THE EFFECT OF LENDER-IMPOSED SWEEPS ON AN ETHANOL FIRM'S ABILITY TO INVEST IN NEW TECHNOLOGY

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Jason Edward Fewell

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Agribusiness and Applied Economics

July 2009

Fargo, North Dakota

North Dakota State University
Graduate School

Title

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ABSTRACT

Fewell, Jason Edward, M.S., Department of Agribusiness and Applied Economics, College of Agriculture, Food Systems, and Natural Resources, North Dakota State University, July 2009. The Effect of Lender-Imposed Sweeps on an Ethanol Firm's Ability to Invest in New Technology. Major Professor: Dr. Cole R. Gustafson.

New federal legislation proposes to reduce greenhouse gas (GHG) emissions associated with biofuel production. To comply, existing corn ethanol plants will have to invest in new more carbon efficient production technology such as dry fractionation. However, this will be challenging for the industry given the present financial environment of surplus production, recent profit declines, numerous bankruptcies, and lender imposed covenants.

This study examines a dry-mill ethanol firm's ability to invest in dry fractionation technology in the face of declining profitability and stringent lender cash flow repayment constraints. Firm level risk aversion also is considered when determining a firm's willingness to invest in dry fractionation technology. A Monte Carlo simulation model is constructed to estimate firm profits, cash flows, and changes in equity following new investment in fractionation to determine an optimal investment strategy. The addition of a lender-imposed sweep, whereby a percentage of free cash flow is used to pay off extra debt in high profit years, reduces the firm's ability to build equity and increases bankruptcy risk under investment. However, the sweep increases long-run equity because total financing costs are reduced with accelerated debt repayment.

This thesis shows that while ethanol firm profits are uncertain, the lender's imposition of a sweep combined with increased profit from dry fractionation technology help the firm increase long-run financial resiliency.

ACKNOWLEDGEMENTS

Many thanks go to my advisor Dr. Cole Gustafson for all his patience, comments, and support during the writing of my thesis. It would not have been possible without his expert guidance. In addition, a special thank you to my committee members, Dr. Gregory McKee, Dr. Scott Pryor, and Dr. William Wilson for their useful insight and editorial suggestions. I greatly appreciate all the help I received while writing this thesis.

I would also sincerely like to thank the faculty and staff in the Department of Agribusiness and Applied Economics for their unending support and unsurpassed instruction during my years at NDSU. I will always value my time spent at this fine institution.

Thank you to my family, friends, and colleagues, for without their presence, support, and assistance, this work would not have been possible.

Finally, a most heartfelt thanks and appreciation to my wife, Teresa for her never-ending love, support, and patience, even in the most challenging times. Without her constant adulation, I never would have finished this work. Words cannot express my appreciation for her during these two years and for her devotion to our family's well-being while I pursued this goal.

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CHAPTER 1. INTRODUCTION AND STATEMENT OF PROBLEM

Introduction

Ethanol production in the United States has increased dramatically in recent years, precipitated in part by federal requirements for renewable fuels to reduce dependence on imported oil and reduce harmful emissions caused by burning fossil fuels. A majority of Americans (nearly 75%) desires an increased use of renewable fuels and believes the government should support renewable fuels through incentives or legislation (Renewable Fuels Now, 2007).

The Renewable Fuel Standard (RFS) contained in the Energy Independence and Security Act of 2007 requires the volume of renewable fuel to increase from nine billion gallons in 2008 to 36 billion gallons annually by 2022 (U.S. Congress, 2007). In addition, beginning in 2015, the amount of renewable fuel produced from corn starch should not exceed 15 billion gallons with the remainder (and subsequent years' increases) coming from advanced biofuels (U.S. Congress, 2007). Advanced biofuels are produced from products such as wood chips, agricultural residue or other waste materials, organic matter, or sugars from sources other than corn starch and have greenhouse gas emissions at least 50% below baseline greenhouse gas (GHG) emissions, which are emissions produced from gasoline in 2005 (U.S. Congress, 2007).

The U.S. Environmental Protection Agency (EPA) proposed new rules in May 2009 that require biofuels produced through conventional methods to reduce GHG emissions at least 20% below the baseline, unless the plant was built before December 19, 2007 (U.S. EPA, 2009b). Current corn-based ethanol reduces emissions by only 16% when including direct and indirect land use (U.S. EPA, 2009a). Changes in production of crops requiring

different amounts of field work, along with the processing, transportation, and finally use of crops and crop co-products changes the way GHG emissions are released into the atmosphere (Feng, Rubin, and Babcock, 2008). Changes in GHG emissions also occur when replacing corn and soybean meal with dried distiller's grains with soluble (DDGS) in an agronomy and post-agronomy stage—that is production of corn and soybeans and use of the crops for food, feed, or fuel (Feng, Rubin, and Babcock, 2008).

The EPA's proposed regulations also require analysis of increasing the percentage of ethanol blended into gasoline from 10% to 15% (U.S. EPA, 2009b). This may become necessary because current blending requirements may not use all of the nation's potential ethanol production (U.S. EPA, 2009b). It also would further reduce GHG emissions.

In the early 1990s, the current U.S. corn-based ethanol industry began as a benefit to two groups. First, rural communities gained by providing employment for their citizens and second, farmers (who frequently owned the plants) benefited when corn prices were low because ethanol revenue was high (Swenson, 2009). Many ethanol plants formed as cooperatives where the equity holders were local farmers. Investors living near new plants saw economic benefits of value-added agricultural processing for their communities and local farmers (Sims, 2007).

As economies of scale, profitability, and investor returns increased in the ethanol industry, especially in the early 2000s, more equity financing became available, particularly from the private sector. For instance, historically low corn prices and increasing crude oil prices contributed to increased ethanol profits and Wall Street investors began investing in rural America (Gustafson, 2008). Ethanol plants were able to reduce debt quickly and offer large returns to equity investors. Ethanol plant size increased

as production costs per gallon of ethanol produced declined partly due to technology that yielded "sure" quantities of ethanol and helped provide stable returns (Gustafson, 2008).

With the increased size of ethanol plants from small 10 to 15 million gallon plants to 30 to 100 million gallon plants, the share of financing by farmers steadily decreased until only 26% of new construction was funded by farmers in 2005 (Kenkel and Holcomb, 2006). Sources of financing shifted from farmers to other private investors as profitability in ethanol production increased (Sims, 2007).

Some companies became publicly traded, such as Pacific Ethanol in May 2006, and VeraSun Energy and Aventine Renewable Holdings, Inc. in June 2006 (Gelsi, 2006). Other firms merged to allow firms to spread operating costs and obtain new revenue sources from diversity of business operations (Wyka, 2008). In April 2008, VeraSun Energy completed a merger with rival U.S. BioEnergy to increase its production to more than one billion gallons annually (DTN Ethanol Center, 2008). Table 1 from the Renewable Fuels Association (2009) shows how, particularly from 2003 to 2008, the farmer-owned share of ethanol production fell while total production continued to expand. The high profitability enticed other entities to invest in ethanol production, but as corn prices increased and ethanol profitability declined, investment slowed.

Table 1. U.S. Ethanol Industry Overview

Year	2003	2004	2005	2006	2007	2008
Total Ethanol Plants Operating	68	72	81	95	110	170
Production Capacity (mgy)	2,706.8	3,100.8	3,643.7	4,336.4	5,493.4	10,5699.4*
Plants Under Construction/Expanding	11	15	16	31	76	24
Capacity Under Construction/Expanding (mgy)	483	598	754	1,778	5,635.5	2,066
% Farmer-Owned Capacity	29%	34%	38%	39%	39%	28%
Farmer Owned Plants	28	33	40	46	46	49
U.S. Fuel Ethanol Demand (mgy)	2,900	3,530	4,048.9	5,337.4	6,846.6	9,636.9

*12,475.4 mgy capacity including idled capacity

Due, in part, to high profitability in ethanol production, new plant construction and existing plant expansion from 2006 to 2007 increased rapidly, causing ethanol production to out-pace demand and the federal mandates. This increased production depressed ethanol prices, and, when coupled with increasing input costs for corn and energy, caused ethanol profit margins to decline. Corporate stockholders or venture capitalists became less willing to finance new plant construction as profitability fell (Sims, 2007). Investors began pulling financing from the ethanol industry as construction costs ballooned and the continuation of ethanol production incentives (tax credits) became uncertain or almost nonexistent for large capacity plants (Gustafson, 2008). Environmental concerns about water use and corn's use as a fuel instead of food also weighed on investor's decisions whether to invest in new plants (Gustafson, 2008). The (coming) transformation from corn-based ethanol to cellulosic technologies also caused investors to wait for new development before investing (Gustafson, 2008).

In addition, the required debt-to-equity ratio to build an ethanol plant is approximately 50-50, while in the past it was 60-40 (Sims, 2007). Assuming investors are risk averse, the lower debt-to-equity ratio indicates they are less willing to take the risk of losing capital, and that decreasing profitability is likely a reason for the decreased amount of debt capital available.

Bankruptcies due to decreased margins also caused investors to slow or stop their funding for ethanol plants. Ethanol plants in Kansas and California filed for Chapter 7 bankruptcy, and plants in Illinois and Nebraska filed for Chapter 11 bankruptcy (Neely, 2008b). Renova Energy's nine plants in South Dakota, Wyoming, and Idaho filed for Chapter 11 bankruptcy in June 2008 (Neely, 2008b). In addition, during June 2008,

VeraSun Energy, one of the nation's largest ethanol producers, delayed startup for three new ethanol plants totaling over 300 million gallons per year of production due to increasing corn prices and decreasing profit margins (Suzukamo, 2008). In November 2008, VeraSun Energy filed for Chapter 11 bankruptcy due to high corn prices, low margins, and decreased short-term credit availability (Pushed by Credit Crunch, Ethanol Producer Declares Bankruptcy, 2008).

Tight credit markets have created difficulties for firms attempting to invest in new technologies to diversify their operations (Otto, 2009). The added risk of bankruptcy creates nervousness among lenders and potential investors.

Debt financing is important for firms in a variety of industries. For agricultural firms, risk is sometimes greater due to weather, disease, or other factors outside of normal supply and demand issues. The two primary types of risk are business risk and financial risk: the former is risk dealing with production and pricing; the latter with the probability and size of financial hardship caused by a producer not being able to meet debt obligations (Boehlje and Ray, 1999). Lower business risk will often allow an investor to borrow more (Boehlje and Ray, 1999). One of the most important risks faced by an ethanol producer is price risk for inputs and output. Figure 1 shows Nebraska ethanol, corn, and unleaded gasoline prices since 1982. Ethanol and unleaded gasoline are rack prices FOB Omaha, and corn is price received by farmers.

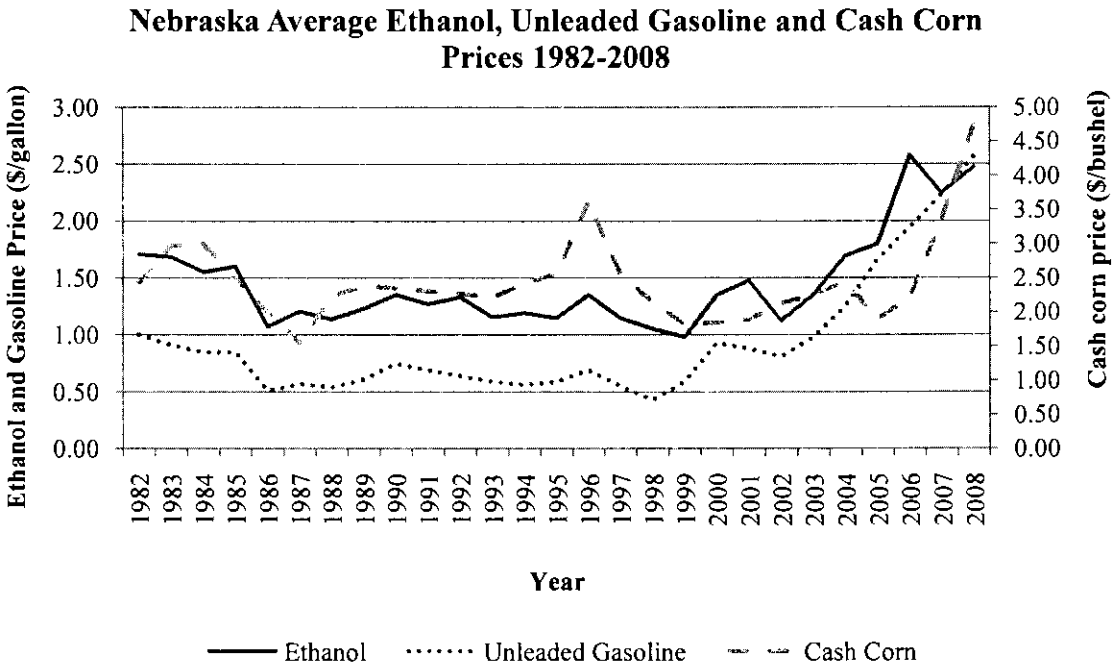


Figure 1. Nebraska average annual ethanol, unleaded gasoline, and corn prices received.

In addition to bankruptcy risk, ethanol producer margins have decreased. Ethanol price increases have not matched the rising pace of corn price increases, depressing profits for many ethanol producers and delaying new construction (Cummins, 2008). Ethanol prices are dependent upon supply, demand, and the prices of other energy products such as crude oil and gasoline, while corn price is dependent upon factors such as weather, prices of other commodities, international trade, and its demand as food or livestock feed (Board of Trade of the City of Chicago, 2007).

Many states have instituted subsidies for ethanol producers to mitigate some price risk. For instance, during the 2005 to 2007 biennium, the state of North Dakota subsidized eligible ethanol producer's output by $0.002/gallon when average quarterly ethanol prices

fell below $1.30/gallon or by $0.001/gallon when average quarterly corn prices rose above $1.80/bushel (N.D.C.C. §17-02-03).

For lenders, assessing a firm's risk is important because the likelihood of repayment falls with high-risk borrowers. High levels of risk can cause a firm to lose its ability to borrow funds to finance new ventures or expand existing facilities. One way for a lender to mitigate the risk associated with lending to high-risk firms is to impose a sweep on the firm's debt obligation.

In traditional finance literature, a sweep is a bank account that transfers amounts above or below a certain amount into a higher-returning investment account (usually money market funds) for a customer without the customer's need for constant attention (Investopedia.com). In this study, sweeps are lender-imposed requirements on a firm to repay some portion of a loan(s) from excess cash flows, issued debt or equity, or asset sales (Ackert, Huang, and Ramirez, 2007) in periods of high profitability. Ackert, Huang, and Ramirez (2007) indicate that a firm under sweep covenants is more likely to be private because of higher risk or asymmetric information associated with private firms.

Most ethanol producers are private firms, and sweeps are a useful tool for lenders to guarantee loan repayment during periods of high firm profitability. Lenders such as CoBank request that their investment be repaid at an accelerated rate in the form of sweeps, whereby up to 75% of free cash flow per year is repaid in high profit situations (Grawe, 2007). While excessive lender control could drive a firm into bankruptcy, an underlying assumption of this thesis is that individual investors' personal liability is protected should bankruptcy occur.

The sweep constraint may lessen the firm's ability to make new investments, similar to the horizon problem many cooperatives face. The horizon problem exists for cooperatives who need to make new investments, but whose members are only willing to invest more capital if the investment has a quick return (Sexton, 1991). Sweeps also limit the amount of cash reserves available for firms during periods of excessive risk, which have occurred in the ethanol industry.

Maintaining adequate cash reserves is important for a firm that needs to make new investment, particularly in times of financial stress (Arslan, Florackis, and Ozkan, 2006). Firms without adequate reserves are more susceptible to adverse changes in the overall economy, which negatively influence their ability to make new investments (Arslan, Florackis, and Ozkan, 2006). Nonetheless, investment in new technology is important for firms as a way to mitigate risk and remain competitive.

