ethanol Production Incentive but has a substantially lower annual cost of $487,894. The three-year rolling average based subsidy had the least impact on rate of return on equity and probability of bankruptcy, and, correspondingly, cost the least with an annual payment of $107,385. From a cost standpoint, the Ethanol Production Incentive and margin-based subsidy are the most expensive but also the most effective.

The 2006 through 2008 sensitivity shows the costs of the different subsidies dramatically change. The Ethanol Production Incentive had the lowest cost at $365,203, while the margin subsidy payout increased to $669,187. The three-year average subsidy payment jumped to $719,231, giving it the greatest impact of the subsidies; however, it only had a relatively minor impact overall.

Results indicate the Ethanol Production Incentive has a significant impact on plant rate of return and that it reduces plant risk of bankruptcy. The margin-based subsidy had a lesser impact on plant rate of return and risk of bankruptcy. Overall, the Ethanol Production Incentive subsidy produced the best results of the different subsidy structures tested. In the base model, the Ethanol Production Incentive had the largest payout and the greatest impact on risk of bankruptcy, which shows it functions as intended to give ethanol plants greater support when market conditions are more difficult. In the 2006 through 2008 sensitivity, the Ethanol Production Incentive payment dropped by nearly half, which demonstrates how the subsidy reduces support as market conditions improve. Conversely, the alternative subsidies made significantly larger payments under improved market conditions of the 2006 through 2008 sensitivity, essentially increasing support to ethanol plants as conditions improve, rather than reducing support as logic would dictate.

6.3. Study Limitations

For this study, a model was developed to determine the impact of the Ethanol Production Incentive on plant survivability and explore ways the subsidy could be structured more efficiently. One issue that arose was the limited data available for price of ethanol and DDGS in North Dakota since detailed records did not exist until only a few years ago. With a better DDGS data set, it would be possible to forecast future DDGS prices particular to North Dakota. Forecasting DDGS prices would allow a more accurate representation of plant net income.

Another limitation was the lack of local survey data. Given the differing characteristics of each ethanol plant, individual plant production costs vary greatly while each geographic location offers certain advantages and disadvantages. The technical data used to determine plant costs were survey data from plants located throughout the Midwest, and while it was the best data available, none of the plants surveyed were in North Dakota (Perrin, Fretes, &

Sesmero, 2008). The lack of local data creates the potential for biased results that do not necessarily reflect what ethanol plants in North Dakota are experiencing.

An additional issue that made a study pertaining to North Dakota difficult was the state's legislation. At present the specific goals of the North Dakota legislation remain unclear, which was a significant limitation to this study. While designed to enhance the survivability of new plants, it is uncertain whether the Ethanol Production Incentive is meant to encourage new plant construction or to simply keep plants in business. It is also unclear whether the legislature intends to adapt the program when ethanol plants using cellulosic technology are constructed.

The formula used to calculate the subsidized rate of return on equity is another piece of the study that could be improved. In years with large losses, the subsidy reduced the size of the loss and preserved plant equity. However, in the following years when net income was once again positive, the rate of return on equity was higher for the non-subsidized plant because the plant had less equity. This minimized the impact the subsidy had on rate of return and resulted in instances where the subsidized 10-year average rate of return on equity was lower than the non-subsidized rate of return.

Finally, price spikes were another limitation for this study. Spikes are more difficult to forecast since the most recent spike is atypical to what the prices have been historically. The spike also needed to be included because given the continued volatility in prices, another spike in the future is possible.

6.4. Future Study

Another significant input in ethanol production not simulated here is energy cost; in most cases natural gas. With the recent price spike of fossil fuels, the cost of energy to produce ethanol is another area where producers are vulnerable. A subsidy for energy costs is an alternative to the current method of subsidizing ethanol plants that could be examined.

Cellulosic technology is seen as the future of ethanol production, and with this new technology come new questions regarding how these plants will survive the fluctuating markets. The Ethanol Production Incentive could be redesigned to provide assistance for these new plants in adverse markets.

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APPENDIX A

DDGS Sensitivity

This section adds DDGS as a stochastic variable to the base model. Corn and ethanol prices are also correlated to DDGS.

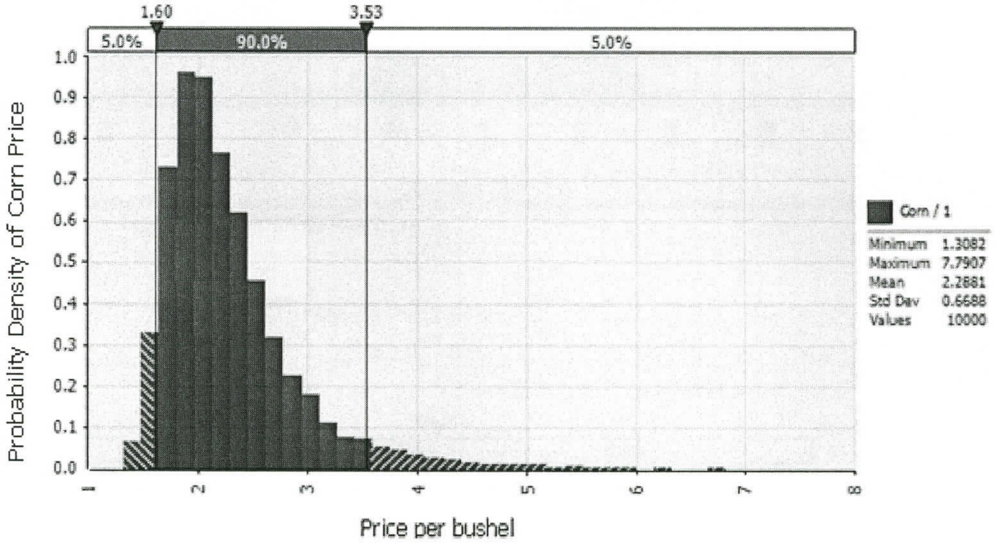

Figure A.1. Corn Price DDGS Sensitivity

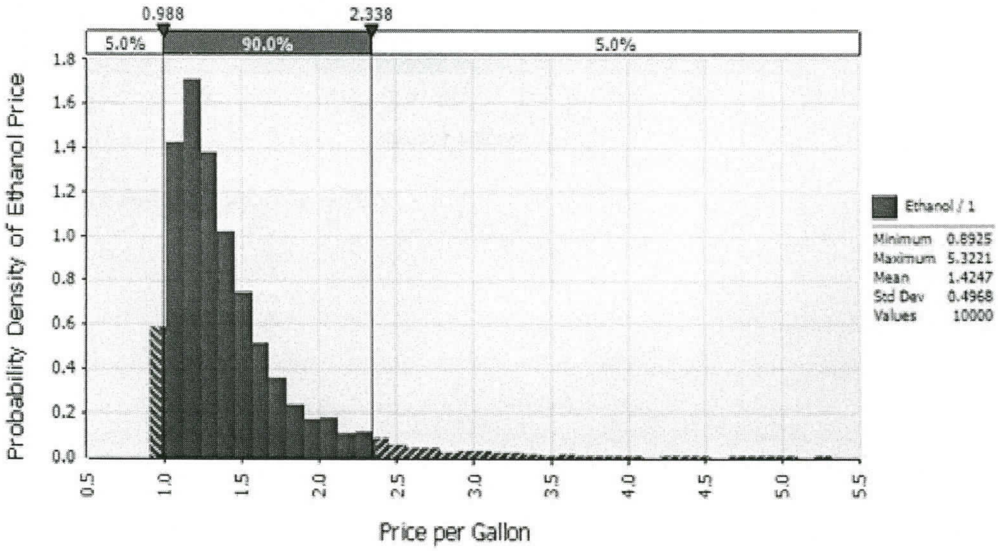

Figure A.2. Ethanol Price DDGS.

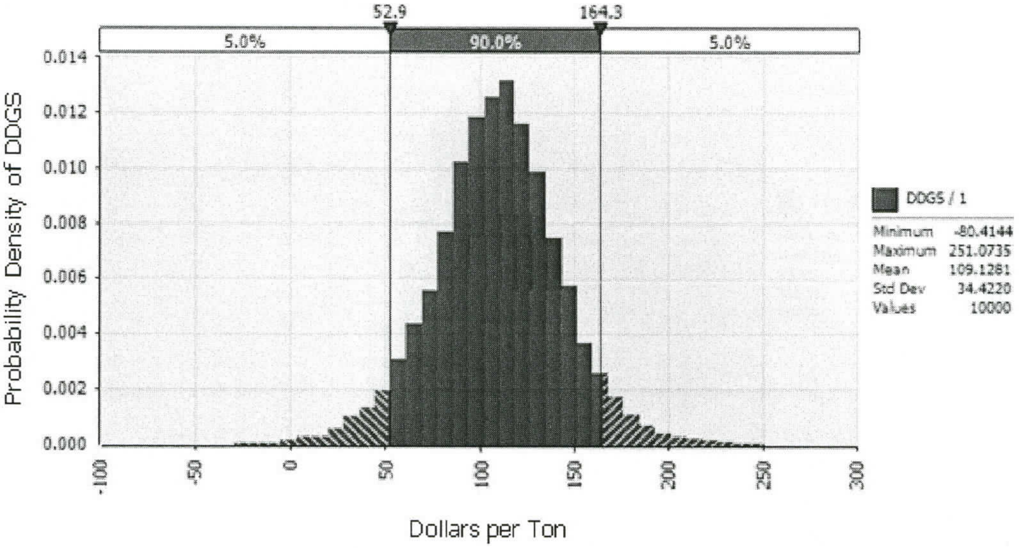

Figure A.3. DDGS Price.

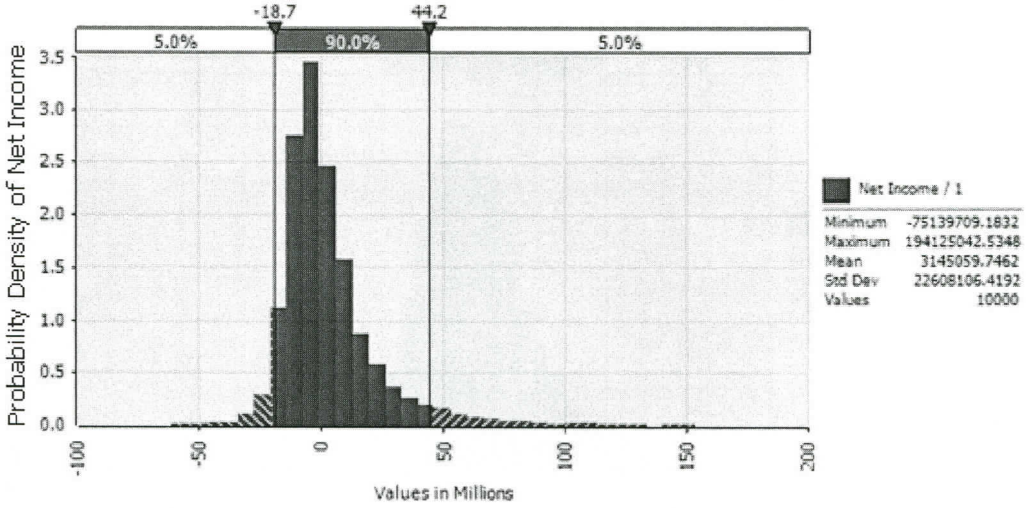

Figure A.4. Net Income DDGS.