Technology

Debt financing is a necessary component to adopting new production methods. With decreased credit availability and the imposition of sweeps, affording new technology becomes difficult for many firms. However, ethanol production technology is changing rapidly, and firms must invest in these new production techniques to remain profitable and help meet production requirements set forth by the Renewable Fuels Standard (RFS).

One of these new processing technologies is dry or "front-end" fractionation. This paper discusses a firm's potential investment in dry fractionation because of its ease in fitting to an existing dry mill ethanol plant and lower installation costs than other technologies. Dry fractionation is an additional processing step that separates each corn kernel into its germ, pericarp, and endosperm (Murthy, et al., 2006a). In this type of

process, corn is fractionated prior to milling, which is distinct from other types of fractionation performed on the DDGS after conventional dry milling.

Dry fractionation benefits ethanol production by lowering the time required to produce ethanol from corn over traditional dry milling. The process increases ethanol throughput, reduces the amount of the co-product dried distiller's grains with solubles (DDGS) and replaces them with high-protein DDGS, and provides corn germ as another revenue source (Rajagopalan, et al., 2005; Murthy, et al., 2006b). Dry fractionation benefits hog and poultry producers by providing them with another high-quality feed source, since traditional DDGS are difficult for non-ruminant animals to digest (Baker and Babcock, 2008).

Competitors who do not adopt new technologies may be forced to close due to lost economies of scale that result from increased output and lower processing costs. However, investing in new technology is difficult in times of declining profitability or tight credit markets. Lenders' imposition of sweeps is likely during times of increased uncertainty as a way to lessen their risk. This creates difficulties for firms who must maintain adequate cash flow and equity to provide for investment in these new technologies. While the benefits of efficiencies created from dry fractionation are high, challenging economic times make investment in these technologies difficult for ethanol producers (Voegele, 2009).

Adopting new, more efficient, technology can lessen concerns over input supplies and help a firm stay profitable. At the same time, keeping debt low will help plants remain viable by ensuring adequate working capital to meet short-term debt obligations (Wisner, 2009). Lender-imposed sweeps will help a firm keep its debt low, but will restrict cash flow needed to make the investment in new technology.

Problem Statement

Minnesota ethanol producers, as early entrants into the industry, know the value of adopting new technology and carrying low debt. While many firms are closing or delaying startup, ethanol production in Minnesota continues to progress, in part because many of the plants are farmer-owned, and the farmers can benefit from either high-priced corn, or ethanol (Cummins, 2008). Adopting new technology benefits ethanol producers through increased efficiencies. Inefficiency is one reason many ethanol producers have had difficulty maintaining profitability (Wisner, 2009). Increased ethanol output per bushel of corn will allow ethanol producers to increase profits with higher revenue and lower costs.

Increasing energy costs and uncertain input supplies are important considerations for ethanol producers. A Renewable Fuels Association survey showed that 22 ethanol plants surveyed from 2001 to 2007 increased their output of ethanol per bushel of corn: 6% for dry mill plants and 2% for wet mill plants, which reduces energy costs and supply concerns (Neely, 2008a). Efficiency in ethanol production decreased fossil fuel and electricity use for dry mill plants by 22% since 2001 and 7% for wet mill plants. Water use decreased 27% for dry mill plants from 2001 to 2007 (Neely, 2008a).

Investing in new corn-based ethanol production technology is necessary because ethanol production from corn will be more cost-effective in the short term. In 2007, the U.S. Department of Energy committed over $1 billion in research funding to explore new production methods for ethanol and other bioenergy, particularly with cellulosic or other biomass (Ebert, 2007). Other forms of producing ethanol must be cost-competitive with corn by 2012, according to the RFS (Ebert, 2007); therefore, much research is going into production from other feedstocks. However, increasing efficiency in corn-based ethanol

through processes such as dry fractionation receives less funding even though the technology is available immediately while large-scale cellulosic ethanol production is not economically viable (Otto, 2009).

Increased ethanol production requires increased construction or short-run modification of existing ethanol plants. Federal mandates requiring alternative feedstocks for ethanol production in 2016 necessitate the use of other technologies for producing ethanol from products such as sugar, field peas, or cellulosic material. New technologies require investment in addition to that already necessary for a new plant using existing technology. Additional research also is necessary before investment in new technologies can proceed.

Debt and equity capital available for ethanol producers decreases as input price volatility increases and as the likelihood of high profits declines. This creates difficulties for ethanol producers who must invest in technology that is more efficient to remain competitive but lack sufficient capital reserves due to sweeps' requirements that excess cash be used to pay down debt.

Objective

The optimal investment pace in new technologies is uncertain because of volatility in corn and ethanol prices and the availability of debt and equity capital. The objective of this research is to determine corn ethanol processing firms' ability to adopt new corn-based ethanol production technology subject to stringent lender constraints during periods of high profitability.

CHAPTER 2. BACKGROUND AND LITERATURE REVIEW

The background and literature review contains three sections. The first section is a brief history of ethanol production in the United States, the second discusses alternative ethanol production technology, particularly dry fractionation, and the third contains research concerning financing new technology and associated risks.

History of Ethanol in the United States

Ethanol's first use was to power an engine in 1826, and in 1876, Nicolaus Otto, the inventor of the modern four-cycle internal combustion engine, used ethanol to power an early engine (Energy Information Administration, 2005). Ethanol also was used as a lighting fuel in the 1850s, but its use curtailed when it was taxed as liquor to help pay for the Civil War (Energy Information Administration, 2005). Ethanol use as a fuel continued after the tax was repealed, and fueled Henry Ford's Model T in 1908 (Energy Information Administration, 2005). The first ethanol blended with gasoline for use as an octane booster occurred in the 1920s and 1930s, and was in high demand during World War II because of fuel shortages (Energy Information Administration, 2005).

Today's ethanol industry began in the 1970s when petroleum-based fuel became expensive and environmental concerns involving leaded gasoline created a need for an octane substitute (Energy Information Administration, 2005). Corn became the predominant feedstock for ethanol production because of its abundance and ease of transformation into alcohol (Energy Information Administration, 2005). Federal and state subsidies for ethanol helped keep the fuel in production when ethanol prices fell with crude oil and gasoline prices in the early 1980s (Energy Information Administration, 2005). This also helped spawn the "Minnesota Model" for ethanol production, in which farmers began

producing ethanol to add value to their corn (Bevill, 2008). The Minnesota Model is an agreement between local public and private parties who work to keep profits in the community by providing jobs (and the economic benefits associated with population) and adding value to agricultural products while strengthening rural communities (Bevill, 2008). Ethanol's use as an oxygenate to control carbon monoxide emissions, encouraged increased production of the fuel through the decade and into the 1990s (Energy Information Administration, 2005).

With the phasing out of Methyl Tertiary Butyl Ether (MTBE) as an oxygenate and a desire to decrease dependence on imported oil and increase the use of environmentally friendly fuels, ethanol's demand increased dramatically. In 2005, the first Renewable Fuels Standard (RFS) became law as part of the United States' energy policy (Renewable Fuels Association, 2005a). It provided for ethanol production of four billion gallons in 2006 with an increase to seven and one-half billion gallons by 2012 (Renewable Fuels Association, 2005a). Since that time, The Energy Independence and Security Act of 2007 signed by President Bush requires renewable fuel usage to increase to 36 billion gallons annually by 2022 (Renewable Fuels Association, 2008b).

The new RFS states that only 15 billion gallons of production should be produced from corn—the remaining 22 billion should come from sources other than corn starch (U.S. CONGRESS, 2007), which helps mitigate perceived concerns about ethanol production's impact on higher food prices. Some economists, politicians, livestock producers, and opinion writers vilify corn-based ethanol as the root cause of world food shortages, food inflation, and increased strains on the U.S. Midwest transportation sector. In June 2008, the governors of Connecticut and Texas called on the U.S. Environmental Protection

Agency (EPA) to allow reductions in the Renewable Fuels Standard, which calls for nine billion gallons of ethanol production in the year 2008 (Rispoli, 2008). The group Food Before Fuel petitioned New Jersey's governor as well, saying increases in corn-based ethanol production have caused food prices to skyrocket (Rispoli, 2008). Under The Energy Independence and Security Act of 2007 (EISA), the EPA Administrator has the right to reduce corn-based ethanol production requirements if corn supplies become short (U.S. CONGRESS, 2007).

The EPA proposed new regulations in May 2009 that require renewable fuels reduce greenhouse gas emissions by increasing amounts to meet requirements of RFS2—the Renewable Fuels Standard developed under the EISA of 2007. These changes would take effect January 1, 2010. For conventional biofuels, such as corn-based ethanol, the reduction must be at least 20%, and for cellulosic biofuels, the reduction must be 60% (U.S. EPA, 2009b). EPA's proposed regulations include global land use when determining carbon dioxide emissions, which makes corn less attractive as a feedstock for ethanol. Conventional corn-based ethanol reduces greenhouse gas emissions by only 16%, which necessitates modifications such as fractionation to comply with the proposed regulation (U.S. EPA, 2009a).

Increasing efficiency of corn-based ethanol production will help mitigate some concerns over competition for corn between food and fuel, reduce carbon emissions released by corn-based ethanol, and allow firms to become more profitable. Dry fractionation is one of many new technologies that can make corn ethanol more efficient and compliant with new regulations.

Alternative Technologies

Traditionally, ethanol from corn has primarily been produced through dry- and wet-milling processes. The majority of U.S. ethanol production is from dry-grind technology (Neely, 2008a). The traditional dry-grind process grinds the whole corn kernel and mixes it with water and enzymes. The mash is then cooked to liquefy the starch further. The mash is then cooled and mixed with more enzymes to convert the remaining sugar polymers to glucose before fermenting to ethanol (Murthy, et al., 2006a). The components of the kernel not fermented include the germ, fiber, and protein, and are concentrated in the DDGS (Murthy, et al., 2006a). While dry milling is less capital intensive, it also yields less ethanol per bushel of corn than wet milling (Rajagopalan, et al., 2005).

Wet milling involves steeping the corn for up to 48 hours to assist in separating the parts of the corn kernel. Processing the slurry separates the germ from the rest of the kernel, which is processed further to separate the fiber, starch, and gluten. The fiber and corn gluten become components of animal feed while the starch is fermented to become ethanol, corn starch, or corn syrup (Renewable Fuels Association, 2005b).

Fractionation is an additional step to traditional dry-grind processes. Research has determined benefits such as increased efficiency and higher value co-products from a change in conventional dry-grind technologies to dry corn fractionation or other modifications to the dry-grind process. These studies analyze how the quantity of ethanol increases, the quantity and quality of DDGS decreases and increases, respectively, and plant profitability increases when adopting this alternative technology.

Dry fractionation involves removal of the germ, fiber, and endosperm from the corn kernel (Murthy, et al., 2006a; Murthy, et al., 2006b). Fractionating before fermenting can

reduce the volume of DDGS, which benefits ethanol producers because the market for the feed will become saturated with increased ethanol production (Murthy, et al., 2006a; Murthy, et al., 2006b). New technologies for dry fractionation prior to dry-grinding have been developed, and can increase the protein level in the DDGS (Martinez-Amezcua, et al., 2007). This benefits producers of non-ruminant animals (Martinez-Amezcua, et al., 2007). Ethanol-production equipment manufacturer ICM calls these higher quality DDGS "Hi-Pro DDGS" because of the increased protein content per ton of dry matter.

Another benefit of dry fractionation is that it can greatly increase biofuel efficiencies. For example, the germ of a corn kernel produces corn oil, which is a potential feedstock for biodiesel, and, as noted above, DDGS production decreases from fractionation (Eidman, 2007). Higher quality (high-protein) DDGS can lead to increased value as hog and poultry feed (Eidman, 2007; Martinez-Amezcua, et. al., 2007; Baker and Babcock, 2008; Otto, 2009), and increases the value of the co-product to animal feed manufacturers. Ethanol producers benefit by adding higher values to the co-products (Baker and Babcock, 2008). While DDGS exports increased in 2005 (Eidman, 2007), larger amounts of DDGS from increased corn-based ethanol production continue to pose a problem for ethanol producers needing to sell the co-product, and exports likely cannot keep up to production. Therefore, dry fractionation, which leads to lower volumes of DDGS, helps ethanol producers by keeping DDGS prices higher.

Rajagopalan, et al. (2005) show that using degermed defibered corn (DDC) (dry-fractionated corn) increases return on investment by about two percent (at 2005 prices) on a hypothetical 40 million gallon per year plant. The additional quantity of ethanol production, as well as higher protein DDGS, more than offsets increased capital costs for

the new technology. The processing design used in the study increased ethanol production by about 11%, thus increasing sales. At the same time, processing costs fell. In addition to DDC, an oil expeller added to the analysis separates the oil from the corn kernel. The oil is useful as food or turned into biodiesel, and the plant gains additional revenue (Rajagopalan, et al., 2005). Increases to earnings before interest, taxes, depreciation, and amortization made dry fractionation a viable alternative to traditional milling.

Protein content of DDGS produced through fractionation increases over that from conventional dry-grind processing (Srinivasan, et al., 2006). After the ethanol process is complete, DDGS can be sifted to separate DDGS from the fiber (Srinivasan, et al., 2006). The elusieve process developed at the University of Illinois at Urbana-Champaign combines sieving and elutriation to separate the fiber from the DDGS. These enhanced DDGS receive higher prices due to increased protein content, thus adding to the economic feasibility of the added step involved in fractionation (Srinivasan, et al., 2006). Using payback period, net present value, and internal rate of return analysis, Srinivasan, et al. (2006) show that the costs associated with increased investment for a sifter and aspirator necessary to separate fiber from DDGS are offset by the increased revenue received for higher quality DDGS. While dry fractionation is not the only technology available for corn ethanol producers to increase efficiency or throughput, it fits a conventional dry-mill plant well, and can form a bridge to cellulosic ethanol (Deutscher, 2009).

Another type of fractionation is recycling of the DDGS produced from conventional dry-grind processes. This is another way to increase overall efficiency for corn-based ethanol producers. After going through the traditional dry-grind process, DDGS' polysaccharides can be hydrolyzed with enzyme treatment. The soluble sugars can then be

fermented with the cornstarch, increasing ethanol production for the plant (Perkis, Tyner, and Dale, 2008). The resulting DDGS, which Perkis, Tyner, and Dale (2008) refer to as eDDGS (enhanced dried distillers' grains with solubles), have a higher feed value than traditional DDGS, in part because increased protein levels allow more product to be fed to swine.

The value of adopting this new technology for an ethanol producer with a nameplate level of 100 million gallons per year is significant because another 12.7 million gallons of ethanol is produced (Perkis, Tyner, and Dale, 2008). While variable costs for enzymes increase with additional output, and liquefaction and saccharification tanks' costs increase because their use does not increase greatly with additional throughput, other costs remain the same (Perkis, Tyner, and Dale, 2008). Hammer milling costs remain the same because the quantity of corn does not change, and in the case of eDDGS, costs fall because drying time falls relative to conventional DDGS (Perkis, Tyner, and Dale, 2008). Capital investment increased 6.9% in the study, but with additional ethanol output, the value per gallon fell $0.07 per gallon from that of a traditional dry-grind plant (using ethanol prices of $2.23 per gallon and corn costs of $3.82 per bushel) (Perkis, Tyner, and Dale, 2008).

While an ethanol producer can benefit from fractionation technology, stressful financial periods may mean a firm is better situated to invest in a cheaper technology until financial conditions improve. Procuring the necessary financing also is difficult during stressful financial times.

Financial Risks

Technological Adoption Risk

Some risks are associated with adoption of new technology. For example, as outlined by Voola (2006) in a study relating to the petroleum industry, it is noted that as oil exploration technology advanced from a two-dimensional seismic method to a more accurate three-dimensional seismic method, costs for oil exploration fell. As the costs fell, the number of firms producing the new technology increased. This caused more firms to purchase the technology. When more petroleum companies owned the technology, competition among them increased, which caused profits to decline. In the wake of lower profits, petroleum firms merged (Exxon-Mobil, BP-Amoco, Chevron-Texaco, and Royal-Dutch Shell) to become larger relative to their competitors and become more aggressive in their exploration (Voola, 2006). The same could happen in the ethanol industry as more firms adopt technologies such as fractionation to become more profitable.

Nonetheless, adopting new technology helps firms remain profitable. Hochman, Sexton, and Zilberman (2008) show that a shift in ethanol production from corn to other biomass can lessen price volatility for ethanol producers and reduce the chance of bankruptcy.

High energy and crop prices and increased volatility in corn and ethanol markets occurred in 2007 and 2008. Ethanol production mandates increased the cost of staple food crops, especially corn, which further links volatile food prices to volatile energy prices (Hochman, Sexton, and Zilberman, 2008). Volatility of input and output prices creates a difficult situation for ethanol producers trying to remain profitable. Firms use various hedging methods to "lock in" prices for inputs and outputs to reduce volatility of returns

(Hochman, Sexton, and Zilberman, 2008). The partial equilibrium model developed by Hochman, Sexton, and Zilberman (2008) graphically shows that increases in ethanol mandates increase demand for food staple crops, which then increase food prices. While the degree to which ethanol production affects food prices is unclear, some relationship does exist (Hochman, Sexton, and Zilberman, 2008).

Switching from growing corn to other biomass on marginally productive land will lessen the need for intensive agricultural land use to produce food and fuel. Dry corn fractionation is a step toward lessening the demand for corn by increasing ethanol plant throughput. Technical innovation in ethanol production can reduce the intensive use of land to produce both food and fuel, and along with agricultural biotechnology, will allow famers and ethanol producers to make better use of land when producing feedstocks for biofuels, whether the crop is corn or some other biomass (Hochman, Sexton, and Zilberman, 2008).

Risk-Return Tradeoffs

In addition to the aforementioned financial risk, a firm's risk-return tradeoff is important to analyze its willingness to invest in technology. A common assumption is that they will maximize returns or utility, but that they are risk averse. Over time, a firm or individual will attempt to maximize utility subject to the constraint of given technology (Engler-Palma and Hoag, 2007). Engler-Palma and Hoag (2007) model the value of the technology investment, in the future, as dependent on its present value, a portion of the present value earned over the period, a market discount factor, and a stochastic component of net income. The authors model utility maximization as a function of technology's present value, known present value earnings (revenue stability), and firm risk level. In

their analysis, they separate stability, stability and risk, and risk aversion to determine each one's effect on utility. The level of utility gained by a decision maker largely depends on their level of risk aversion, their desired level of stability, and the payoff to investments (Engler-Palma and Hoag, 2007). Considering stochastic and deterministic components helps determine the optimal level of utility maximization. Fluctuating cash flows (income) over time change the utility maximizing level, isoutility curve, and the decision maker's risk perceptions.

However, a firm's utility is not always determinable. When utility is unknown, analysis of the risk-return tradeoff determines actual returns for a specific level of risk. The "expected value-variance of returns" (E-V) rule illustrates the trade-off. Markowitz (1952) indicated that investors, or firms, do not always attempt to be profit maximizers because simply maximizing profits does not consider the risk of the investment. Assuming investors diversify to reduce risk, an increase in returns alone will not satisfy a risk adverse investor. Therefore, using the E-V hypothesis helps show how firms are willing to accept a return based on a certain level of risk aversion. E-V analysis has been used extensively to determine risk-return tradeoffs among agribusiness and non-agribusiness firms. Disadvantages to this approach are assumptions made about the data's distributions, the shape of a firm's utility function, normal wealth distribution, and the lack of the use of risk aversion coefficients (Lambert and McCarl, 1985). Including risk aversion and varying levels of wealth, assuming quasi-concave utility functions, provides a more accurate representation of a firm's willingness to invest in a new project subject to its ability to tolerate risk (Lambert and McCarl, 1985).

Risk Aversion

Other research determined the desirability of maximizing utility subject to a level of risk aversion. Risk aversion coefficients differ depending on a relative level of risk aversion or an absolute level of risk aversion. A relative risk aversion coefficient (RRAC) depends on a decision maker's level of wealth and willingness to accept risk for some payoff. The level of risk aversion will change for a decision maker when the level of wealth changes. The certainty equivalent model developed in Chapter 3 contains an ARAC rather than a RRAC.

Absolute risk aversion coefficients depend on a decision maker's utility of wealth. Pratt's coefficient of risk aversion is a function of the utility function of wealth specified as: $r(W) = -U''(W)/U'(W)$; where $U(W)$ is the utility of wealth, W is the level of wealth, and $U'(W)$ and $U''(W)$ are first and second derivatives, respectively, of $U(W)$ with respect to W, the level of wealth (McCarl and Bessler, 1989). Pratt also developed a model to relate a risk premium to an asset's risk (defined by the variance) and risk aversion (McCarl and Bessler, 1989). McCarl and Bessler (1989) use Pratt's risk aversion foundation to determine the upper bound of risk aversion when utility is unknown. Instead, they develop bounds for risk aversion with a variety of methods.

One of their methods establishes upper bounds on risk aversion by including the standard deviation of expected returns in their calculations, indicating the necessity of including expected returns' volatility when assuming risk aversion. For instance, a confidence interval method assumes the maximum relative risk aversion coefficient is two times the number of standard deviations from the mean, divided by the standard deviation

(McCarl and Bessler, 1989). The number of standard deviations used in the formula establishes the confidence interval.

Average wealth for multiple scenarios can determine the range of ARACs. Subjectivity still helps assume a range of ARACs beginning with zero, indicating risk-neutral and including higher values that indicate greater levels of risk aversion. Lender constraints also affect risk aversion by placing restrictions on a firm's ability to borrow or maintain adequate cash flow.

Cash Flow Sweeps

Cash flow sweeps increase long-run ethanol plant profitability. Tiffany and Eidman (2004) indicate an increase in net income of over two million dollars per year when estimating profits for a hypothetical 40 million gallon per year plant. With lender-imposed sweeps, debt obligations were paid in full in seven to eight years rather than ten years specified in the loan terms (Tiffany and Eidman, 2004). Borrower risk varies among firm types and loan types, so lenders impose loan covenants to compensate for these differing levels of risk (Ackert, Huang, and Ramirez, 2007). Lenders use a different loan pricing method for private versus public firms due largely to the lack of information from private firms (Ackert, Huang, and Ramirez, 2007). For private firms with asymmetric information, lenders are more likely to impose sweeps and require collateral than for public firms who have multiple lenders and whose credit rating is typically higher (Ackert, Huang, and Ramirez, 2007). Sweeps can help mitigate risk for both the lender and borrower while increasing profits in the long run.

Summary

Previous research indicates that alternative technologies enable a firm to increase efficiency and remain profitable in the face of competition. However, risks of adopting technology and staying competitive and profitable face firms in different ways. Each firm must evaluate its own level of risk and the returns it is willing to take depending on that risk. Many methods that exist for a firm to evaluate its risk-return tradeoff and its ability to invest in new technology have been applied in previous research. However, no single method is viewed to be the best. Too many factors affect businesses on specific levels to assume one method fits all situations. Chapter 3 will present a conceptual framework around which an ethanol-producing firm can estimate profits and its ability to maintain sufficient equity to invest in new technology when lenders impose sweeps on extra cash flow to reduce their own risk.

CHAPTER 3. THEORETICAL MODEL

Ethanol producers are subject to profitability problems due to volatile input costs and output prices and changes in both technology and government policy. In times of low profits, the reduced cash flow can create difficulties for a firm trying to meet financial debts. Investment in alternative technologies also becomes difficult to finance under these conditions because of increased risk to lenders. The firm carries a level of risk aversion that affects decision-making regarding new investment. Variance of returns on assets is an important consideration because volatility can affect a firm's decision to invest in new technology. Lenders will also be less willing to finance new investment when repayment becomes more uncertain.

This chapter will develop a conceptual model to help determine optimal levels of debt and equity for an ethanol producer intending on making an investment in new technology, subject to lender's sweep constraints and the firm's risk aversion.

Theoretical Model

Assuming ethanol producers are profit maximizers, their decision can be modeled as a profit-maximizing function of the form:

$$\Delta E = R(y) - C(y) - B \tag{1}$$

where ΔE is change in equity, or profit, $R(y)$ and $C(y)$ are total revenue and variable cost, respectively, y is output quantity, and B is fixed costs.

To make this equation more specific to a traditional corn-ethanol producer, the output quantities can be specified as y_e for ethanol and y_d for DDGS. Important input quantities can be specified as x_c for corn, x_E for energy, and x_m for miscellaneous expenses. Output prices can be specified as p_e for ethanol and p_d for DDGS. Input costs can be

specified as w_c for corn, w_E for energy, and w_m for miscellaneous expenses. Fixed costs will be depreciation and other capital expenses. Then, the model expands to:

$$\Delta E = (p_e)(y_e) + (p_d)(y_d) - (w_c)(x_c) - (w_E)(x_E) - (w_m)(x_m) - B \quad (2)$$

Next, looking at an ethanol plant using dry fractionation, there are three primary sources of revenue: ethanol, high-protein DDGS, and corn germ. Expanding Equation (2) shows the firm's new profit function with additional revenue sources. Costs for corn, energy, and miscellaneous expenses also increase, but will adjust with changes in production.

$$\Delta E = (p_e)(y_e) + (p_{hd})(y_{hd}) + (p_{cg})(y_{cg}) - (w_c)(x_c) - (w_E)(x_E) - (w_m)(x_m) - B \quad (3)$$

where the total revenue portion of the profit function for this type of firm contains $(p_e)(y_e)$ for ethanol, $(p_{hd})(y_{hd})$ for hi-pro DDGS, and $(p_{cg})(y_{cg})$ for corn germ, with prices p and quantities y. Total costs for corn, energy, and miscellaneous expenses are $(w_c)(x_c)$, $(w_E)(x_E)$, and $(w_m)(x_m)$, respectively, where w is the cost of the input and x is quantity of the input. Fixed costs are still depreciation and other capital expenses such as interest on borrowed capital.

This paper's purpose is to analyze a firm's ability to invest in dry fractionation technology subject to debt, lender constraints, and risk. Therefore, profit is considered not only as a function of revenue and costs, but as the change in investment too. Investment is a function of the firm's cash flow and equity—the portion of the business owned by the firm. The model also includes the firm's risk aversion coefficient and variance of returns because these are important considerations for a firm. A certainty equivalent model will help accomplish this.

A certainty equivalent is the amount a decision maker will accept that makes him or her indifferent between taking risk and taking a certain payment (Hardaker, et al., 2004). Certainty equivalence can help evaluate a risk taker's willingness or unwillingness to assume risk based on a personal level of risk aversion and a certain payment. Using a range of risk aversion coefficients with estimated certainty equivalents helps analyze how investors' preferences change among alternatives—in this case choosing whether to invest in new technology (Wilson, Gustafson, and Dahl, 2006). The risk aversion measures can be used to rank a firm's willingness to invest given a certainty equivalent (Wilson, Gustafson, and Dahl, 2006).

Risk aversion coefficients can be negative or positive where negative indicates the firm is risk preferring and positive indicates the firm is risk averse. A common assumption is that risk aversion coefficients are in the range $0 \leq r(W) \leq +\infty$, because firms are either risk-neutral or risk averse, but rarely risk preferring except in extreme cases of high profits corresponding with a minimal amount of risk (McCarl and Bessler, 1989; Hardaker, et al., 2004; Wilson, Gustafson, and Dahl, 2006).

Assuming a firm will maximize profits subject to risk and variance, a certainty equivalent model can show how a decision maker maximizes expected utility of profits with an optimal level of debt. Start with a profit maximizing equation under uncertainty with debt and equity (modeled after Robison and Barry, (1987)).

$$\max y_{CE} = E(E_0 + \Delta E) - \frac{\lambda}{2}\sigma^2(E_0 + \Delta E) \tag{4a}$$

where $E(\cdot)$ is the expected value operand,
max y_{CE} is the maximization of equity in certainty equivalent terms,
E_0 is beginning equity,
ΔE is net profit earned during the period
$\frac{\lambda}{2}$ is the risk aversion measure, and

σ^2 is variance of returns.

Next, add the new plant investment to the base model. Here, it is assumed that because assets = debt + equity, equity = asset (I_0) – debt (D_I).

$$\max y_{CE} = E(E_0 + \Delta E + I_0 - D_I) - \frac{\lambda}{2}\sigma^2(E_0 + \Delta E + I_0 - D_I) \tag{4b}$$

where I_0 is new investment (assumed to be constant), and D_I is debt on new investment. Equation (4b) also can be stated as:

$$\max y_{CE} = E(E_1) - \frac{\lambda}{2}\sigma^2(E_1) \tag{4c}$$

where E_1 is ending equity.

To determine ending equity, E_I, from Equation (4c), including the new investment from Equation (4b), form Equation (5) with equity, debt, and new technological investment.

$$E(E_1) = r(D_0 + E_0) - i_D D_0 + E_0 + I_0 + r_I - i_I D_I \tag{5}$$

where $E_1 = E_0 + \Delta E + I_0 - D_I$,
$r(D_0 + E_0)$ is return on assets ($A_0 = D_0 + E_0$),
D_0 is beginning debt,
$i_D D_0$ is cost of beginning debt,
E_0 is beginning equity,
I_0 is investment in new technology,
r_I is return on investment, I, and
$i_I D_I$ is cost of debt on new investment, I.

Variance of ending equity is

$$\sigma^2(E_I) = \sigma_r^2(D_0 + E_0)^2 \tag{6}$$

The new certainty equivalent model becomes:

$$\max y_{CE} = r(D_0 + E_0) - iD_0 + E_0 + I_0 + r_I - i_I D_I - \frac{\lambda}{2}\sigma_r^2(D_0 + E_0)^2 \tag{7}$$

The cash flow constraint model, or sweep model (after Robison and Barry, (1987)) follows. Start with the firm's change in equity, defined as:

$$\Delta E(\varepsilon) = (r_D - \varepsilon - i_D)D_0 + r_E E_0 + r_I I_0 - (i_I + \varepsilon)D_I \quad (8)$$

where $r_D, r_E, and\ r_I$ are returns on *D, E,* and *I*, respectively;
ε is the percentage value of debt that must be repaid from "excess cash flow" in high-profit years;
$i_D,\ and\ i_I$ are the costs of borrowing for *D* and *I*, respectively; and
other variables are defined as above.

Of interest to this study, is to determine the amount of *excess* cash flow that will cause the sweep to take effect, and then to determine how the sweep's effect on residual cash flows affects the firm's ability to make new technological investments. The probability that the sweep will be implemented depends on profits. The profit maximization model under the cash flow constraint begins with the following: if $E_1 = E_0 + \Delta E(\varepsilon_0)$; then $E_1 = E_0 + [(r_D - \varepsilon_0 - i_D)D_0 + r_E E_0 + r_I I_0 - (i_I + \varepsilon_0)D_I]$. Therefore, the firm's certainty equivalent maximization model subject to the sweep constraint is:

$$\max y_{CE} = E(E_1) - \frac{\lambda}{2}\sigma^2(E_1) \quad (9)$$

$$\max y_{CE}(\varepsilon_0) = E_o + (r_D - \varepsilon_0 - i_D)D_0 + r_E E_0 + r_I I_0 - (i_I + \varepsilon_0)D_I - \frac{\lambda}{2}\sigma_r^2(D_0 + E_0)^2 \quad (10a)$$

First order conditions will help determine the firm's optimal debt level, given the sweep constraint. Here, first order conditions can show how a change in profit, interest rates, rates of return, or the sweep percentage will affect a firm's optimal debt level, equity, ability to make technological investments, or its willingness to take risk. For example, the first derivative of the certainty equivalent model with respect to debt will show how the return to debt, sweep constraint percentage, interest rate on debt, and risk aversion will affect profits. Equations (10b) through (10e) show the first derivatives of the certainty equivalent model with respect to beginning debt, beginning equity, investment, and

investment debt. These show how profit is affected if the firm desires to increase or decrease debt, equity, or new investments.