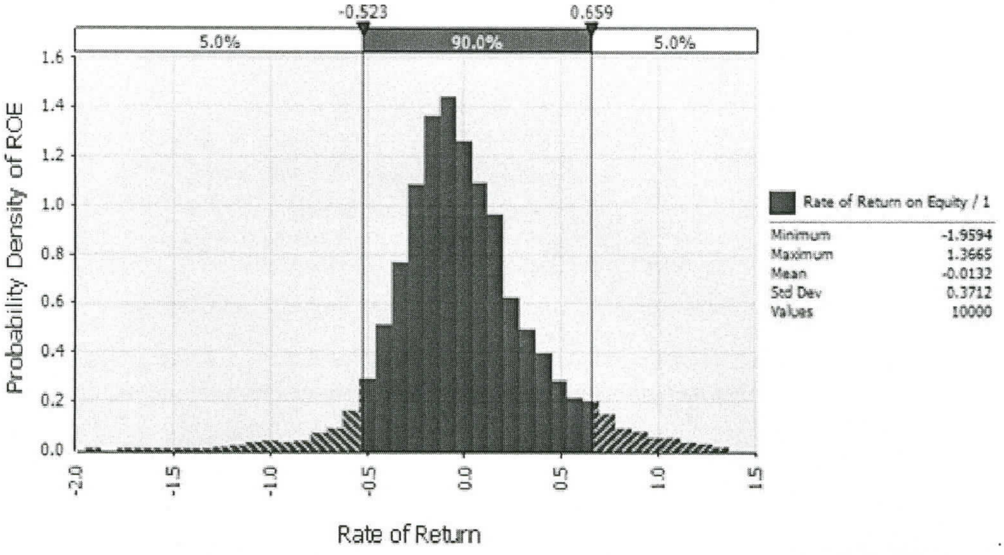

Figure A.5. DDGS Sensitivity Rate of Return on Equity Base Model.

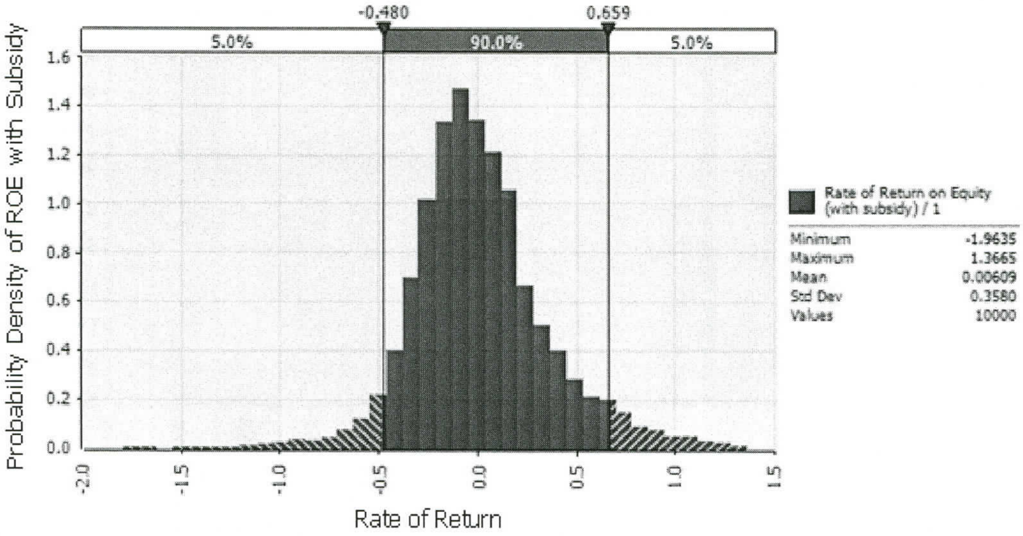

Figure A.6. DDGS Sensitivity Rate of Return on Equity with Ethanol Production Incentive.

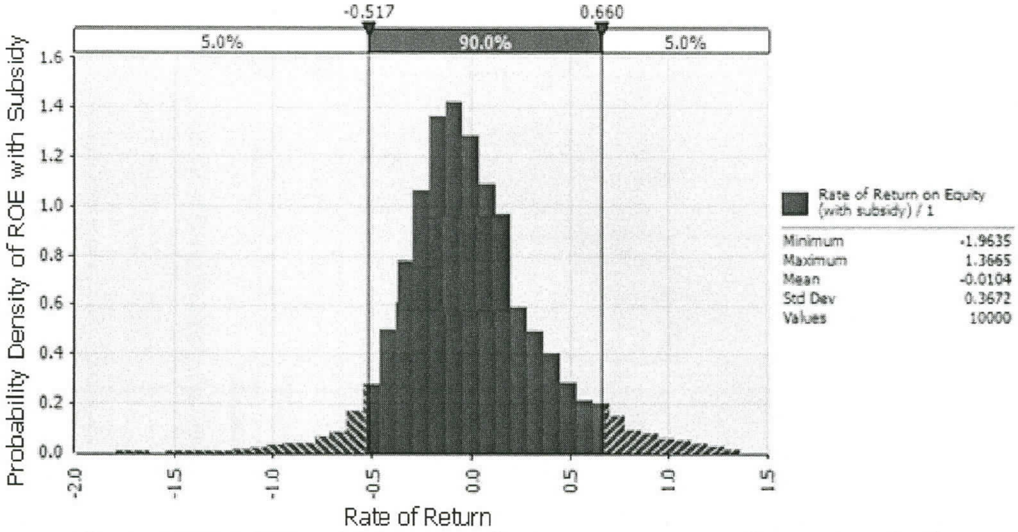

Figure A.7. DDGS Sensitivity Rate of Return on Equity with Margin Subsidy.

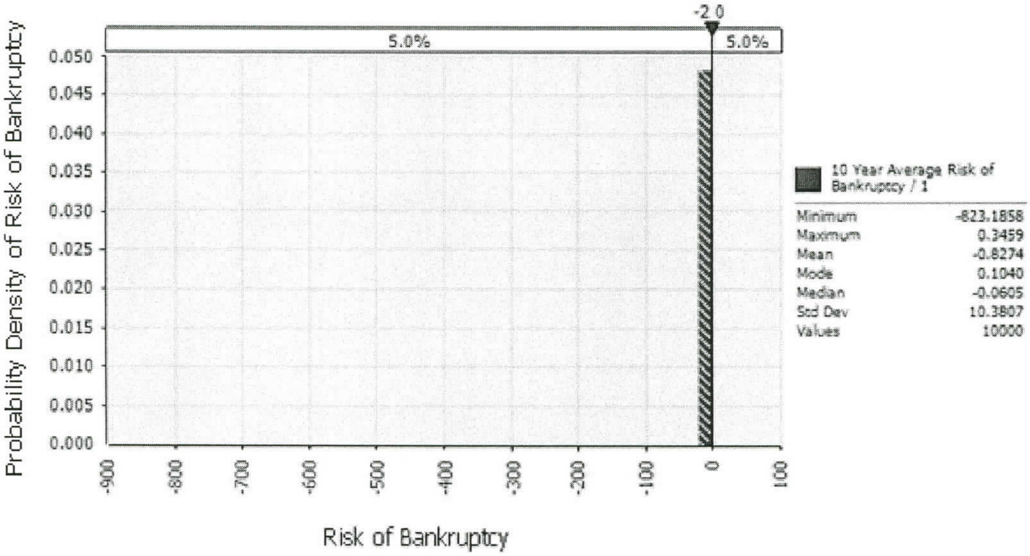

Figure A.8. DDGS Sensitivity Risk of Bankruptcy.

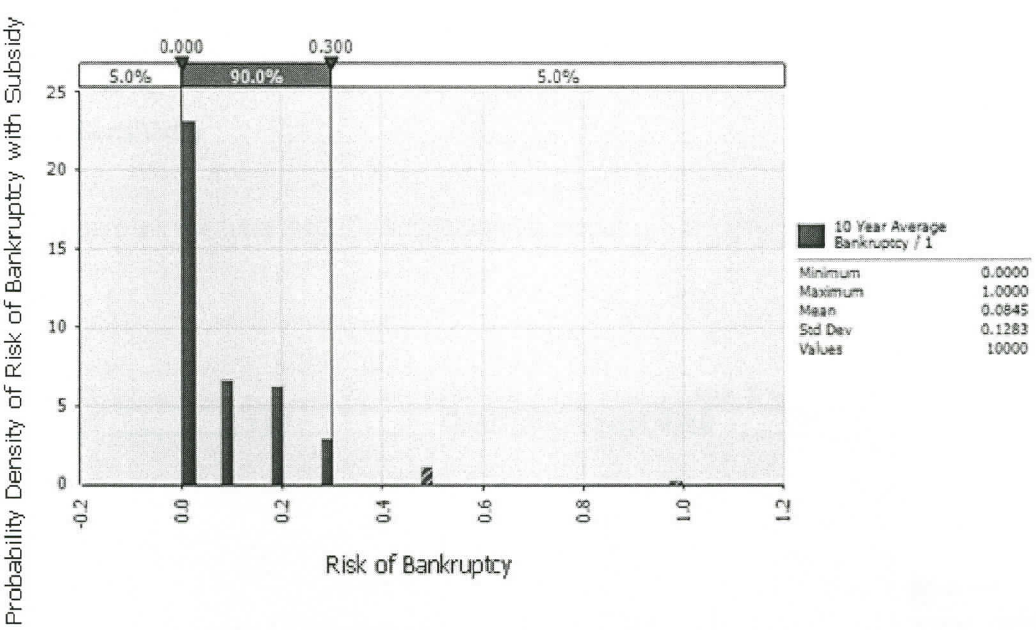

Figure A.9. DDGS Sensitivity Risk of Bankruptcy with Three-Year Average Subsidy.

APPENDIX B

2006-2008 Sensitivity

This section uses the base model with distributions and correlations generated from 2006-2008 data.

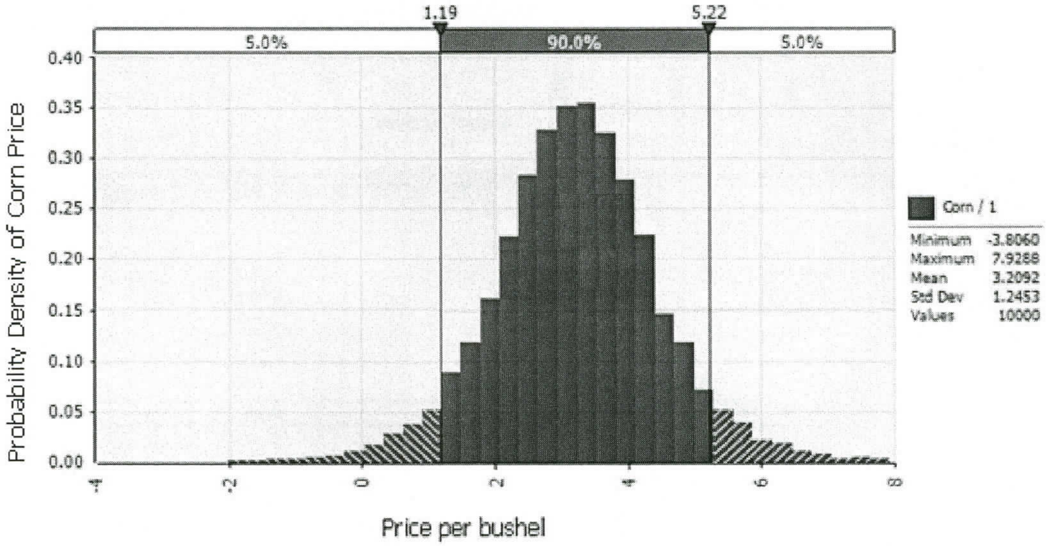

Figure B.1. Corn Price 2006-2008.

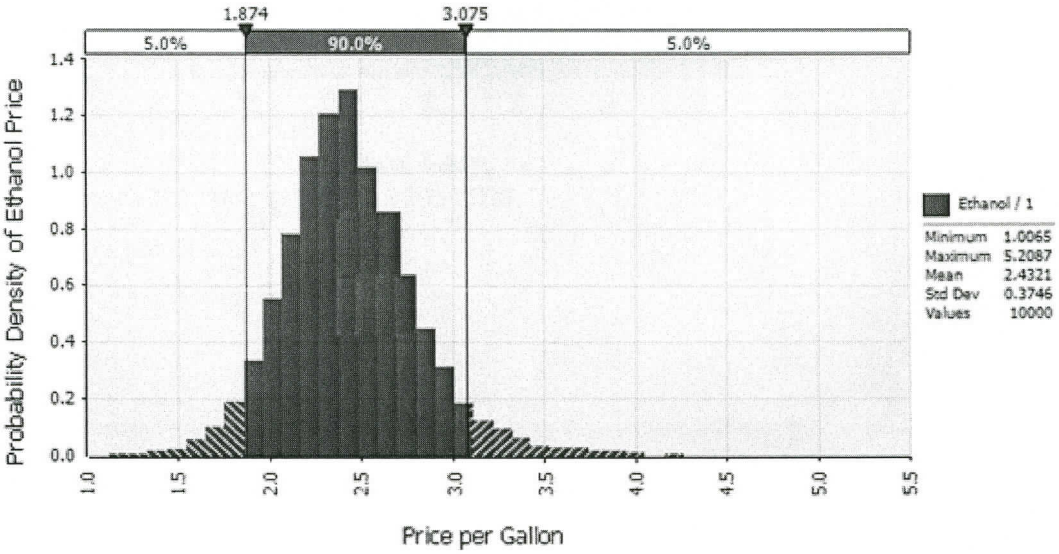

Figure B.2. Ethanol Price 2006-2008

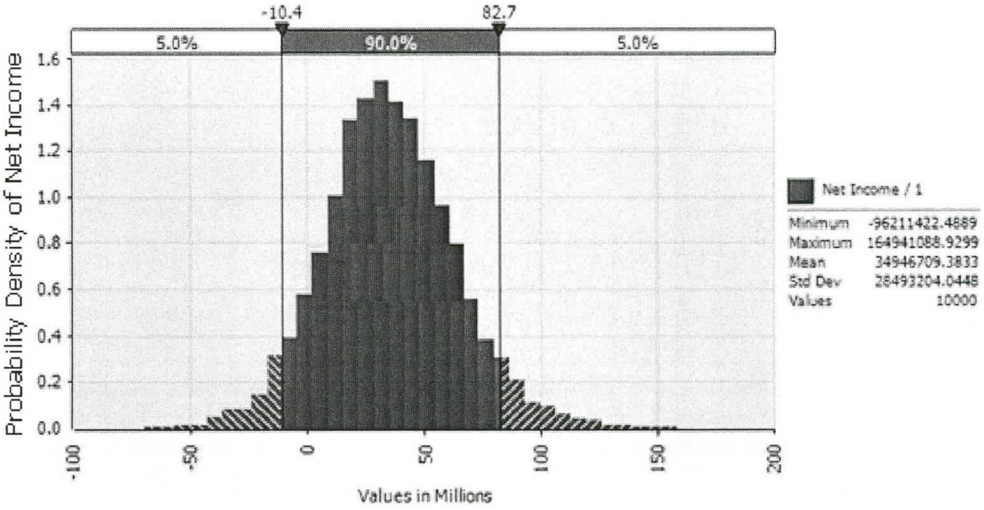

Figure B.3. Net Income 2006-2008.

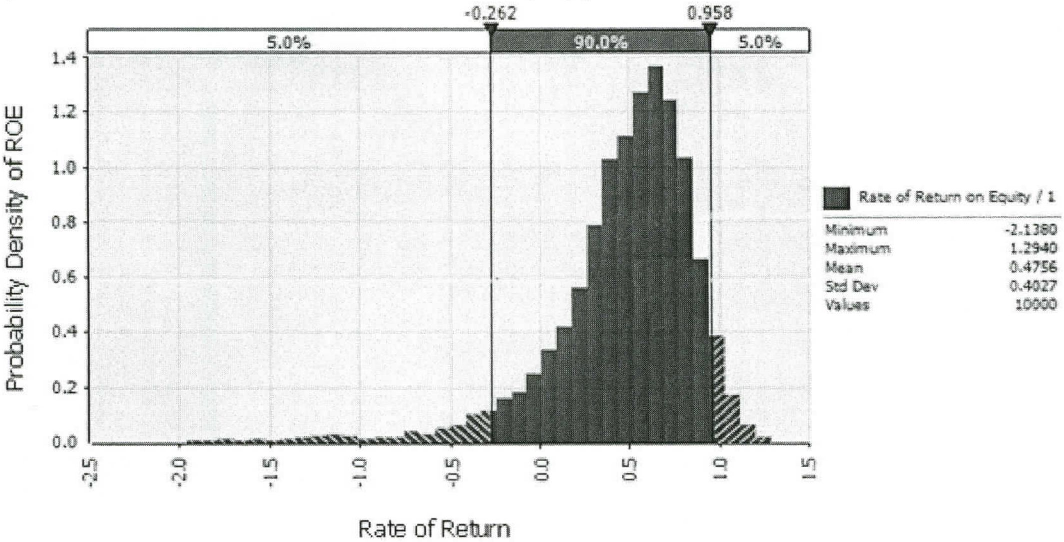

Figure B.4. Rate of Return 2006-2008.

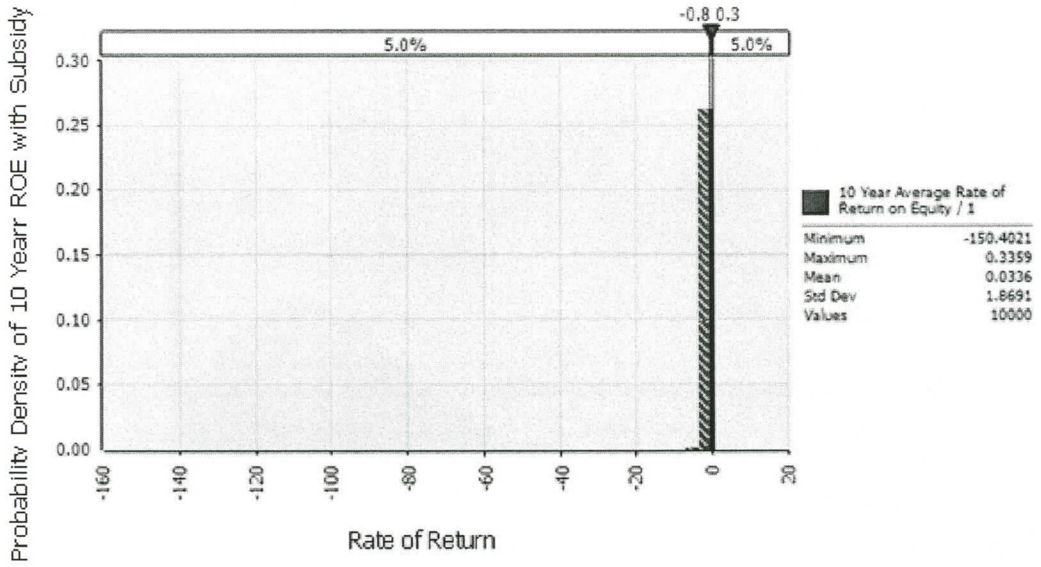

Figure B.5. Ten-Year Average Rate of Return 2006-2008.

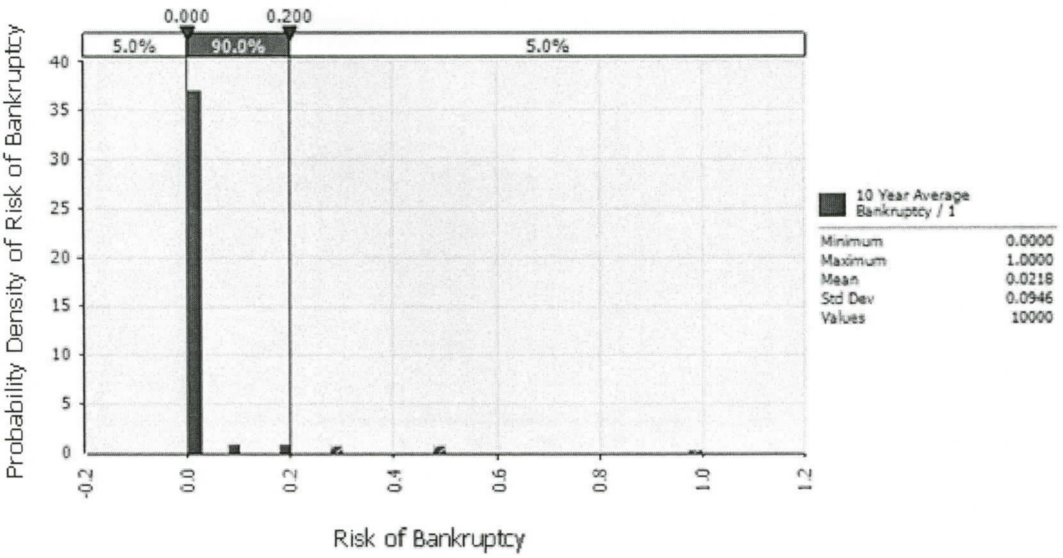

Figure B.6. Risk of Bankruptcy 2006-2008.

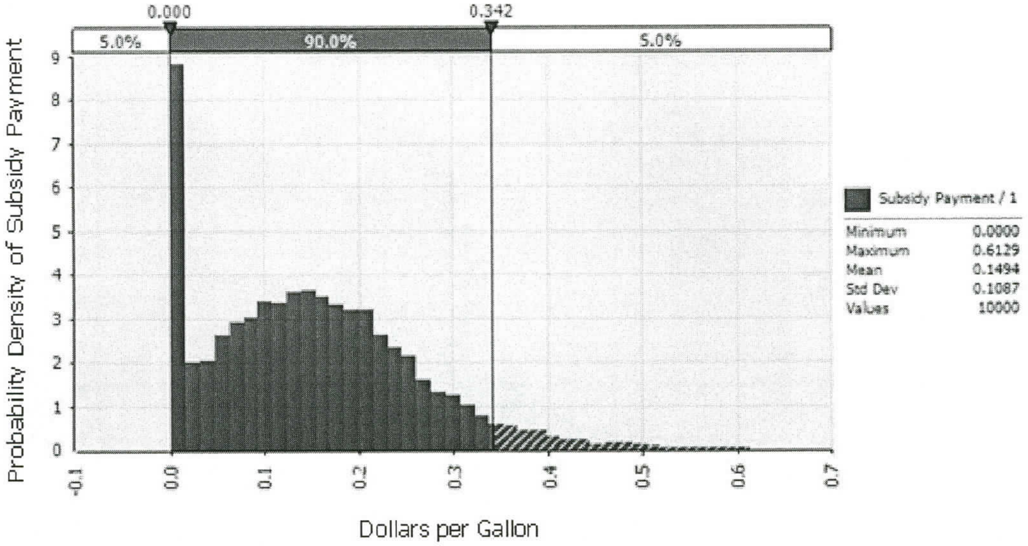

Figure B.7. EPI Payment per Gallon Forecast 2006-2008.