Equation (10b) indicates how an increase (decrease) in a firm's debt increases (decreases) firm profits, here the certainty equivalent, by the percentage return on debt plus the sweep, then less the interest rate paid on debt. It also shows that risk aversion and variance will decrease a firm's willingness to take on more debt.

$$dy_{CE}/_{dD_0} = (r_D - \varepsilon_0 - i_D) - \lambda\sigma_r^2(D_0 + E_0) = 0 \tag{10b}$$

Equation (10c) shows that an increase in equity would raise profits by one plus the percentage return on the firm's equity, but that the level of risk aversion and variance of return to assets will negatively affect profits.

$$dy_{CE}/_{dE_0} = 1 + r_E - \lambda\sigma_r^2(D_0 + E_0) = 0 \tag{10c}$$

Equation (10d) shows that a firm considering investing in new technology makes the decision, at least in part, based on the return to the investment. A positive return on investment will increase the firm's certainty equivalent amount.

$$dy_{CE}/_{dI_0} = r_I = 0 \tag{10d}$$

Equation (10e) indicates how a firm's profit falls by incurring additional debt from new investment by the percentage amount of interest on the investment debt and the sweep amount. Alternatively, if debt decreases, the firm's profit will increase by these percentages. Equation (10e) also shows that the sweep and interest rate on new debt have an inverse relationship.

$$dy_{CE}/_{dD_I} = -i_I - \varepsilon_0 = 0 \tag{10e}$$

Next, isolate debt to determine how optimal debt depends on return to debt and assets ($A_0 = D_0 + E_0$), interest costs on debt, risk aversion, variance, equity, and the sweep. From Equation (10b) debt can be defined as:

$$D_0 = \left\{ {(r_D - \varepsilon_0 - i_D)}/{\lambda\sigma_r^2} \right\} - E_0 \tag{11}$$

Differentiating Equation (11) with respect to ε_0 will show how the sweep affects debt. Equation (12a) shows that incremental increases in the sweep would increase the amount of debt

$$dD_0/d\varepsilon_0 = 1/\lambda\sigma_r^2 - \frac{(r_D - \varepsilon_0 - i_D)(\partial\lambda/\partial\varepsilon_0)}{\lambda^2\sigma_r^2} \tag{12a}$$

If $\left(\frac{\partial\lambda}{\partial\varepsilon_0}\right) < 0$, then for a firm whose aversion to risk is less than zero, the second part of Equation (12a) is positive, thus indicating a firm's willingness to take on more debt if the sweep constraint increases. For a decision maker who has a positive risk aversion, $\left(\frac{\partial\lambda}{\partial\varepsilon_0}\right) > 0$, and the firm would assume less debt when the sweep constraint increases. Similarly, differentiating Equation (11) with respect to r_D and i_D will show how, when a firm's aversion to risk is low, higher returns will induce the firm to take on more debt, but high aversion to risk will not necessarily cause a firm to assume more debt. Increasing interest rates will cause a firm to reduce debt, since the right-hand side of Equation (12c) will be negative.

$$dD_0/dr_D = 1/\lambda\sigma_r^2 - \frac{(r_D - \varepsilon_0 - i_D)(\partial\lambda/\partial r_D)}{\lambda^2\sigma_r^2} \tag{12b}$$

$$dD_0/di_D = -1/\lambda\sigma_r^2 - \frac{(r_D - \varepsilon_0 - i_D)(\partial\lambda/\partial i_D)}{\lambda^2\sigma_r^2} \tag{12c}$$

Finally, differentiating debt with respect to equity will show how a change in equity affects a decision maker's willingness to assume more debt. From Equation (11),

$$dD_0/dE_0 = -\frac{(r_D-\varepsilon_0-i_D)(\partial\lambda/\partial E_0)}{\lambda^2\sigma_r^2} - 1 \tag{12d}$$

Equation (12d) shows that an increase in equity will cause a smaller decrease in debt if $\left(\frac{\partial\lambda}{\partial E_0}\right) < 0$, and equal size decrease in debt if $\left(\frac{\partial\lambda}{\partial \varepsilon_0}\right) = 0$, and a larger decrease in debt if $\left(\frac{\partial\lambda}{\partial \varepsilon_0}\right) > 0$ because the firm is risk averse.

Isolating E_0 will help determine the effect of interest, return on equity, risk aversion, and variance on beginning equity. From Equation (10c), equity can be defined as:

$$E_0 = \left\{(1 + r_E)/\lambda\sigma_r^2\right\} - D_0 \tag{13}$$

To determine the effect of return on equity on beginning equity, take the derivative of Equation (13) with respect to r_E.

$$dE_0/dr_E = 1/\lambda\sigma_r^2 - \frac{(1+r_E)(\partial\lambda/\partial r_E)}{\lambda^2\sigma_r^2} \tag{14}$$

This helps show that if return on equity is negative, a firm's equity will decrease, and if the risk aversion coefficient is high, the firm would be less willing to accept this than if they are indifferent to risk.

Summary

A certainty equivalent model will estimate the impact of risk and lender constraints on an ethanol producer's profits and ability to maintain adequate equity to invest in new technology. The derivations for debt and equity show that regardless of the other

parameters under evaluation, risk aversion is included as an important consideration when determining optimal debt and equity levels. Chapter 4 will develop an empirical profit model to study the effects of a sweep and risk aversion on an ethanol plant's ability to maintain cash flow for additional investment.

CHAPTER 4. DATA AND EMPIRICAL METHOD

The certainty equivalent model developed in Chapter 3 will show whether a firm is able to invest in new technology subject to a given level of risk. Before estimating the certainty equivalent, an MS Excel-based profit model estimates ethanol plant profitability. This study's purpose is to determine an ethanol producer's ability to invest in technology (dry fractionation) subject to lender constraints. An assumption used in the model is that lenders require a firm to have at least 40% equity on hand before qualifying for construction loans or loans for additional investment (Tiffany and Eidman, 2004). The primary source of equity for an existing firm is its residual cash flows. Therefore, the profit model computes residual cash flows for a conventional dry mill plant during the first five years' production, subject to a sweep. This determines if the firm has adequate equity available to make a down payment on new investment in dry fractionation.

Chapter Four will present the data used in this study followed by the empirical method developed to predict an ethanol firm's ability to invest in new technology subject to lender constraints and risk, and conclude with the variables' probability distributions.

Data

As explained in Chapter 3, an ethanol producer's profits are a function of revenues less variable and fixed costs. Sources of revenue for a dry mill ethanol plant using dry fractionation are ethanol, DDGS, hi-pro DDGS, and corn germ. Corn comprises the largest cost to ethanol producers. Data for all other miscellaneous costs are explained below. Fixed costs are depreciation, amortization, and other capital expenditures. They are determined from assumed construction costs. Data sources and descriptions for these

components of profit follow. Figures 2 and 3 are historical price graphs for ethanol, corn, DDGS, and corn germ.

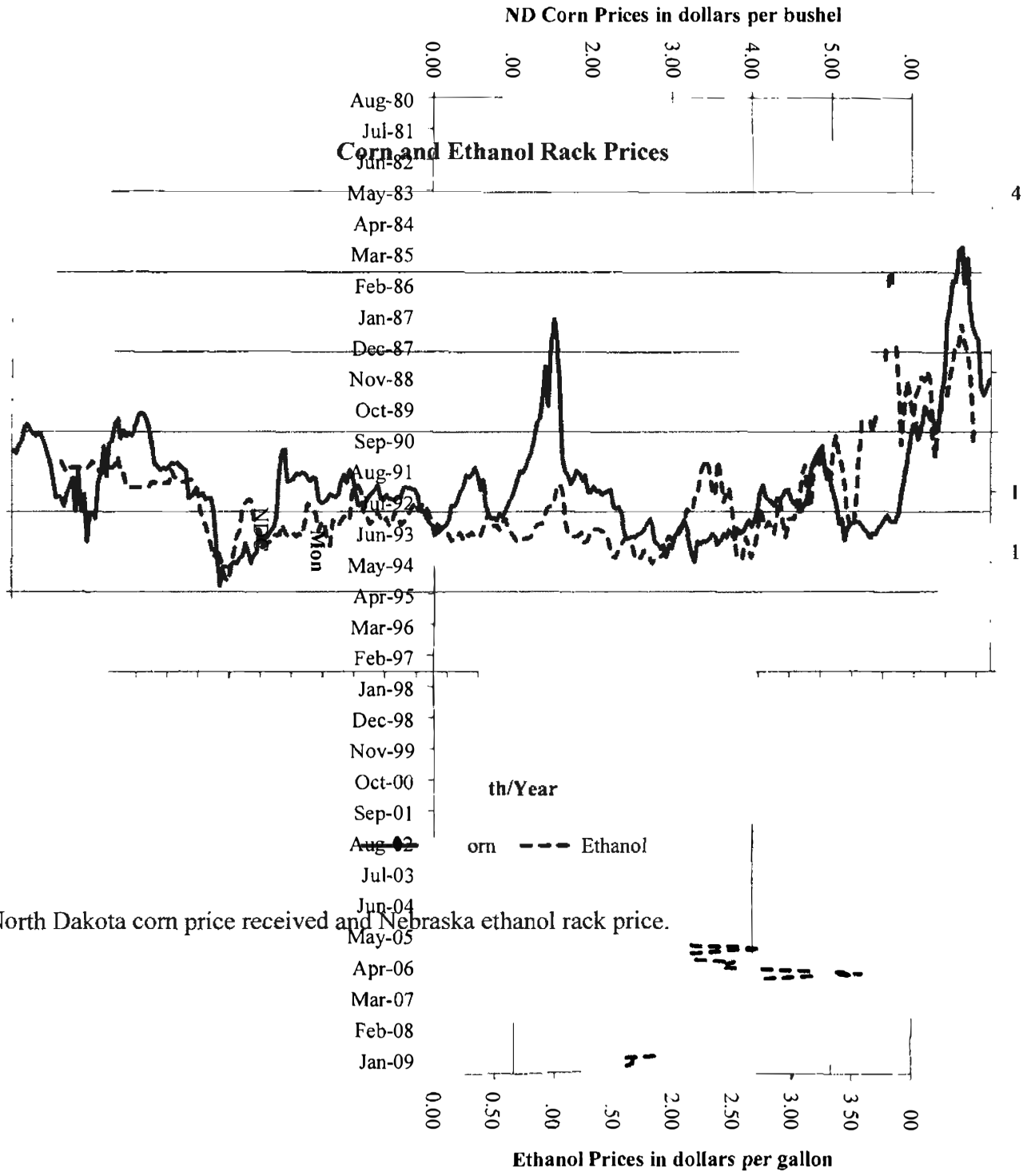
Ethanol

The Nebraska Energy Office provides average monthly rack prices for unleaded gasoline and ethanol, F.O.B. Omaha from January 1982 to January 2009 (Nebraska Ethanol Board, 2009). This price series is used to estimate ethanol price as a share of revenue.

DDGS and Hi-Pro DDGS

DDGS prices vary by plant because the product is sometimes fed to local, or nearby livestock facilities. Most of the DDGS are not sold locally and shipped to other areas in or out of the U.S., but each plant markets its own product. The longest-running monthly series available through USDA's Economic Research Service Feed Grains Database (2009) is the monthly wholesale price at Lawrenceburg, IN, which begins in September 1981 and continues through December 2008. These prices are for traditional DDGS, not high-protein DDGS, which may have a higher value to swine or poultry producers because of increased feed value. Because dry fractionation technology to produce high-protein DDGS is not widely used, no established market prices exist. However, the product's value can be determined based on its feed value.

Important nutrients for cattle, swine, or poultry are protein, calcium, total fat, and phosphorus. Analyzing the feed value of enhanced, or non-traditional, DDGS shows the increased amount of protein makes the feed more suitable for swine. Increasing the value of DDGS can cause the price for non-traditional DDGS to be 2.11% higher than that of traditional DDGS (Fabiosa, 2008). For simplicity, hi-pro DDGS are valued 2.11% higher than traditional DDGS when performing revenue calculations.



2. North Dakota corn price received and Nebraska ethanol rack price.

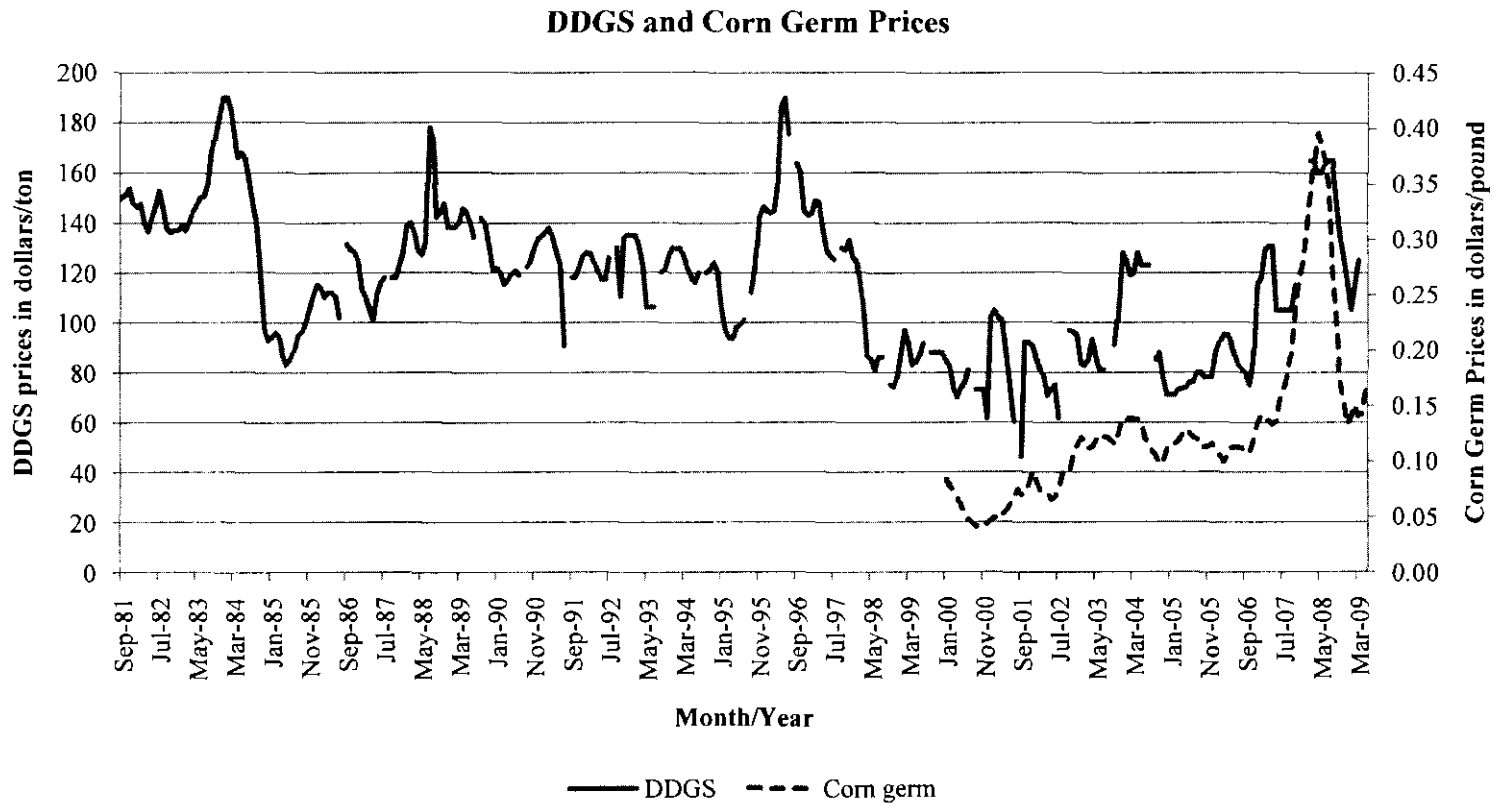


Figure 3. DDGS wholesale prices and corn germ price.

Corn Germ

Corn germ is another revenue source for an ethanol producer employing dry fractionation. Because corn germ prices are not available, the value is estimated from the value of its two primary products: corn oil and corn gluten feed. Corn oil is primarily used as cooking oil and it is useful as a feedstock for biodiesel plants. Corn gluten feed is a livestock feed produced from corn germ separation. Monthly prices for crude corn oil in dollars per hundredweight and corn gluten feed in dollars per ton beginning in January 2000 are available from USDA's Agricultural Marketing Service Livestock and Grain Market News (2009). The formula used to determine corn germ prices is developed later in the paper.

Corn

North Dakota monthly yellow #2 corn prices available from NASS are the average prices received by farmers (USDA, NASS, 2009). Ethanol producers will pay competitive prices for corn to secure adequate inputs for their plants. This study uses values from August 1980 to January 2009 because ethanol prices are only available from the early 1980s.

However, using very long historical price data series may not always provide accurate price projections. Recent increases in corn prices and corn price volatility may cause correlations among other products' prices to differ greatly from historical price correlations. In addition, recent price activity may be a better indication of future price activity. For instance, prices North Dakota farmers received for corn fell to nearly $1.00 per bushel on multiple occasions in the past, but have not been at that level for over 20 years. In addition, ethanol prices are low relative to corn prices in the recent past. To

reflect this as it relates to present-day ethanol producers, the means of the price distributions are adjusted to estimate ethanol profits under current price situations. While keeping the same distribution for each variable, the means of each distribution shift up or down to match most recent market observations. For example, the most recent price for corn is $3.65 per bushel while the total series indicates a mean price of $2.34 per bushel, and for ethanol, the most recent price is $1.70 per gallon versus a mean of $1.46 for the total series. The mean for each respective price distribution changes to these values while the distributions' scale, location, and shape parameters remain the same. Tables 2 and 3 indicate the calculated and "forced" mean prices, respectively.

Table 2. Descriptive Statistics and Probability Distributions

	Total-Year Series			5-Year Series		
Variable	Mean	Std. Dev.	Distribution	Mean	Std. Dev.	Distribution
ND Corn Price ($/bu)	2.35	0.70	Log-Logistic	2.87	1.07	Log-Normal
Ethanol Price ($/gal)	1.46	0.45	Log-Logistic	2.12	0.503	Weibull
Traditional DDGS ($/ton)	116.68	28.57	Weibull	107.48	28.72	Pearson 5
Hi-Pro DDGS ($/ton)	119.14	29.18	Weibull	109.74	29.32	Pearson 5
Corn Germ ($/lb.)	0.13	0.075	Log-Logistic	0.16	0.080	Log-Logistic

Table 3. Last Period Observation for Input Variables

Variable	"Forced Mean"
ND Corn Price ($/bu)	3.65
Ethanol Price ($/gal)	1.60

Because price volatility and correlations are different using a shorter time series, an analysis using the most recent five years' observations is included. In addition, mean values for corn and ethanol are adjusted to reflect the most recent observations--$3.65/bushel for corn and $1.70/gallon for ethanol.

Miscellaneous Variable Costs

Miscellaneous costs are adapted from Perrin, Fretes, and Sesmero (2008). Their study is used to calibrate the empirical model that is being developed to test the theoretical constructs presented in Chapter 3. The study surveyed corn ethanol plant revenues and costs for seven operating plants in the Midwest with an average operating capacity of 53.1 million gallons. An advantage of using these survey data over information found in other studies is that it provides known rather than estimated or engineered costs prepared by previous authors or industry construction firms. The study's data represent ethanol producers in Iowa, Michigan, Missouri, Nebraska, South Dakota, and Wisconsin. However, costs will still vary among plants in different geographic areas due to variations in transportation or costs of living (in the case of labor). Perkis, Tyner, and Dale (2008) also used costs from survey data when estimating ethanol plant profitability.

The total series includes all observed values (as listed above) for each revenue or cost contributor. The five-year data series is used to estimate revenue and cost, but include price volatility and correlations associated with the recent past.

Cross-variable Relationships

Correlations among variables are important to ensure a simulation's random draws include cross-variable relationships in the model (Wilson, Gustafson, and Dahl, 2006). A correlation matrix of related variables corn, ethanol, hi-pro DDGS, and corn germ is included in the model. @Risk creates a correlation matrix based on the input data available—historical prices for corn, ethanol, DDGS, hi-pro DDGS, and corn germ—and incorporates the matrix into the model's probability density functions when making the prices' random draws. Variables' correlations across time are included as well to ensure

that outside factors' (e.g. supply and demand) effects on one variable in a certain year are included on the other variables. Table 4 is a correlation matrix for the variables used in the model.

Table 4. Cross Variable Relationships

		Ethanol	DDGS	Hi-Pro DDGS	Corn	Corn Germ
Total-Year Series	Ethanol	1				
	DDGS	0.0570	1			
	Hi-pro DDGS	0.0570	1	1		
	Corn	0.4680	0.5480	0.5480	1	
	Corn Germ	0.5355	0.8032	0.8032	0.8506	1
Five-Year Series	Ethanol	1				
	DDGS	0.2732	1			
	Hi-pro DDGS	0.2732	1	1		
	Corn	0.2539	0.8826	0.8826	1	
	Corn Germ	0.3253	0.7998	0.7998	0.7952	1

Positive correlations exist among all variables because each is produced from corn. Corn, DDGS, and corn germ, each being important components in livestock feed, exhibit very high correlation. Ethanol's correlations among the other variables are not as high in part, because ethanol price is dependent on the price of gasoline.

The longest data series' observations exhibit the lowest correlations between DDGS and ethanol. This is likely due to DDGS' use only as a feed product, and over time, the demand for feed products does not follow energy markets precisely, and vice versa. The higher correlation between DDGS and ethanol in the five-year series indicates the DDGS and ethanol markets follow each other more closely as supply of both products increased dramatically.

The shorter data series' observations indicate the lowest correlations between corn and ethanol. Recent years' energy price volatility caused ethanol prices to vary differently than corn prices, although both exhibited increased volatility in recent years.

Ethanol Plant Risk Estimation

This section discusses the profit model and price distributions.

Revenue and Cost Calculations

The empirical model utilized in this study is based on a 100-mgy conventional dry mill ethanol plant. Plant construction costs are estimated at $1.80/gallon of nameplate capacity (Farmdoc; Perrin, et al., 2008). Plant revenues on a per gallon basis from both ethanol and DDGS co-products are determined by multiplying production by the prices estimated in the distributions above. Ethanol's contribution to plant revenue is the ethanol rack price multiplied by the quantity in gallons. The following formula calculates DDGS's contribution to plant revenues on a per gallon basis.

$$R_{DDGS} = (P_{DDGS})(18) \div (2000)(2.8) \tag{15}$$

where R_{DDGS} is DDGS revenue in dollars per gallon, P_{DDGS} is DDGS price in dollars per ton, 18 is the number of pounds of DDGS per bushel of corn produced during conventional dry mill ethanol production, 2000 is number of pounds per ton, and 2.8 is the number of gallons of ethanol produced per bushel of corn (Board of Trade of the City of Chicago).

Similar to the calculation for ethanol's contribution to plant revenue, corn cost is determined by multiplying the number of corn bushels needed to produce a gallon of ethanol by the distribution function determined with @Risk software. Corn cost is estimated from the price distribution for North Dakota corn prices to inject variability in the model.

Miscellaneous operating costs for the plant are assumed from Perrin, Fretes, and Sesmero (2008). Their survey of seven plants averages variable input costs from each plant and reports the costs on a per gallon basis. Miscellaneous costs include electricity, natural gas, a denaturant, enzymes, labor and management, maintenance, and miscellaneous expenses. After fractionation, the cost of natural gas decreases because the quantity of DDGS that needs drying decreases. An assumption is that natural gas consumption falls by half. Other costs per gallon are assumed constant.

Capital (fixed) costs are depreciation and interest on debt. Straight-line deprecation for 15 years of useful life and no salvage value is assumed (Farmdoc; Ag Decision Maker; Tiffany and Eidman, 2004). Construction costs for an ethanol plant are financed with a variable rate loan at LIBOR plus 450 to 500 basis points (Aberle, April 2009). Tiffany and Eidman (2004) also note many lenders link their rates to LIBOR. An annual fixed interest rate of 6% on the construction loan and loan for new investment is assumed.

This study assumes an investment in corn fractionation technology can occur at any time after five years of initial construction to assure the plant is operational and attained financial stability.

ICM, an ethanol equipment manufacturer, prices their dry fractionation equipment at nearly $72 million including the fractionation plant, steam dryer, and bran/syrup combustor (Scharping, personal communication, July 2008). Previous research indicates dry fractionation increases a firm's total ethanol production throughput about 11% (Rajagopalan, et al., 2005). ICM estimates an 18% increase in ethanol production (Scharping, personal communication, July 2008). Ethanol production per bushel of corn declines, but total throughput increases, thus increasing the quantity of corn required for

both studies. The reason throughput increases is because the amount of material fermented in each bushel is reduced. Therefore, fermentation time decreases and the plant can process more corn in the same amount of time. Rajagopalan, et al. (2005) found ethanol production per bushel of corn to be 2.1 or 2.63 gallons per bushel, depending on the fractionation equipment. ICM's spreadsheet estimates 2.67 gallons per bushel (Scharping, personal communication, July 2008). This paper will assume production of 2.7 gallons of ethanol per bushel of corn after dry fractionation.

At the same time, production of DDGS will decrease. Rajagopalan, et al. (2005) found that DDGS yield fell from 18.1 to 10 or 11 pounds per bushel of corn (depending on the fractionation equipment) after dry fractionation, due to the decrease in the amount of fiber and germ, but that protein levels increase. A sample dry fractionation profitability spreadsheet from ICM estimates the yield of Hi-Protein DDGS to be 6.6 pounds per bushel of corn (Scharping, personal communication, July 2008). Equation (16) shows modifications to Equation (15) to reflect dry fractionation's contribution to ethanol profits on a per gallon basis assuming 11 pounds of Hi-Pro DDGs per bushel of corn.

$$R_{HDDGS} = (P_{HDDGS})(11) \div (2000)(2.7) \tag{16}$$

where R_{HDDGS} is revenue in dollars per ton, P_{HDDGS} is the Hi-Protein DDGS price in dollars per ton, 11 is the pounds of Hi-Protein DDGS produced per bushel of corn, 2000 is pounds per ton, and 2.7 is the gallons of ethanol produced per bushel of corn.

Another primary revenue source for an ethanol producer employing fractionation is corn germ. Corn germ can be processed into corn oil and corn gluten feed. For a dry mill ethanol producer employing dry fractionation technology, processing the germ may or may not be economically viable. ICM's processing method removes the germ from the corn

kernel and uses the germ as a revenue source. Their sample spreadsheet estimates fractionating the corn produces 4.5 pounds of germ per bushel of corn (Scharping, personal communication, July 2008). Rajagopalan, et al. (2005), modeling different fractionation equipment produced 4.7 and 5.36 pounds of germ per corn bushel. They also estimated ethanol profits for a hypothetical ethanol plant with a corn oil extraction process and determined earnings before interest, taxes, depreciation, and amortization (EBITDA) and return on investment (ROI) were higher than for a plant selling unprocessed corn germ. Here, 4.5 pounds of germ per corn bushel from a dry fractionation plant is assumed. Under conventional processing, 18 pounds of DDGS are produced from a bushel of corn. For the purposes of this study, 11 pounds of high-protein DDGS and 4.5 pounds of germ are produced. The remaining 2.5 pounds per bushel is the bran, which is combusted and saves natural gas expense.

Dry fractionation does not efficiently remove the germ from the corn kernel because it also removes some starch and bran (Johnston, et al., 2005; Murthy, et al., 2006b). Enzymatic removal of the germ nearly doubles the amount of actual germ for sale by a corn processor and increases the value because less endosperm and fiber is present (Johnston, et al., 2005). Enzymatic germ removal yields approximately 6% of the corn kernel by dry weight (Johnston, et al., 2005). This may be a better alternative for ethanol producers. Regardless of the method used to remove the germ, dry fractionation or enzymatic milling, this study assumes the ethanol producer will opt to sell corn germ rather than separating it into oil and gluten feed. The following formula developed by Johnston, et al. (2005) estimates corn germ prices in dollars per pound.

$$P_{germ} = (y_{oil})(P_{oil}) + (y_{pro})(P_{pro}) - C \tag{17}$$

where P_{germ} is the price, or value, of corn germ; y_{oil} and y_{pro} are the percentages of crude corn oil and protein content of the corn germ, respectively; P_{oil} and P_{pro} are the prices of crude corn oil and protein value of corn gluten feed, respectively; and C is the cost of separating corn germ into crude corn oil and germ meal.

Johnston, et al. (2005) determines the percentages of corn oil and protein content produced from corn germ processing under a number of methods. Enzymatic milling to remove the corn germ allows for further processing into 39% oil and 18% protein (Johnston, et al., 2005). Since corn gluten feed prices are for 21% protein, the value of the protein in corn germ is found by multiplying 18% by the corn gluten price per ton divided by 420 (21% of 2000 lbs). Monetary protein values from other de-germing methods can be determined the same way. The cost of separating the germ into oil and gluten ranged from \$0.0075/pound to \$0.0175/pound (Johnston, et al., 2005). Due to increases in energy costs since 2005, the high end of this cost range is assumed.

Equation (18) shows corn germ's contribution to total revenue.

$$R_{germ} = (P_{germ})(4.5) \div 2.7 \tag{18}$$

Where R_{germ} is revenue in dollars per pound, P_{germ} is the germ price in dollars per pound, 4.5 is the pounds of germ per bushel of corn, and 2.7 is the gallons of ethanol produced per bushel of corn after dry fractionation.

Net earnings are calculated by subtracting depreciation and interest from gross earnings. This is an important component to determine the change in equity, along with cash paid to equity holders. The change in equity is assumed equivalent to profit in the certainty equivalent model.

To determine excess cash flow, principal debt payments and other capital costs are subtracted from earnings before interest, taxes, depreciation, and amortization (EBITDA). The sweep factor percentage is then multiplied by the excess cash flow to determine additional debt repayment amounts. Percentages of free cash flow paid in sweeps can range from 25% to 50%, depending on market conditions, equity, or other factors (Aberle, personal communication, May 2009). Cash paid to equity holders is determined by multiplying net earnings times the percentage return equity holders expect. Tiffany and Eidman (2004) assumed 12%, but other values can be used depending on agreements between the firm and equity holders, or in the case of cooperatives, tax codes in the business's locality (McKee, personal communication, April 2009). Finally, ending equity is calculated by adding the change in equity (net earnings – cash paid to equity holders) to beginning equity for a given year. The ending equity helps determine if a firm has sufficient capital on hand to invest in new technology subject to a given level of risk aversion.