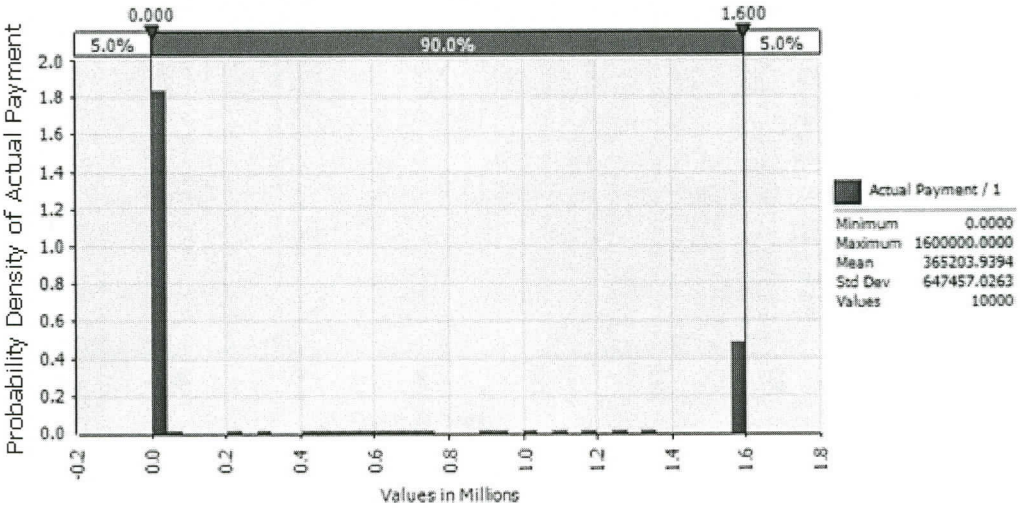

Figure B.8. Total EPI Payment Forecast 2006-2008.

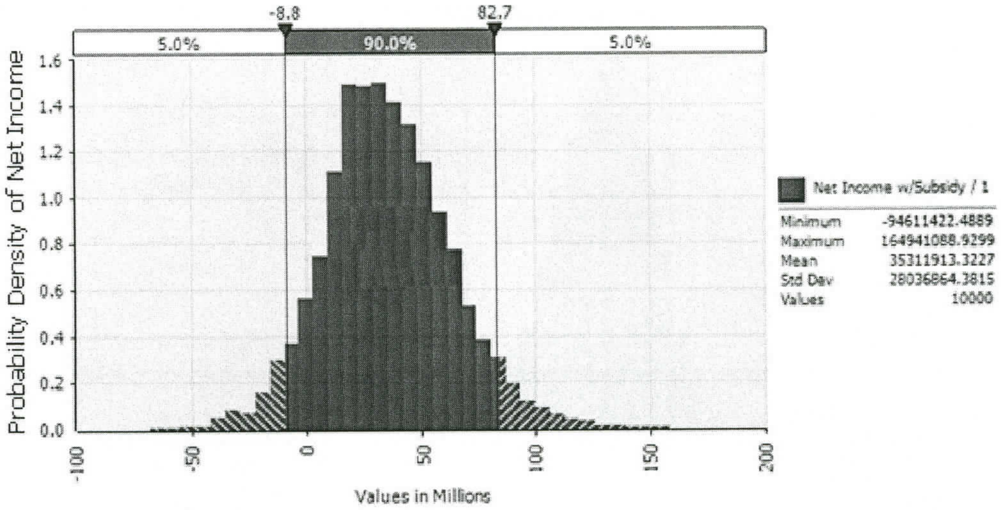

Figure B.9. Net Income EPI 2006-2008.

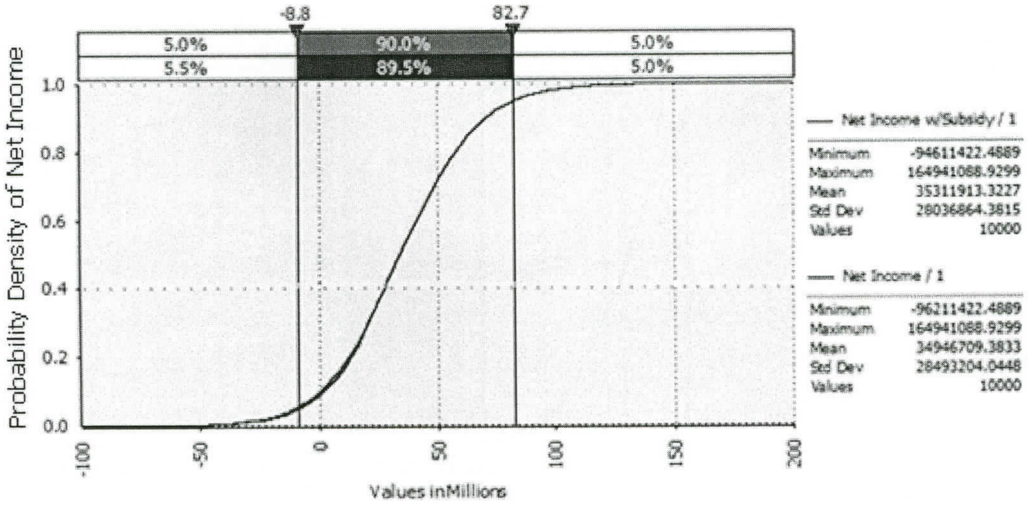

Figure B.10. Net Income Base Model with Net Income EPI 2006-2008.

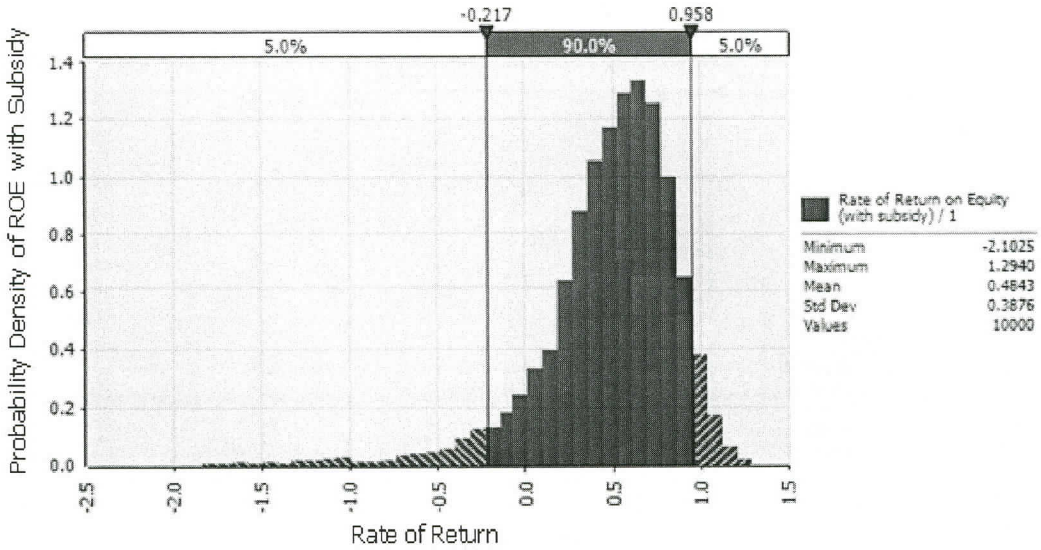

Figure B.11. Rate of Return on Equity EPI 2006-2008.

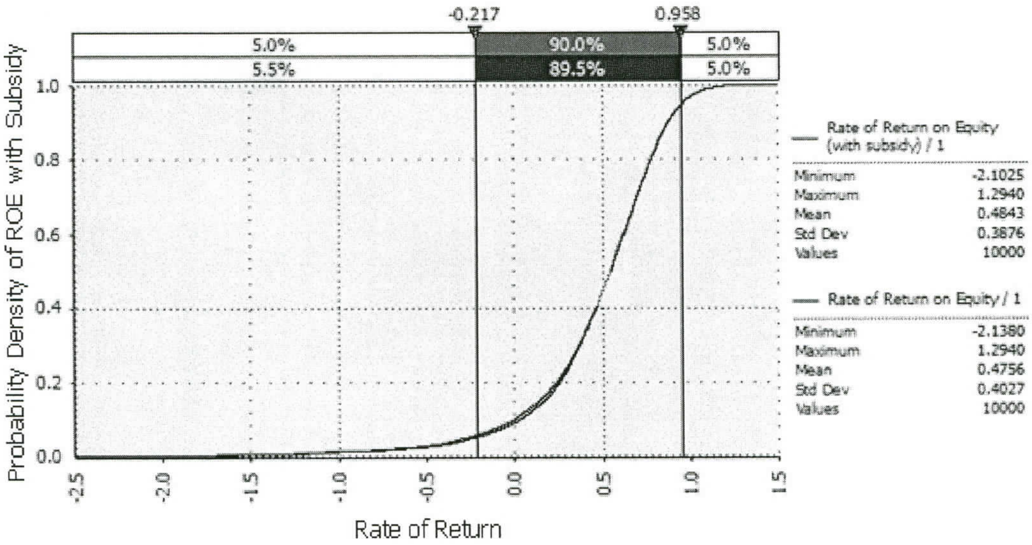

Figure B.12. Rate of Return on Equity EPI 2006-2008 with Rate of Return on Equity 2006-2008.

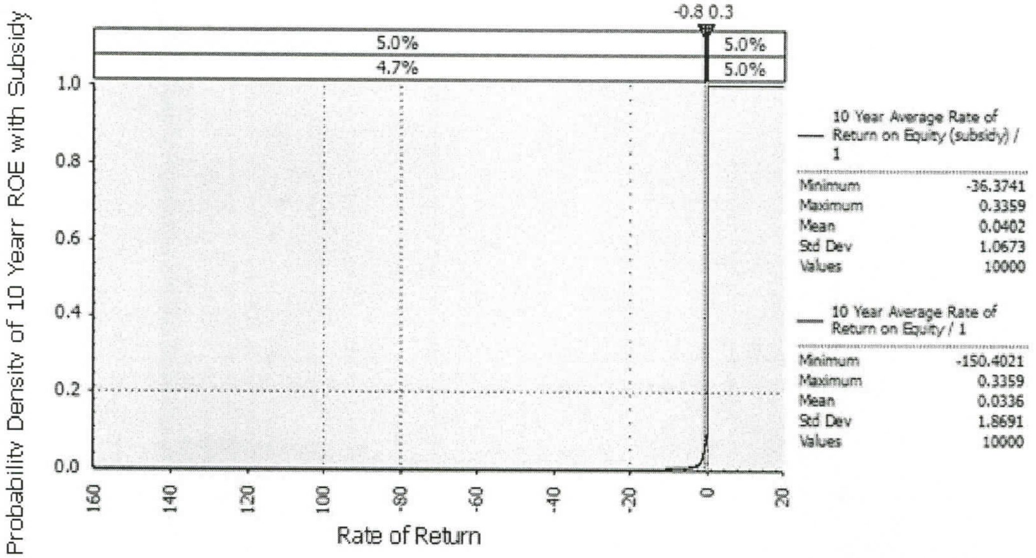

Figure B.13. Ten-Year Average Rate of Return on Equity Base Model 2006-2008 with 10-Year Average Rate of Return on Equity EPI 2006-2008.

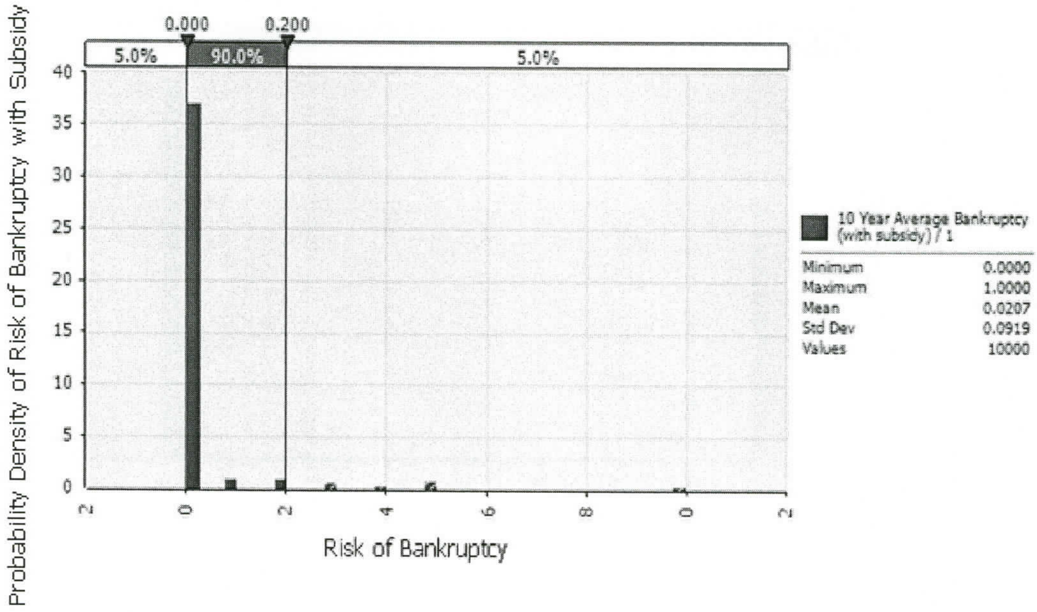

Figure B.14. Risk of Bankruptcy EPI 2006-2008.

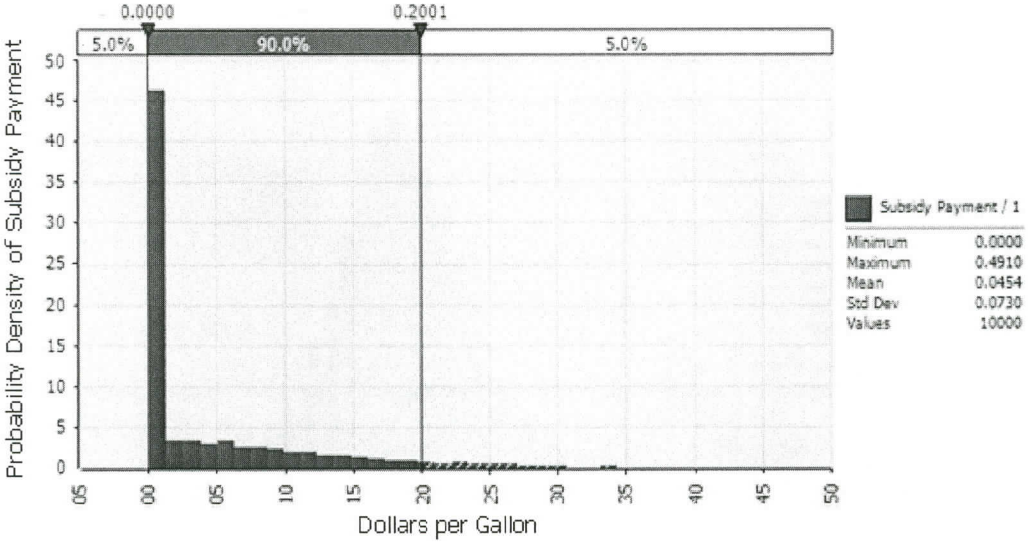

Figure B.15. Margin Payment per Gallon Forecast 2006-2008.

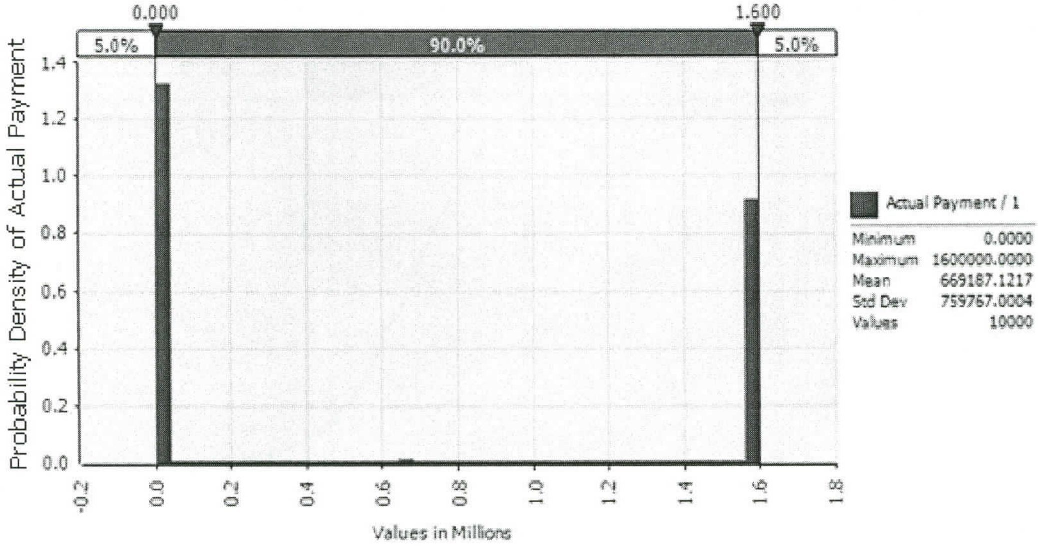

Figure B.16. Total Margin Payment Forecast 2006-2008.

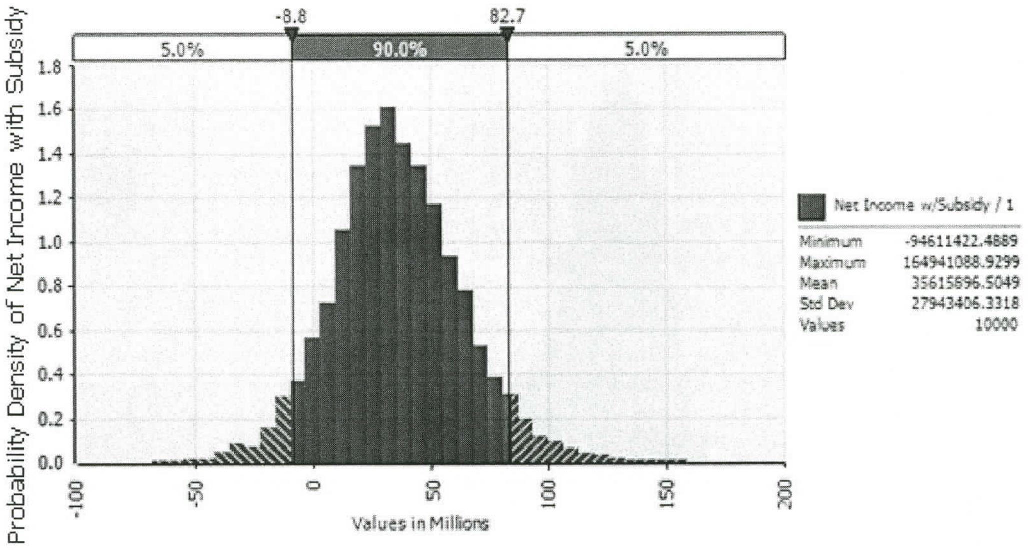

Figure B.17. Net Income Margin 2006-2008.

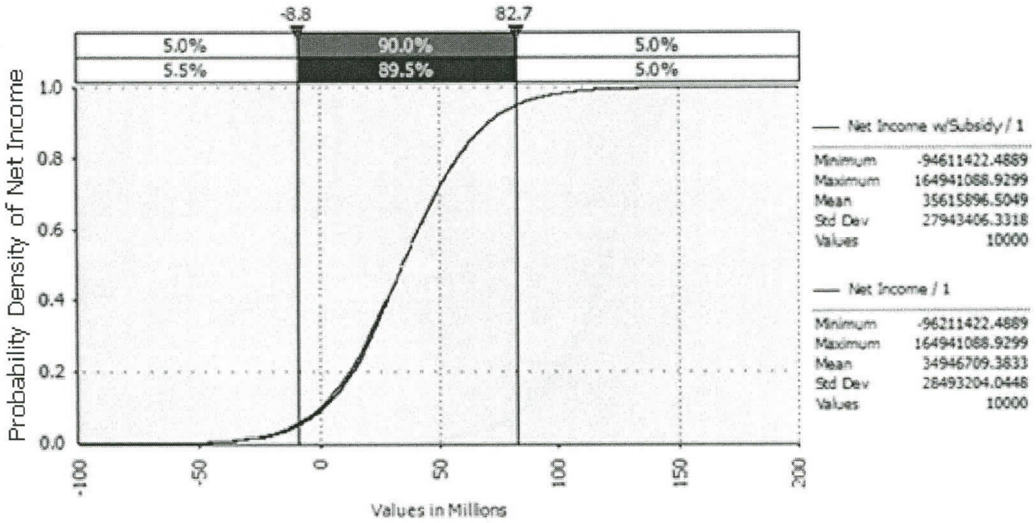

Figure B.18. Net Income Base Model 2006-2008 with Net Income Margin 2006-2008.

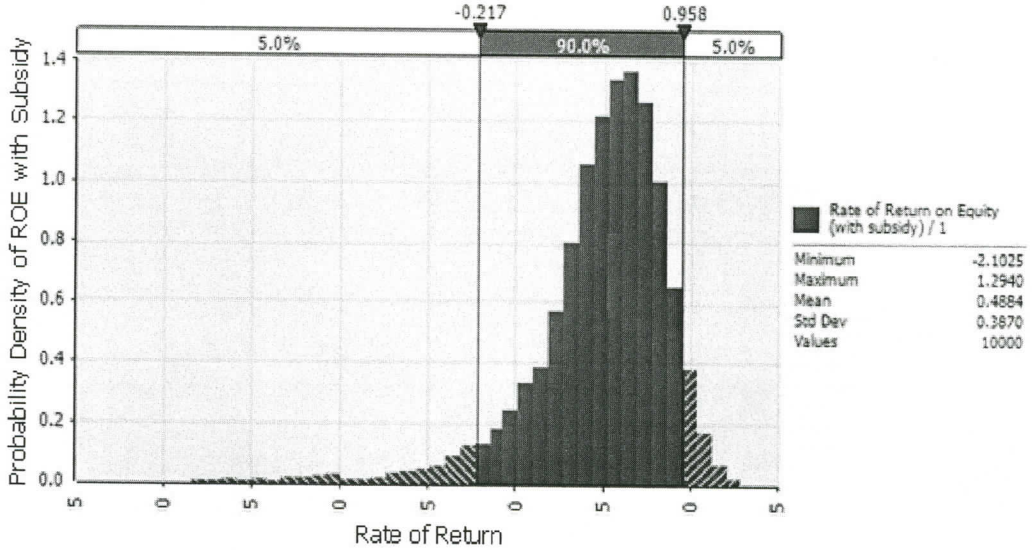

Figure B.19. Rate of Return on Equity Margin 2006-2008.