Coefficient of Risk Aversion

The risk aversion coefficient, $\lambda/2$ in the certainty equivalent model, is determined from a decision maker's aversion to risk given the level of equity. The mean and standard deviation for the level of firm equity is calculated after running 10,000 iterations of the profit model. The Maximum absolute risk aversion coefficients (ARAC) are then calculated following McCarl and Bessler (1989). Based on Pratt's estimation of a risk premium as a function of risk and risk aversion, they find the upper value for the risk aversion coefficient to be $r(W) \leq 2E(Y)/\sigma_Y^2$ (McCarl and Bessler, 1989). Here, $r(W)$ is the risk aversion coefficient, $E(Y)$ is expected return of asset Y, and σ_Y^2 is the variance of the

expected value of asset Y. This equates to "twice the inverse of the coefficient of variation divided by the standard deviation" of an asset's returns (McCarl and Bessler, 1989). Another formula to determine the maximum ARAC is $r(W) \leq 2D/\sigma_Y$, where $r(W)$ is the risk aversion coefficient for a level of wealth W, D is the number of standard deviations from the mean, and σ_Y is the standard deviation of a risky investment Y, in this case, the ethanol plant's equity or net worth. Assume $D = 2$ because 95% of the time, a normal random variable is within two standard deviations of its mean.

To simulate a firm's risk aversion subject to the sweep constraint, an assumption about the sweep value is that it is 30%. Values for the ARACs for the varying data length scenarios are shown in Table 5.

Table 5. Maximum ARACs for 30% Free Cash Flow Sweep

Sweep Percentage	30%
ARAC total-year with shifted mean	9.752 E-08
ARAC 5-year with shifted mean	8.888 E-08

ARACs for sweep percentages other than 30%, while not shown in Table 5, change very slightly. A sweep percentage of 40% will cause the ARAC to change by about 2.0 E-10. In addition, performing sensitivities on ethanol plant profits is easier when the ARAC remains the same and the sweep percentage changes. This indicates that a firm's level of risk aversion stays the same for a certain level of wealth. The maximum ARAC falls the longer a firm operates, which indicates the maximum level of risk aversion lessens the longer a firm is able to continue operations. This would make sense because as debt is paid down, the requirement for additional debt payments falls, and more cash is available for other investment, equity holders, etc. The maximum ARACs shown in Table 5 are

calculated from the first year of operation when risk aversion is at its highest for each level of sweep percentage.

The ARACs used to calculate the certainty equivalent under different levels of risk aversion range from zero (risk-neutral) to the maximum from Table 5, which is the most risk averse case. An assumption used to determine the range of ARACs is that most firms are closer to risk-neutral than very risk averse. To determine a range of risk aversion coefficients for most firms, divide the maximum ARACs by five, four, and three because most firms are closer to risk-neutral than to very risk averse.

Distributions

Determining proper probability distributions is important for estimating profits. Atwood, Shaik, and Watts (2003) determined that incorrectly specifying crop yields' probability distributions would in turn misestimate crop insurance premiums. Assuming normality of crop yields caused the probability of loss to decrease slightly, which would underestimate insurance premiums for many farmers (Atwood, Shaik, and Watts, 2003). Therefore, it is important to find the best fitting distribution when assuming price variability, which has substantial impacts on profit variability.

Stochastic variables in the model include ethanol, DDGS, and corn prices. Corn germ prices, while determined from corn oil and corn gluten feed prices, are still considered stochastic. Stochastic variables cause variability in returns and can greatly affect risk for a firm proposing new investment. Distributions are not included for the variable costs (deterministic variables) because they are adapted from Perrin, et al. (2008).

Distributions of historical input and output prices are included in the model (to account for profit variability) using the "Best-fit" algorithm of @Risk (Palisade

Corporation, 2007). Distributions for the prices of corn, ethanol, traditional DDGS, Hi-Pro DDGS, and corn germ for each length of data are included in Table 3. Figures 4 through 13 show the distributions' graphs and functions. Corn oil and corn gluten are not directly included in the profit calculation explained below, but play an important part in calculating the value of corn germ.

Figures 4 to 13 show distributions for corn, ethanol, DDGS, Hi-Pro DDGS, and corn germ prices for each of the periods observed. Figures 4 to 8 show variables' distributions for the total year series and Figures 9 to 13 show the five-year series' distributions. These help show visually how well the actual input data, indicated by the bars on the graph, fits the probability density function—the function estimated from the data and shown by the line. The total- and five-year series' price distribution characteristics are discussed below.

The Chi-Square, Anderson-Darling (A-D), and Kolmogorov-Smirnov (K-S) tests rank the distributions based on P-values and critical values in @Risk. After analyzing statistics regarding each distribution, subjective decision-making also helps determine the best choice. Because prices paid to farmers or received by ethanol producers will most likely not be negative, distributions that eliminate the possibility of using negative numbers seem to have more relevance. In addition, the rankings of distributions' fit with each test helps determine that high rankings by all three tests show that the distribution chosen are as close as possible. Tables 6 and 7 show the test statistics, P-values, critical values, and ranks of the distributions under the Chi-Square, A-D, and K-S tests for the total and five-year data series' lengths.

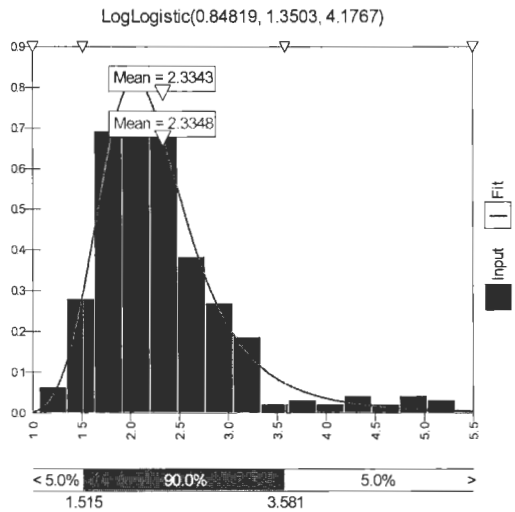


Figure 4. North Dakota corn price distribution.

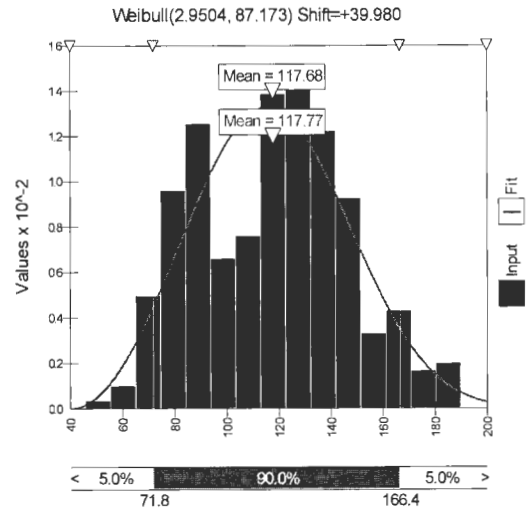


Figure 6. Traditional DDGS prices distribution.

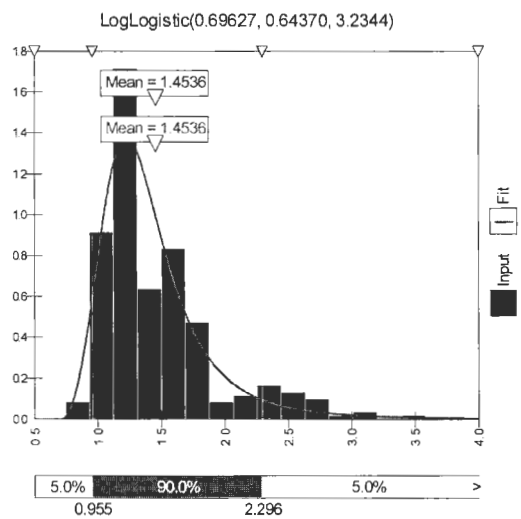


Figure 5. Ethanol price distribution.

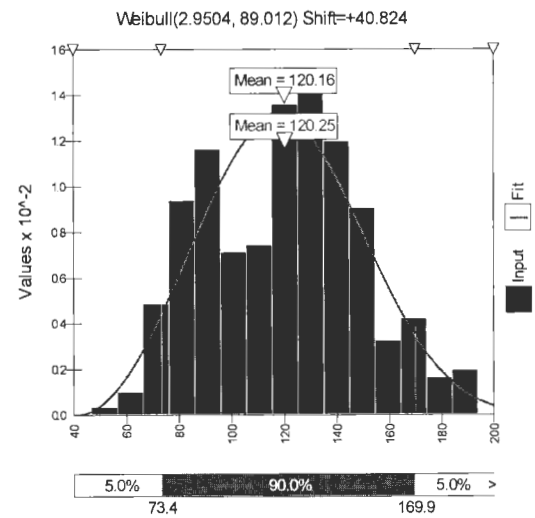


Figure 7. Hi-Protein DDGS price distribution.

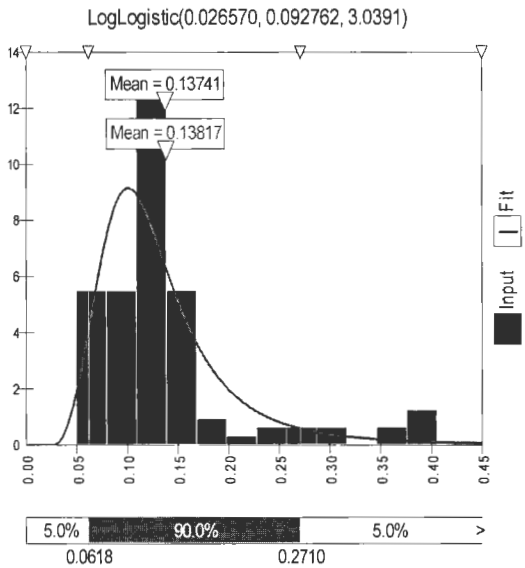


Figure 8. Corn germ price distribution.

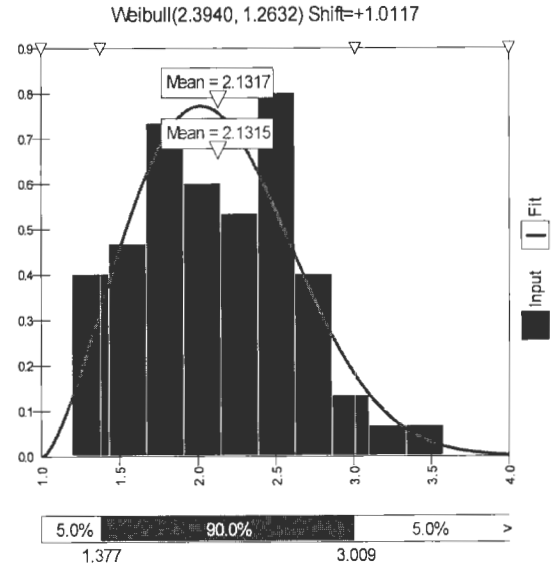


Figure 10. Five-Year ethanol price distribution.

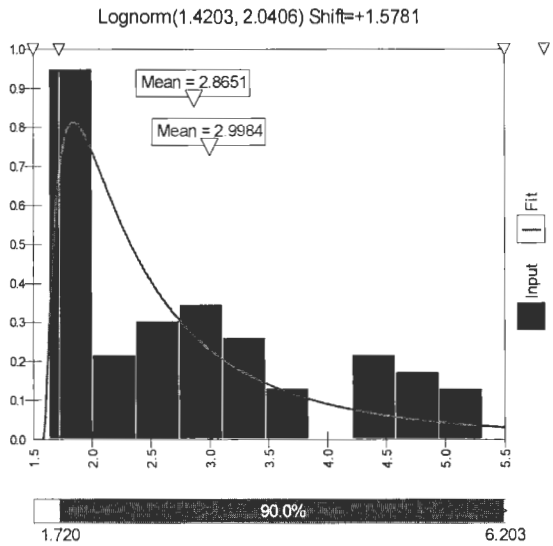


Figure 9. Five-Year corn price distribution.

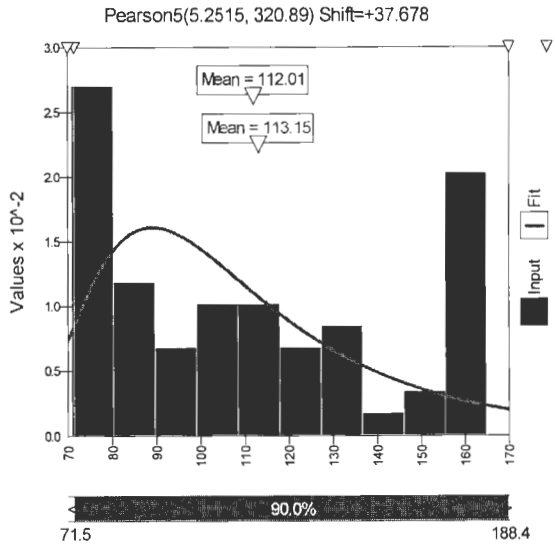


Figure 11. Five-Year traditional DDGS price distribution.

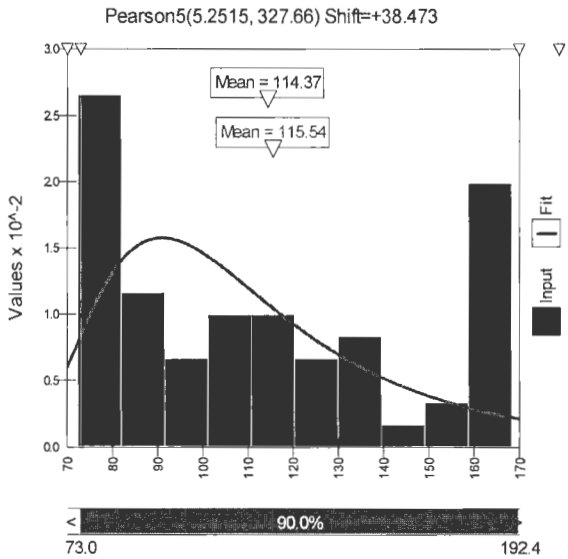


Figure 12. Five-Year Hi-Protein DDGS price distribution.

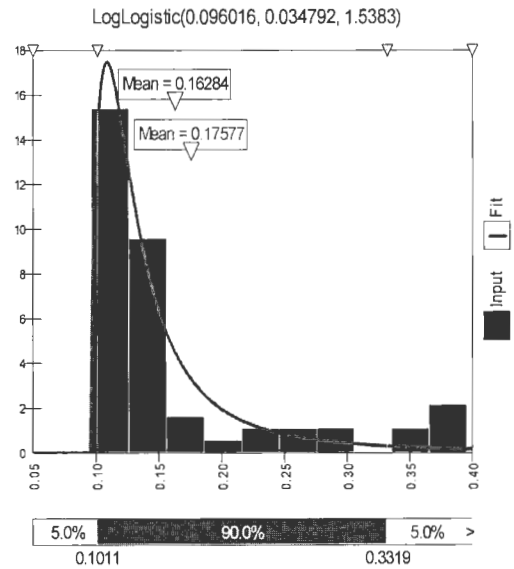


Figure 13. Five-Year corn germ price distribution.

Table 6. Total-Year Data Series Price Distribution Statistics

Test		ND Corn	Ethanol	DDGS	Hi-Pro DDGS	Corn Germ
Chi-Square	Distribution	Log-logistic	Log-logistic	Weibull	Weibull	Log-logistic
	Test Statistic	26.06	76.42	40.94	40.94	38.51
	P-value	0.0984	0.000	0.000	0.000	0.000
	Critical Value α = 0.1	25.9894	25.9894	24.769	24.769	17.275
	Rank	1	2	1	1	1
Anderson-Darling	Test Statistic	0.47751	1.69	1.453	1.453	1.883
	P-value	N/A	N/A	N/A	N/A	N/A
	Rank	1	1	2	2	1
Kolmogorov-Smirnov	Test Statistic	0.04644	0.06	0.0624	0.0624	0.1234
	P-value	N/A	N/A	N/A	N/A	N/A
	Rank	1	1	3	3	1

Table 7. Five-Year Data Series Price Distribution Statistics

Test		ND Corn	Ethanol	DDGS	Hi-Pro DDGS	Corn Germ
Chi-Square	Distribution	Log-Normal	Weibull	Pearson 5	Pearson 5	Log-Logistic
	Test Statistic	12.86	6.857	8.000	8.000	10.29
	P-value	0.1169	0.5521	0.4335	0.4335	0.2455
	Critical Value α = 0.1	13.362	13.362	13.362	13.362	13.362
	Rank	2	4	1	1	2
Anderson-Darling	Test Statistic	1.126	0.3571	1.562	1.5622	0.6916
	P-value	N/A	N/A	N/A	N/A	N/A
	Rank	2	2	3	4	2
Kolmogorov-Smirnov	Test Statistic	0.1183	0.0836	0.1206	0.1206	0.09898
	P-value	N/A	N/A	N/A	N/A	N/A
	Rank	3	4	4	4	2

Total-Year Data Series

Corn, ethanol, and the primary corn products' distributions are skewed left. This indicates high prices occur less frequently and are not as likely as those prices located near the middle or lower range of the data series. Based on these historical prices, an ethanol producer can expect to pay relatively low prices for corn while receiving relatively low prices for ethanol, but as noted below, employing a shorter time series may provide a more accurate assessment of current input costs.

The graphs also help show the probability that prices will fall within a certain range. For instance, Figure 4, the corn price distribution, shows that 90% of the time, the price falls between $1.51 per bushel and $3.58 per bushel. It also indicates that 5% of the time, the price falls below $1.51 per bushel, and 5% of the time the price is above $3.58 per bushel. Similarly, Figure 5 shows ethanol's price falls between $0.96 per gallon and $2.30 per gallon 90% of the time.

The log-logistic distributions for corn, ethanol, and corn germ are reasonable since prices should not be negative, nor are they likely to fall to an unreasonably low value. Log-logistic distributions have a domain of $\gamma \leq x \leq +\infty$, where γ is a location parameter, which is the horizontal distance from the origin, and can be either the minimum or midpoint of the range of possible data points (Evans, Hastings, and Peacock, 2000). However, prices are less likely to reach positive infinity than zero based on history, but the distribution nonetheless has this potential. The distributions can be truncated, which would limit the upper bound of possible draws, but this may limit the potential for high prices received or paid by an ethanol producer.

DDGS prices exhibit a symmetrical distribution around the mean, indicating the values in the right or left tails are less likely to occur than those in the main body of the distribution. The Weibull distribution fits the data well and cannot assume negative values, having a domain $0 \leq x \leq +\infty$. The distribution graphs for DDGS and Hi-Pro DDGS prices in Figures 6 and 7, respectively, show how the Weibull distribution function contains a shift amount which shifts the domain of the distribution to match the data's distribution when the lowest value is significantly higher (or lower) than zero. This is beneficial in this instance because the smallest prices for DDGS are not likely to occur, given historical prices. These estimations are useful to help determine the likelihood that input prices would be extremely high or output prices extremely low. For DDGS, prices fall between \$71.80/ton and \$166.40/ton 90% of the time. Hi-Pro DDGS' price range is 2.11% higher at \$73.40/ton to \$169.90/ton. An ethanol producer can use the distributions' tails to help determine the likelihood of extreme input or output prices.

Five-Year Data Series

The five-year data series distributions show that the 90% confidence interval for prices of all the variables has a higher upper bound than the total-year data series length. This is because agricultural product prices reached historic highs in more recent years.

The log-normal distribution for corn again makes sense because the values are greater than or equal to zero, yet closely follow a normal distribution after determining the logarithm of values (Evans, Hastings, and Peacock, 2000). Parameters for the log normal distribution are the mean and standard deviation of the distribution, and the domain is $0 \leq x \leq +\infty$.

As noted above, the Weibull distribution is useful because it cannot assume negative values. In addition, the somewhat symmetric nature of ethanol prices in the five-year data series also fits the distribution well.

No distribution fits the DDGS data well because most of the values are either low or high, but the Pearson 5 distribution seems to fit the data best, according to the Chi-Square test. Because the values in the main body of the distribution are more likely to occur, the A-D test with a ranking of two carries more weight than the K-S test which focuses on the tails of the distribution. The domain of the Pearson 5 distribution makes sense when analyzing prices, and is $0 \leq x \leq +\infty$.

The log-logistic distribution for corn germ makes sense in part because the total-year data series for this variable is only nine years. In this instance, however, the location parameter is higher than in the total-year data series, but the mean of prices also is higher because of the historically high prices seen in recent years.

Chapter Five discusses results from the empirical model that calculates the certainty equivalent subject to a free cash flow sweep for a risk averse ethanol producer. Separate results are shown for the total- and five-year data series lengths.

CHAPTER 5. RESULTS AND DISCUSSION

This chapter discusses the model's results and provides a discussion on their significance as they relate to a corn-based ethanol producer investing in fractionation technology.

The model's results show the ability of an ethanol producer to build adequate equity to make an investment in fractionation technology. Lender-imposed sweeps affect how quickly a firm can accumulate adequate cash to make the investment. Sweeps only require additional debt be paid in years of excess cash flow. The results also portray firm equity before and after investment in fractionation technology. Finally, the firm's value according to varying levels of risk aversion is portrayed for Year 6, the first year the firm may invest in fractionation.

Tabular and graphic results for an ethanol firm are presented for the base-case, a fractionation model, and a fractionation with sweep model using the total-year data series. Graphs depicting the risk of bankruptcy occurring follow each set of certainty equivalent graphs. The five-year data series graphs will follow and show changes that occur when adjusting the data collection period.

Total-Year Data Series Results

Table 8 shows certainty equivalent values and means, standard deviations, maximums, minimums, and ranges of values for the certainty equivalent over the ten-year period for the base case, fractionation, and fractionation with a 30% sweep when using the total-year data series. The overall risk of bankruptcy and variance of return on assets is included as well. Appendix A contains more complete tables with data for each variable portrayed in Figures 14 to 16.

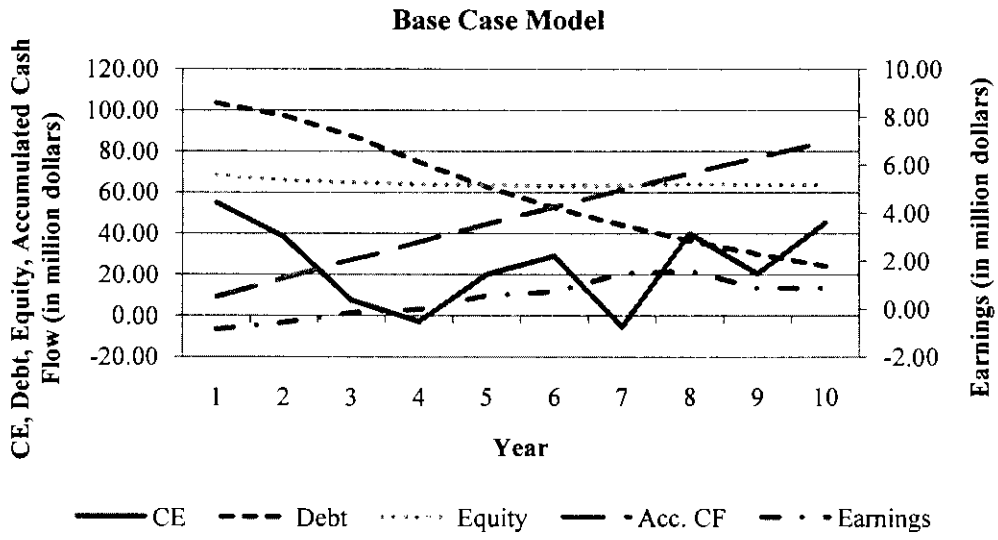
Table 8. Total-Year Data Series Certainty Equivalent Values over the 10-Year Period (Values in Million Dollars)

Year	Base Case	Frac--No Sweep	Frac--30% Sweep
1	55.13	53.14	58.36
2	38.30	39.55	42.39
3	7.48	17.18	11.77
4	-2.84	1.21	-6.49
5	20.05	4.84	-9.09
6	29.07	21.44	45.63
7	-5.32	26.92	56.25
8	40.10	30.50	74.55
9	20.33	50.16	73.62
10	45.39	63.75	86.23
Mean	24.77	30.87	43.32
Std. Dev.	20.53	20.75	33.92
Min	-5.32	1.21	-9.09
Max	55.13	63.75	86.23
Range	60.44	62.53	95.32
Overall Risk of Bankruptcy	29.9%	31.7%	29.1%
Overall Variance of ROA	0.051	0.043	11.341

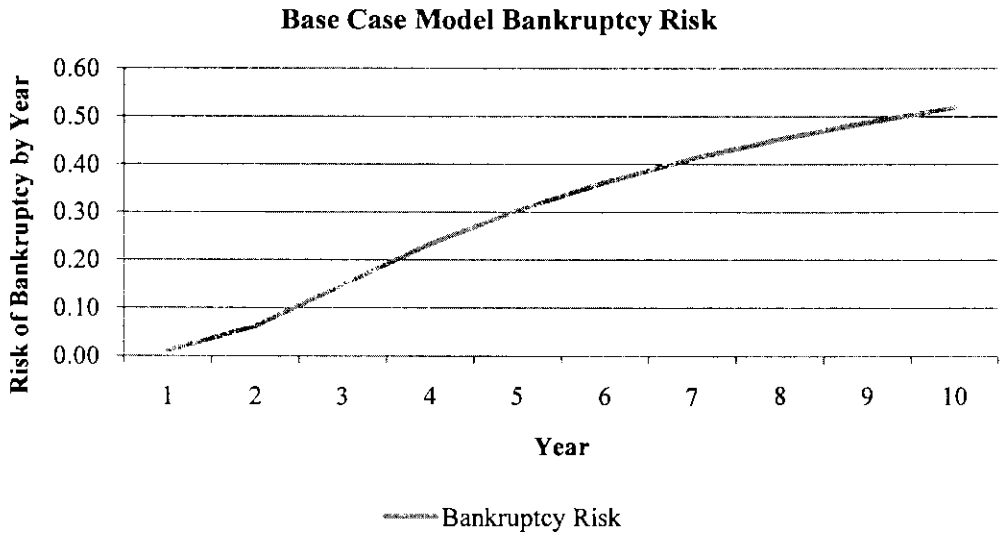
Base-Case

The base-case model determines the certainty equivalent for an ethanol firm without anticipated investment in fractionation or a lender-imposed free cash flow sweep. Results of the base-case model, shown in Panel A of Figure 14 illustrate how an ethanol producer's certainty equivalent, equity, debt, accumulated cash flow, and earnings change over a ten-year period. As expected, debt falls nearly linearly as annual payments are made. Equity shows a slight decrease over the period, indicating the firm is forced to use equity to continue operations, even though firm earnings increase over much of the period. Earnings increase, but stay below zero for the first four years. The firm's profitability is low and only increases because interest expense on debt decreases as debt obligations are

paid. The certainty equivalent declines since equity is decreasing and earnings are low. As debt falls and earnings increase, the certainty equivalent increases, but still exhibits variability over time due to stochastic input and output prices and uncertain profits.



Panel A



Panel B

Figure 14. Total-year data series base case.

In the base-case model, the risk of bankruptcy increases each year of operation as seen in Panel B of Figure 14. By Year 10, there is over a 50% chance the firm will become bankrupt. This is due to steady decreases (or scant opportunity for increases) in equity over the period. As noted in Table 8, there is about a 30% chance the firm will experience bankruptcy in the ten-year period. The fact that equity decreases over time and the certainty equivalent value declines indicates bankruptcy becomes more likely over time. Variance of return on assets (ROA) is relatively low at about 5% over the period. This indicates variability of returns is relatively low and that risk to lenders should be relatively low for the period.

Fractionation Model

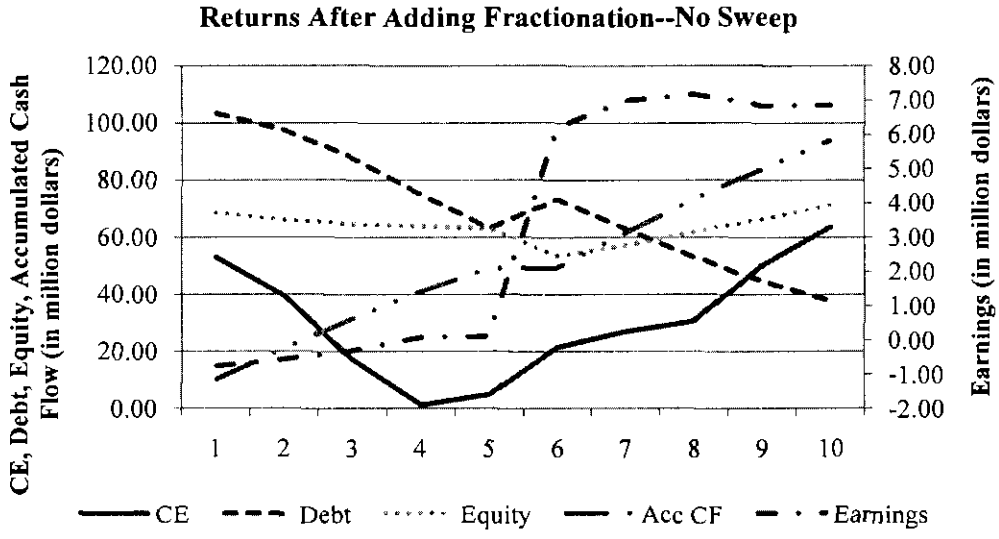
Panel A in Figure 15 shows the firm's certainty equivalent for a firm investing in dry fractionation technology. The first five years' operations match the firm without dry fractionation. Debt decreases at a regular pace, equity and the certainty equivalent decline, and earnings are negative but increase as debt is paid. Even with net earnings losses in the first few years of operation, the firm is able to accumulate sufficient cash flow to invest in new technology. As expected, after investing in new fractionation technology in year six, the annual earnings increase sharply due to increased revenue from the new technology. Earnings increase equity, which increases the certainty equivalent. Debt initially increases with the investment, but then continues decreasing with annual debt payments. Equity initially falls after investment, but increases after adding additional revenue from technology.

Initial increases in profitability are tenuous over time as earnings begin to fall toward the end of the period; also seen in the firm without fractionation. The difference

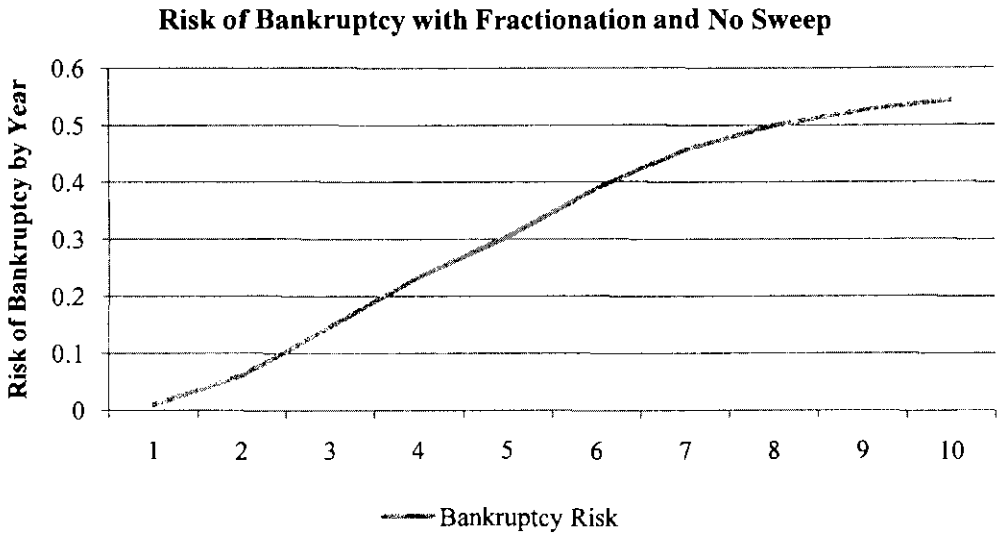
between maximum firm earnings without and with fractionation is about $1.3 million. The certainty equivalent declines as earnings decline later in the period, likely due to uncertainty of returns.