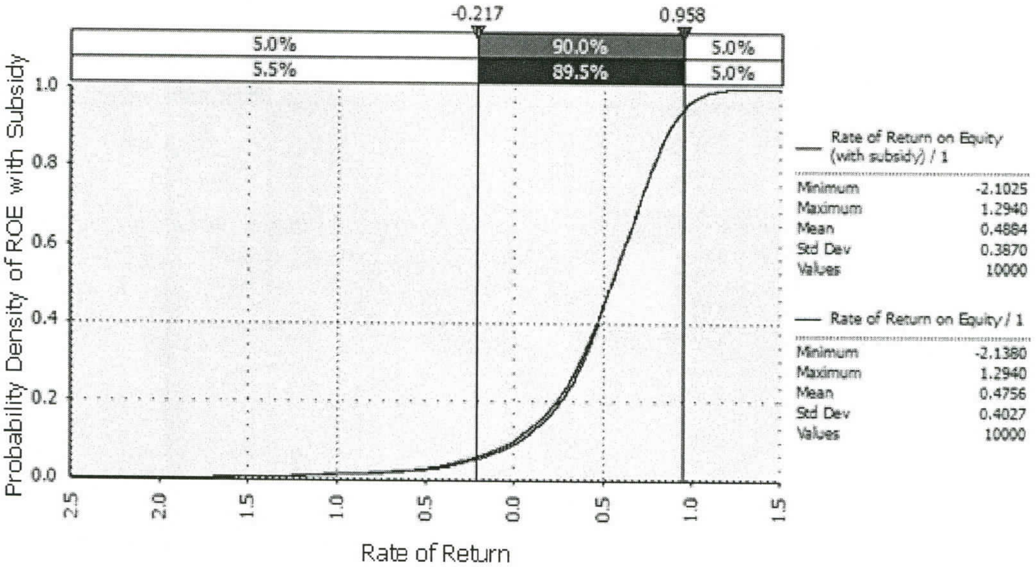

Figure B.20. Rate of Return on Equity Base Model 2006-2008 with Rate of Return on Equity Margin 2006-2008.

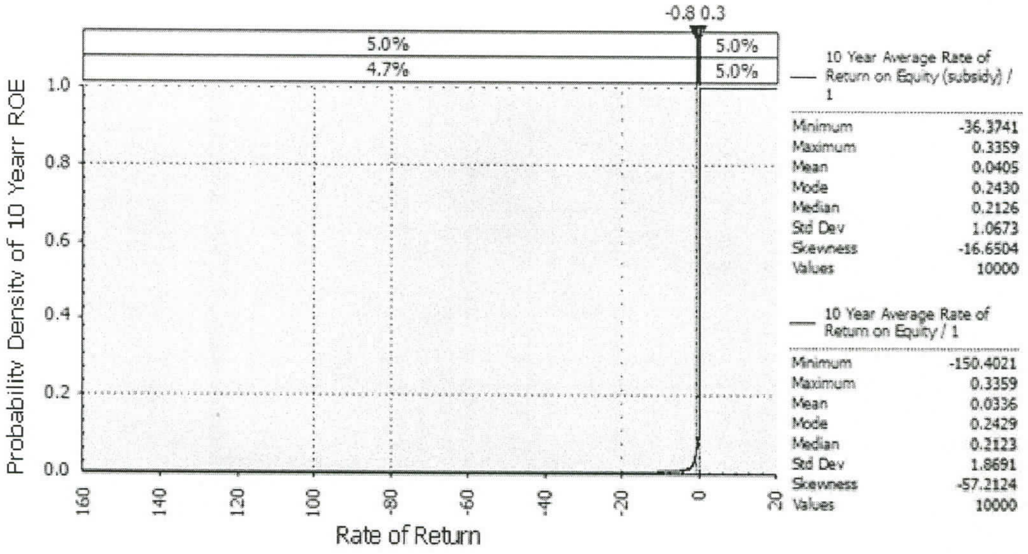

Figure B.21. Ten-Year Rate of Return on Equity Base Model 2006-2008 with 10-Year Rate of Return on Equity Margin 2006-2008.

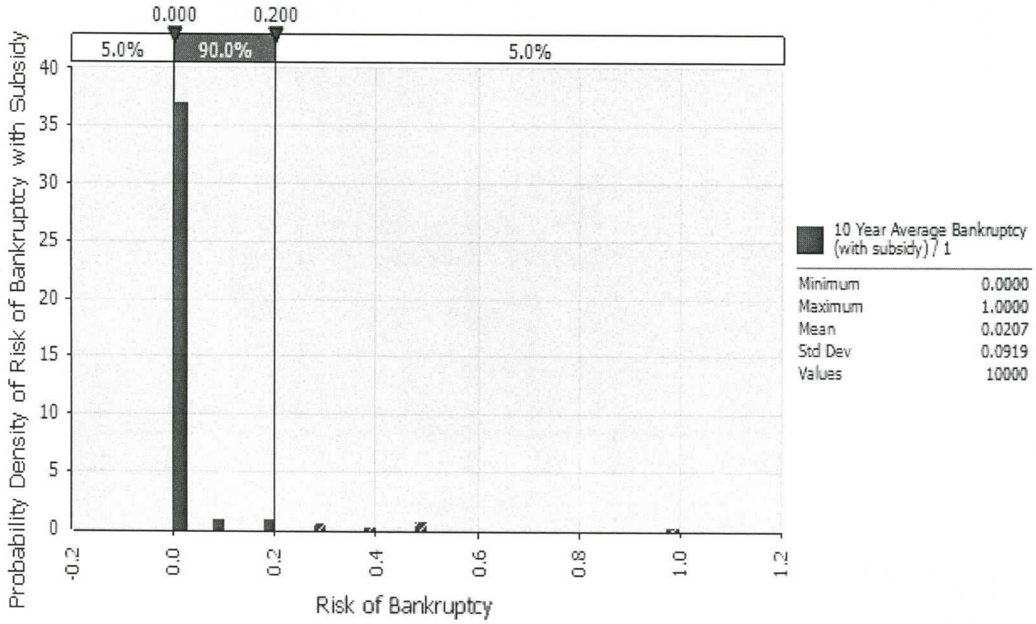

Figure B.22. Risk of Bankruptcy Margin 2006-2008.

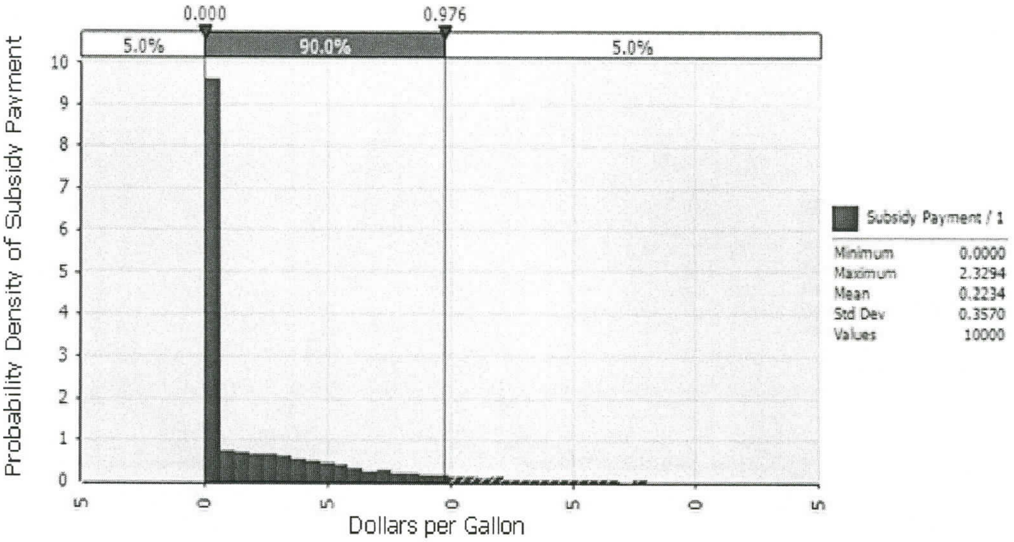

Figure B.23. Three-Year Average Payment per Gallon Forecast 2006-2008.

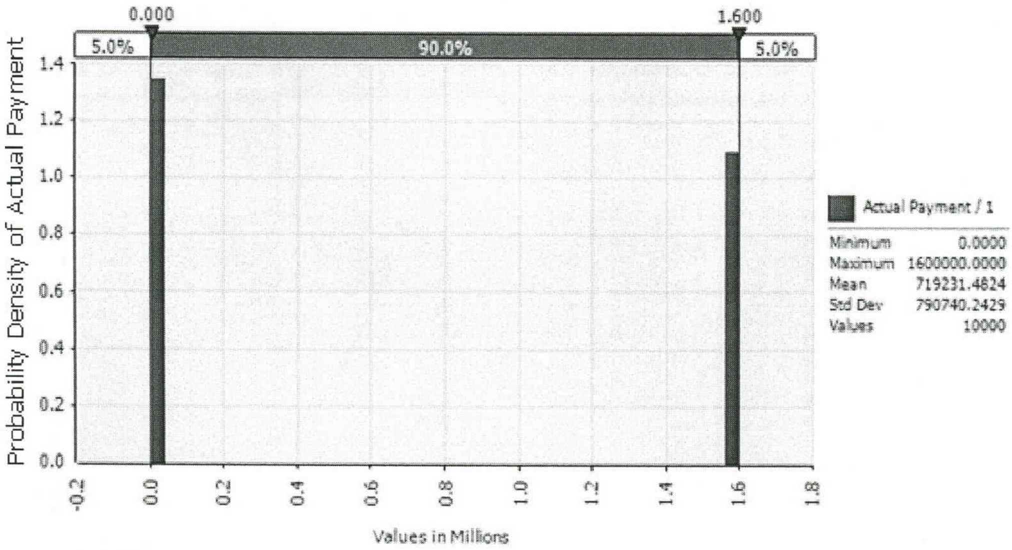

Figure B.24. Total Three-Year Average Payment Forecast 2006-2008.

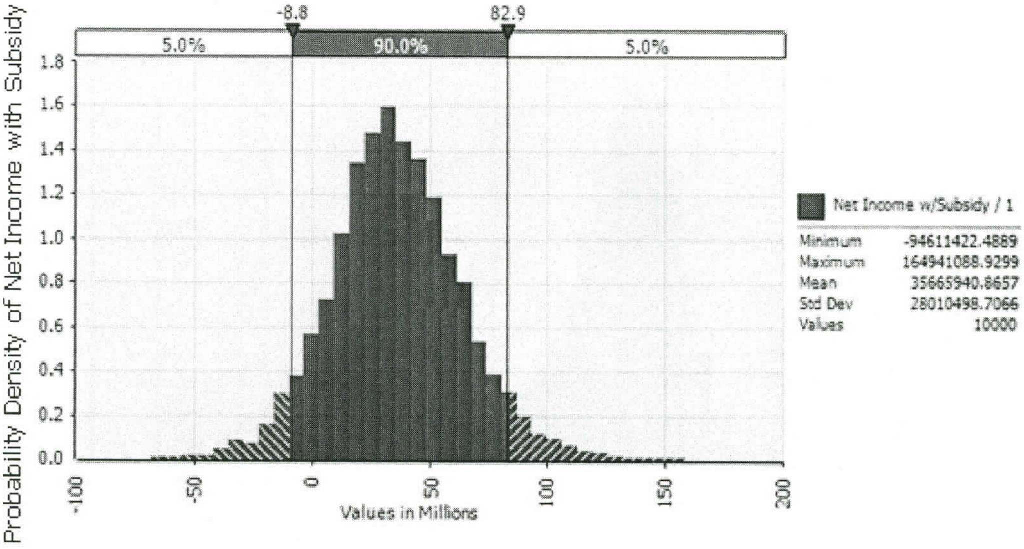

Figure B.25. Net Income Three-Year Average 2006-2008.

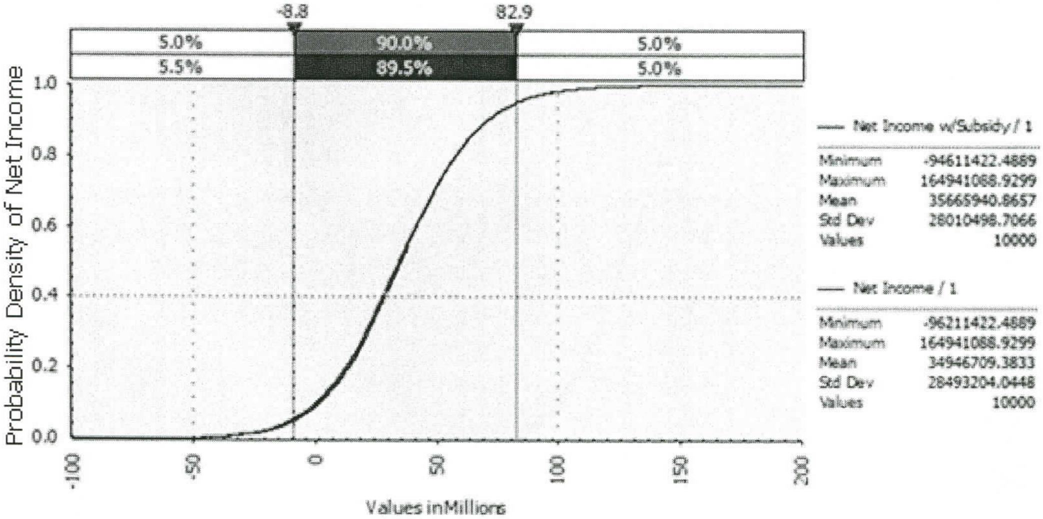

Figure B.26. Net Income 2006-2008 with Net Income Three-Year Average 2006-2008.

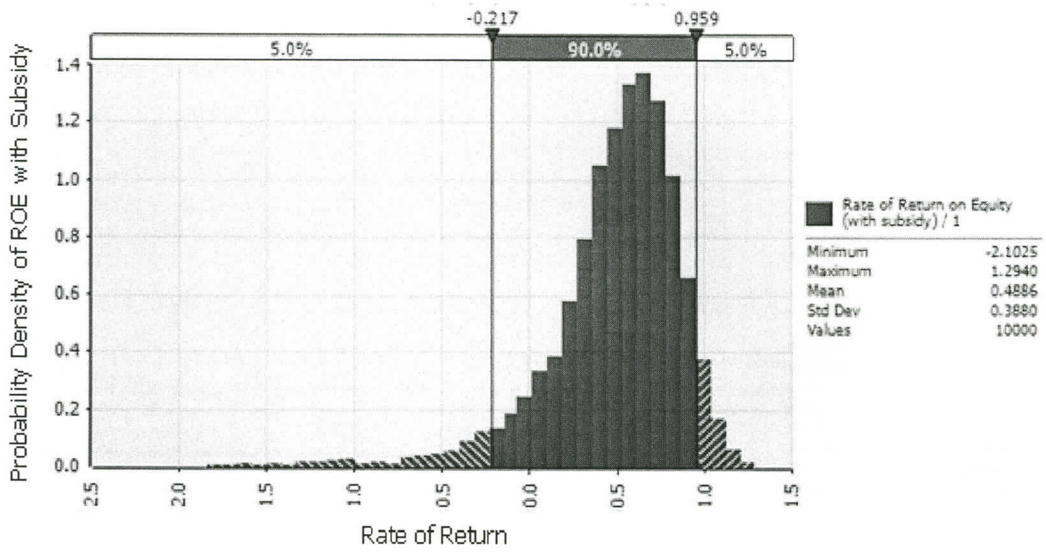

Figure B.27. Rate of Return on Equity Three-Year Average 2006-2008.

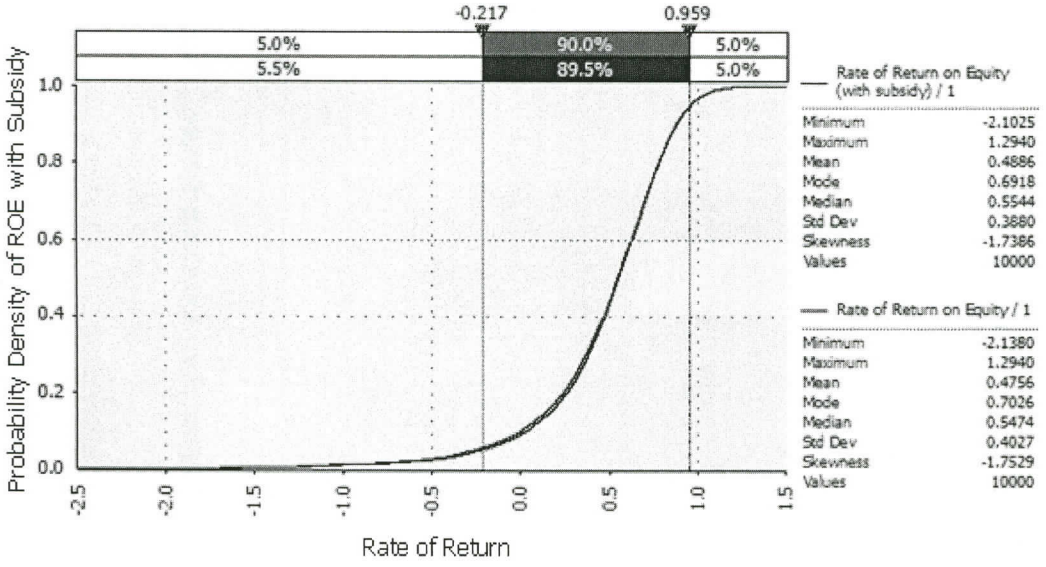

Figure B.28. Rate of Return on Equity 2006-2008 with Rate of Return on Equity Three-Year Average 2006-2008.

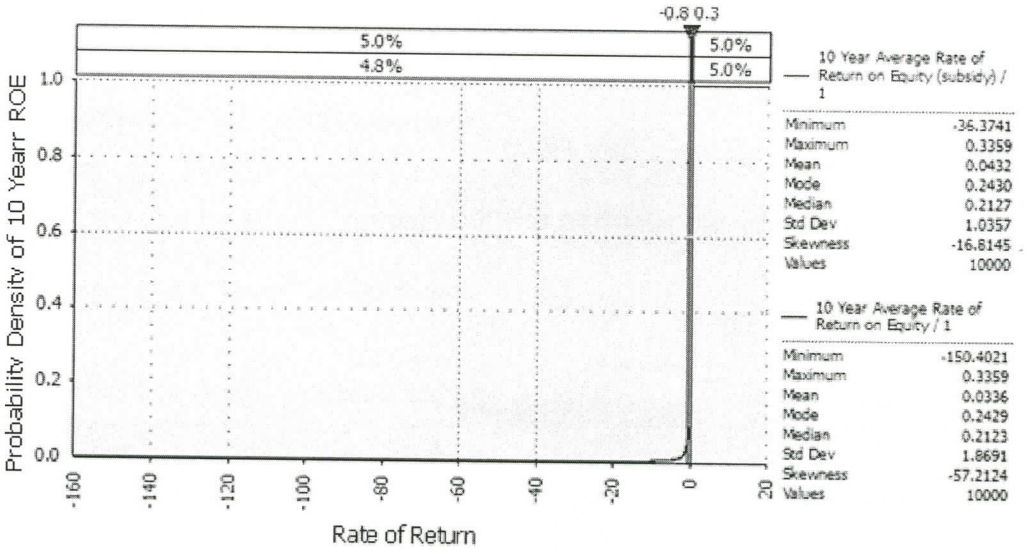

Figure B.29. Ten-Year Rate of Return on Equity 2006-2008 with 10-Year Rate of Return on Equity Three-Year Average 2006-2008.

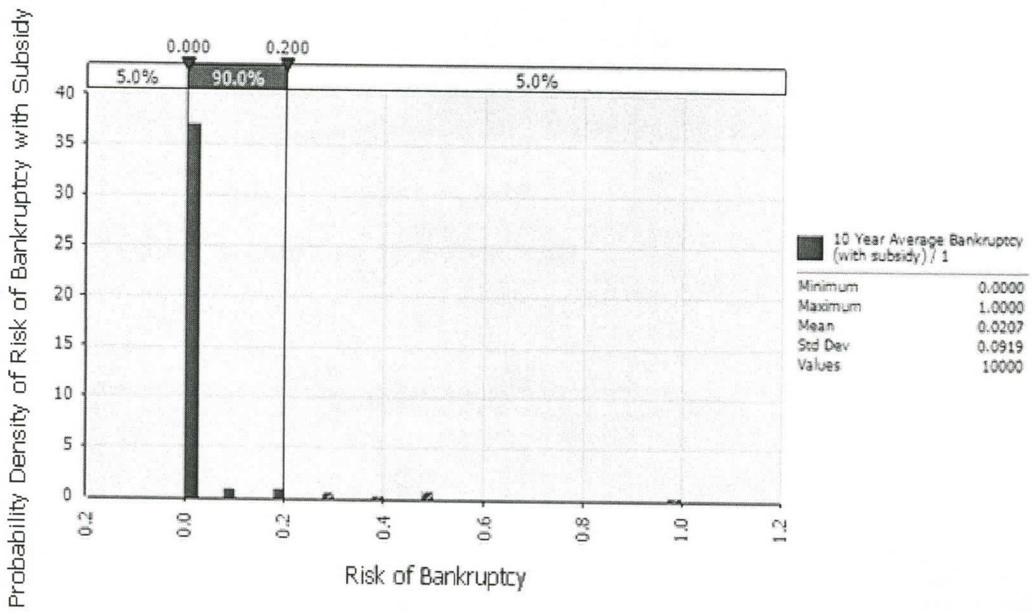

Figure B.30. Risk of Bankruptcy Three-Year Average 2006-2008.

APPENDIX C

Corn Price 2006-2008 with DDGS Sensitivity

This section uses the base model with DDGS as stochastic and using distributions with correlations generated from 2006-2008 data.

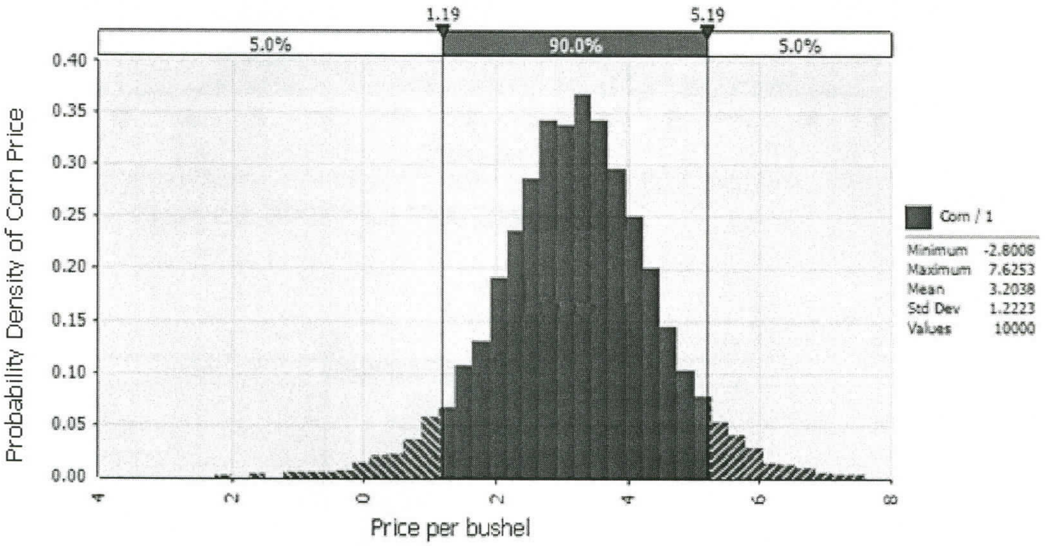

Figure C.1. Corn Price 2006-2008 DDGS.

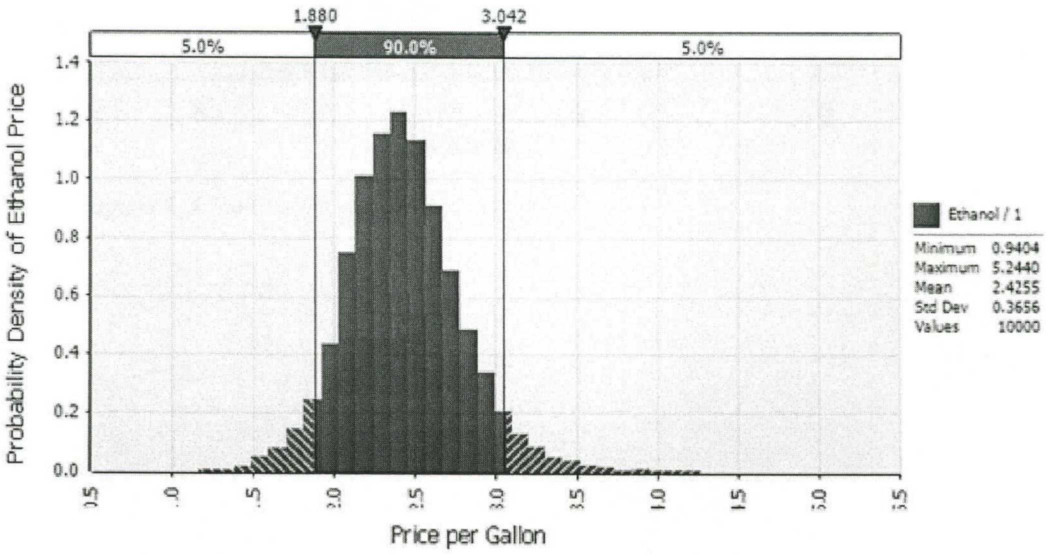

Figure C.2. Ethanol Price DDGS 2006-2008.

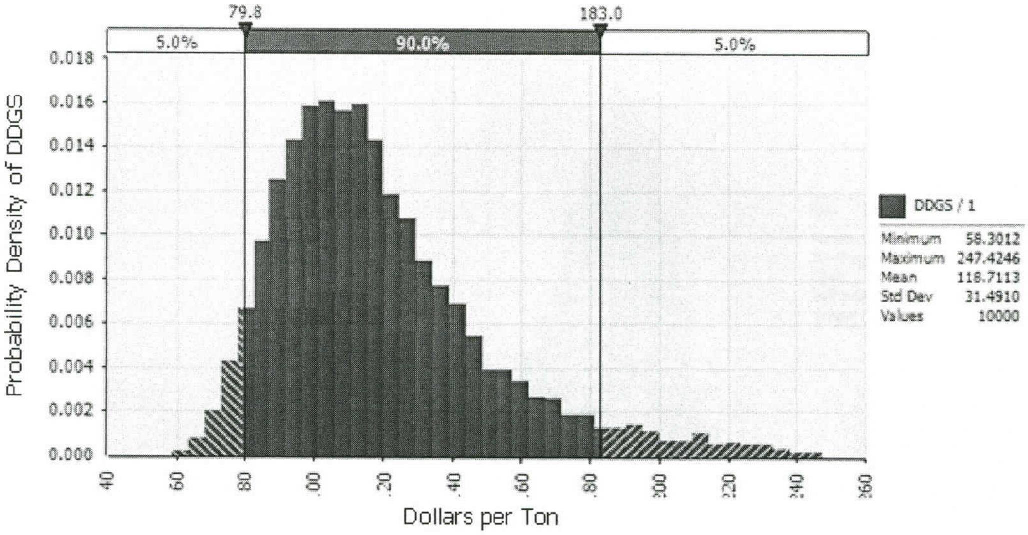

Figure C.3. DDGS Price 2006-2008.

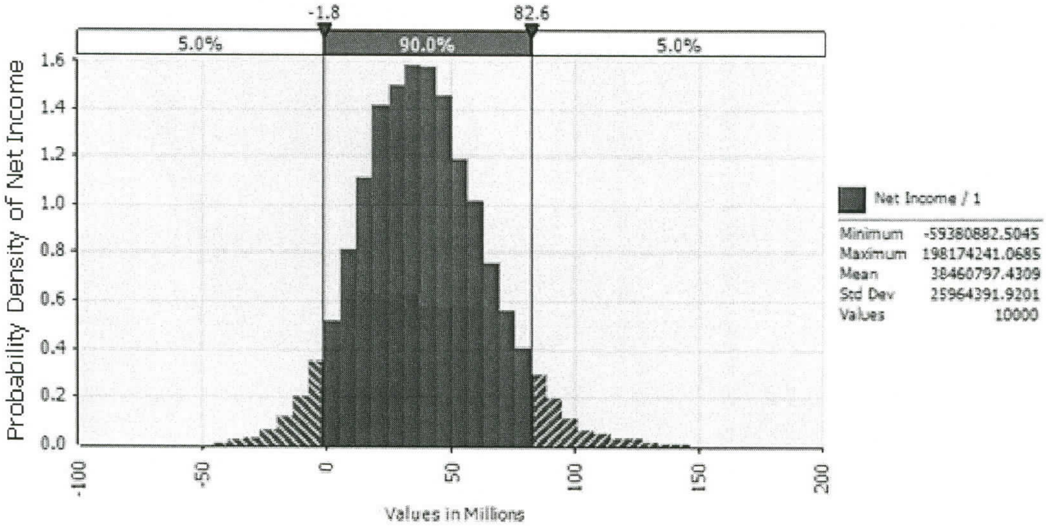

Figure C.4. Net Income DDGS 2006-2008.

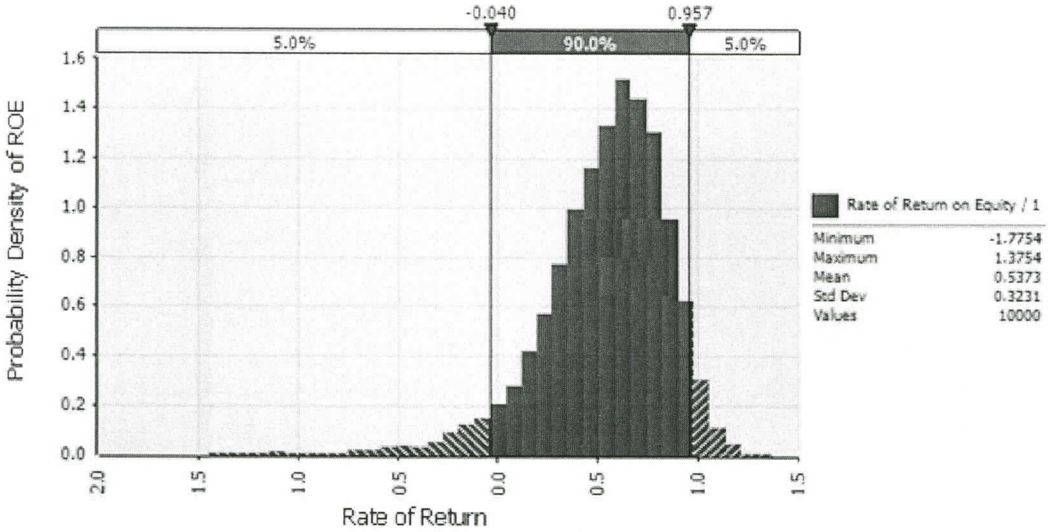

Figure C.5. Rate of Return on Equity DDGS 2006-2008.

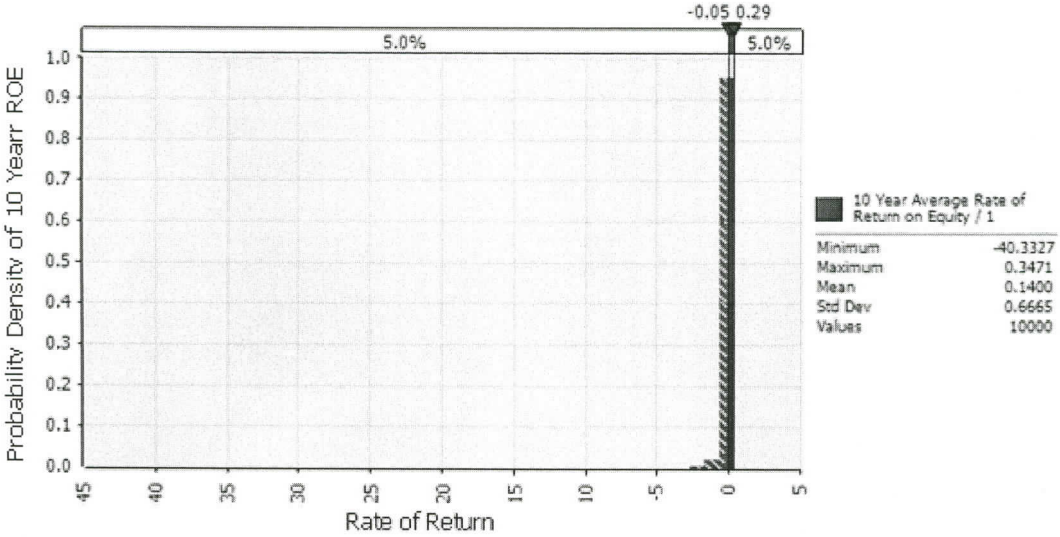

Figure C.6. Ten-Year Average Rate of Return on Equity DDGS 2006-2008.

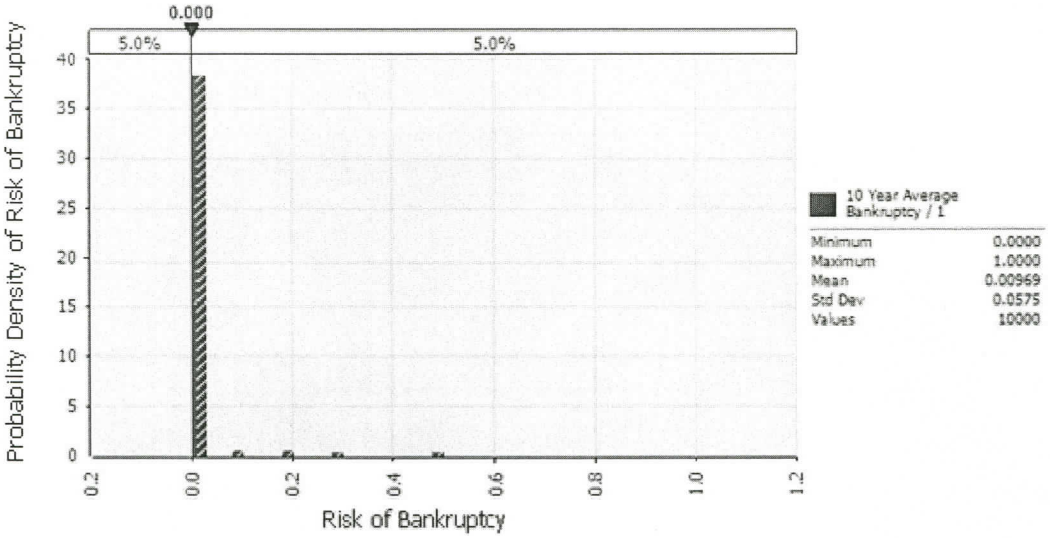

Figure C.7. Risk of Bankruptcy DDGS 2006-2008.