While the firm is able to invest in fractionation technology in Year 6, the risk of bankruptcy still exists. At Year 10, the firm's bankruptcy risk is over 50%, just as it was for the firm without fractionation. Table 8 indicates a slightly higher overall risk of bankruptcy for the firm adopting fractionation, but a lower overall variance of ROA.

A conclusion from this is that investing in dry fractionation helps the firm increase its long-run equity position while paying down debt, but that the risk of bankruptcy, while increasing slightly, is still an important consideration. The firm and its lenders face an added risk by investing in the technology because new technology can yield an uncertain outcome. However, investing in dry fractionation lowers the overall variance of return on assets, which is attractive to lenders and potential investors because it indicates less volatility in firm returns. The certainty equivalent with respect to risk aversion is shown in Figure 17 and follows the discussion on the sweep.



Panel A

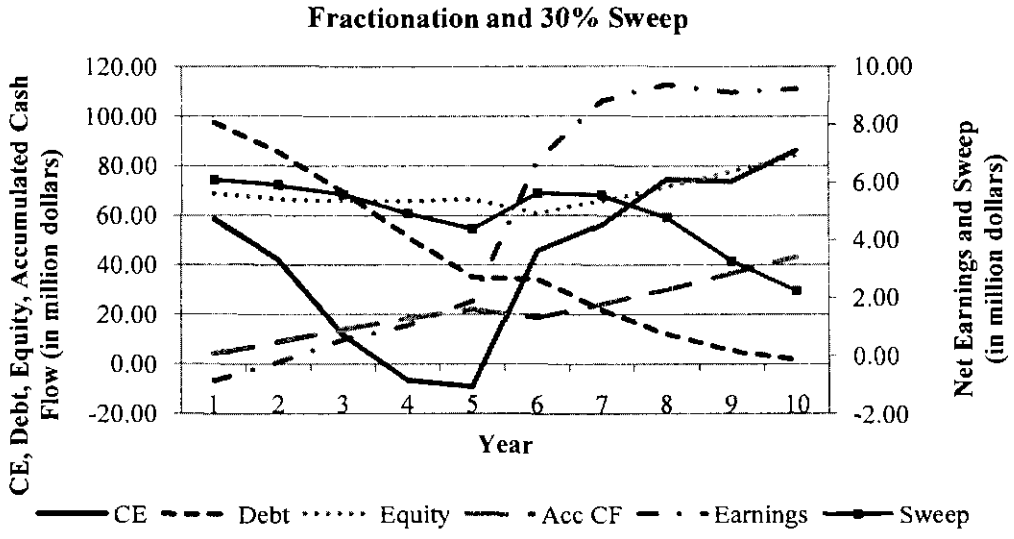


Panel B

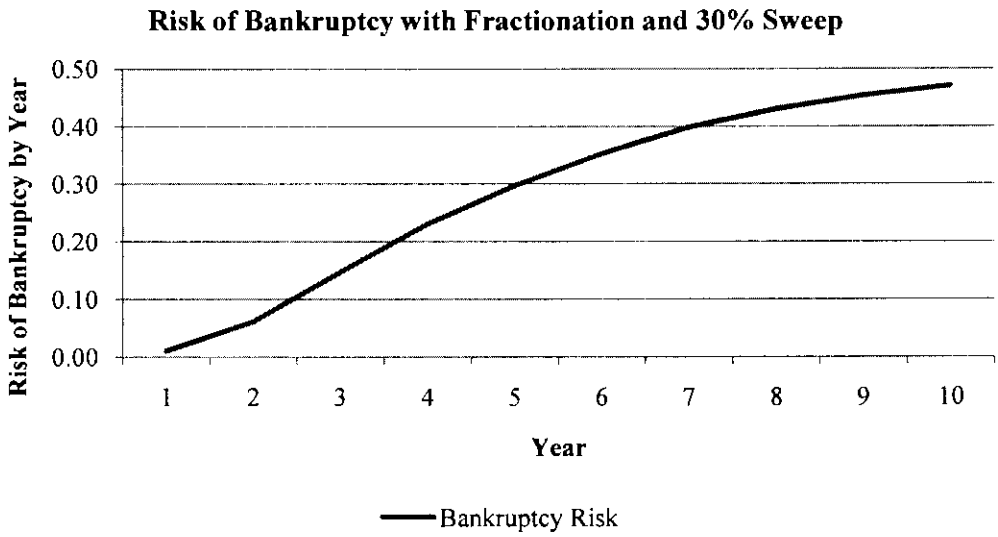
Figure 15. Total-year data series fractionation investment.

Fractionation and 30% Sweep

Panel A in Figure 16 shows the certainty equivalent and associated values for an ethanol producer investing in fractionation technology, but subject to a 30% free cash flow sweep. The sweep requires the firm to pay down debt at a faster rate, assuming excess cash flow exists.



Panel A



Panel B

Figure 16. Total-year data series fractionation investment with sweep.

The certainty equivalent decreases as in previous models, and becomes negative sooner, due to the sweep's negative influence on cash flows. However, after investing in fractionation, the certainty equivalent increases to higher levels than in the two previous examples. The negative values experienced in Year 7 for the first two examples do not occur here. The reason for this is that debt is paid off sooner, and the firm is able to build equity at a fast rate, even with the sweep imposed. Adopting fractionation allows the certainty equivalent to increase rapidly, peaking about $90 million higher at the end of the period than in the fractionation model without the sweep.

Equity also increases to a higher level than in the base case or fractionation model. Like the certainty equivalent, it dips slightly in the early years of operation, and then increases in each successive year. It eventually reaches a point higher than the fractionation model without the sweep or the base case. This helps mitigate concerns over bankruptcy, which, as shown in Panel B, is lower than in the previous cases. Table 8

shows the overall risk of bankruptcy is 0.8% lower than the base case and 2.6% lower than the under fractionation without the sweep.

Debt repayment is nearly complete in Year 10 of a 15-year loan due to the sweep's requirement of excess cash flow being used to retire debt. This enables the firm's equity position to increase relative to debt, which then adds to the firm's certainty equivalent for this scenario. Because debt declines at a faster rate under this scenario, the return to debt component of the certainty equivalent is larger, also adding to higher certainty equivalent values. A disadvantage of the sweep is that additional debt payments reduce the amount of excess cash that would be available to purchase new equipment or cover unforeseen emergencies. Accumulated cash flow does not increase as rapidly as seen in the base case or fractionation without the sweep models, nor does it attain the same high levels seen in the other examples. However, increased earnings due to lower debt interest payments help offset the lower cash flow. As debt is reduced, the amount of the sweep payments also declines, which leaves more cash available for increased equity, savings, or other investment.

The risk of bankruptcy is lower for each of the years when compared to the models without the sweep. Since the sweep's requirement that debt be reduced more quickly, and higher earnings follow, the firm can build equity against the risk of bankruptcy. Variance of ROA is much higher under this scenario than the previous two examples. One reason for this would be increased volatility in debt and equity levels. The sweep will cause debt and equity values to decrease or increase at different rates than may be expected from normal debt amortization. In addition, higher earnings may exhibit more variability, which will cause variance of ROA to exhibit greater volatility.

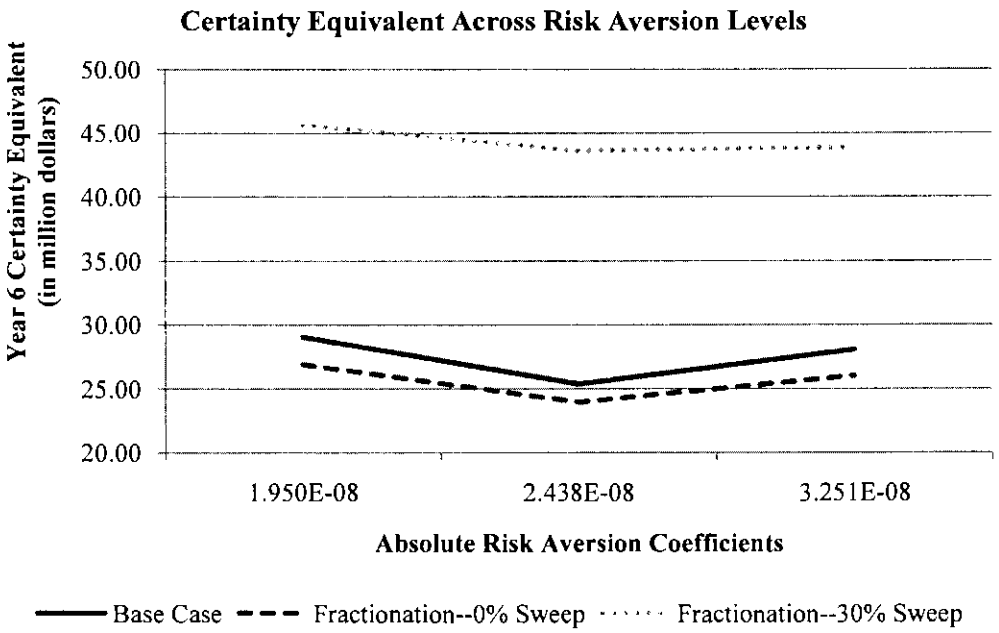


Figure 17. Certainty equivalent subject to absolute risk aversion coefficients in Year 6.

Figure 17 shows the certainty equivalents for varying levels of risk aversion in Year 6. The sixth year is significant because it is the first year of production employing fractionation technology assuming the firm has sufficient equity to make new investment after Year 5. A risk-neutral investor will have an absolute risk aversion coefficient (ARAC) of zero, and the most risk averse firm will have the maximum value determined in Chapter 4. However, most firms fall between these extremes, and those values are represented here. The lowest to highest ARACs portrayed in Figure 17 are determined by dividing the maximum ARAC by 5, 4, and 3, respectively, to reflect a moderately risk averse firm.

The graph shows the certainty equivalent changes little as risk aversion increases with a slight increase for the most risk averse firm over the risk-neutral firm under the base

case and fractionation without the sweep models. This indicates growth opportunities exist for an ethanol producer under these circumstances regardless of the firm's level of risk aversion. Results also indicate a firm should choose to invest even when subjected to the sweep because the certainty equivalent is higher for all levels of risk aversion.

The sweep has a positive effect on the certainty equivalent because the firm can build equity fast when applying 30% of free cash flow toward debt reduction, which also increases firm profits. Removing the sweep causes the firm to earn a lower certainty equivalent value and high profits are not as likely for each level of risk aversion. This result is expected since the firm will want to be compensated for taking on the added risk of the sweep requirement.

The certainty equivalent decreases at the highest risk aversion level with a sweep in place, which indicates highly risk averse firms are willing to accept a lower payment in lieu of additional risk associated with the sweep. Figure 17 indicates a firm receives a lower certainty equivalent for each level of risk aversion by investing in fractionation without the sweep. This result may occur since technological investment reduces risk and the firm will accept a slightly lower payment at each level of risk aversion when employing a risk-reducing strategy.

Table 9 and Figure 18 show the certainty equivalent differences among each of the above scenarios. The table and graph indicate the difference between the base case and fractionation without the sweep, the base case and fractionation with the sweep, and fractionation with and without the sweep over the ten-year period. To determine the values, first, the base case value is subtracted from the fractionation model without the sweep. Second, the base case value is subtracted from the fractionation model with the

sweep. Last, the fractionation without the sweep value is subtracted from the fractionation model with the sweep value.

Table 9. Differences in Certainty Equivalent Values under each Scenario (Values in Million Dollars)

Year	Frac—No Sweep less Base Case	Frac—30% Sweep less Base Case	Frac—30% Sweep less Frac—No Sweep
1	-1.99	3.24	5.22
2	1.25	4.09	2.83
3	9.70	4.28	-5.41
4	4.06	-3.64	-7.70
5	-15.20	-29.13	-13.93
6	-7.63	16.56	24.19
7	32.24	61.57	29.33
8	-9.60	34.45	44.06
9	29.84	53.29	23.46
10	18.36	40.84	22.48
Mean	6.10	18.55	12.45
Std. Dev.	16.30	28.33	18.88
Minimum	-15.20	-29.13	-13.93
Maximum	32.24	61.57	44.06
Range	47.44	90.70	57.99

Little variation exists for the first four years among the three scenarios, but, by Year 5, it is seen that the sweep has a negative effect on the certainty equivalent. The differences between the fractionation with sweep and base case and fractionation with sweep and fractionation models are negative in that year indicating higher certainty equivalents without the sweep. However, after investing in the new technology, the differences are positive for the duration of the period with the sweep in place. This again shows how the sweep benefits the firm in the long run.

The difference between investing and not investing is negative for most of the period, indicating the firm would be better off not investing than investing. However, as noted above, employing a risk-reducing strategy will cause the firm to accept a lower certainty equivalent for given levels of risk aversion.

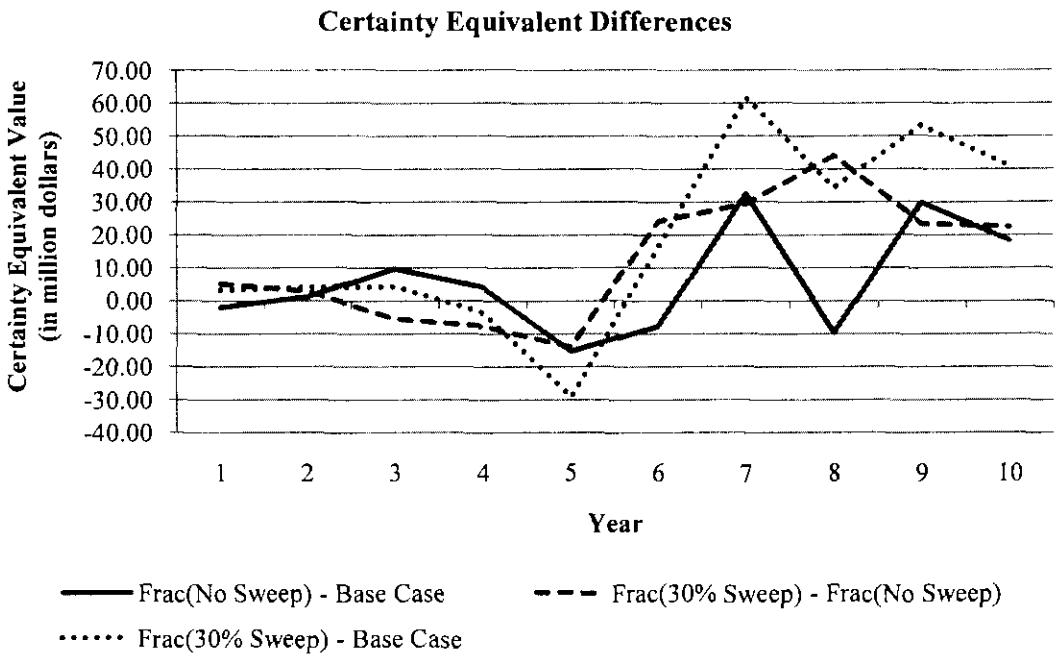


Figure 18. Certainty equivalent differences across scenarios.

Five-Year Data Series Results

Results using the shorter time series of data are discussed below. Correlations among the variables changes, as noted in Table 4. The correlation between ethanol and corn decreases when examining data from January 2004 to May 2009, but is still positive. Falling from 0.47 to 0.25 indicates that while prices move in the same direction, the strength with which they move together is decreased. Therefore, plant revenue and costs do not necessarily increase and decrease together to the degree seen when using the total-

year data series. In addition, the correlation between ethanol and DDGS increases, likely due to increased production of both products. The change from 0.06 to 0.27 indicates prices for each product will increase or decrease together, which will have a more pronounced impact on the degree to which ethanol plant revenue increases or decreases. Table 10 shows values for the certainty equivalent with a more complete table with data for the following graphs located in Appendix B.

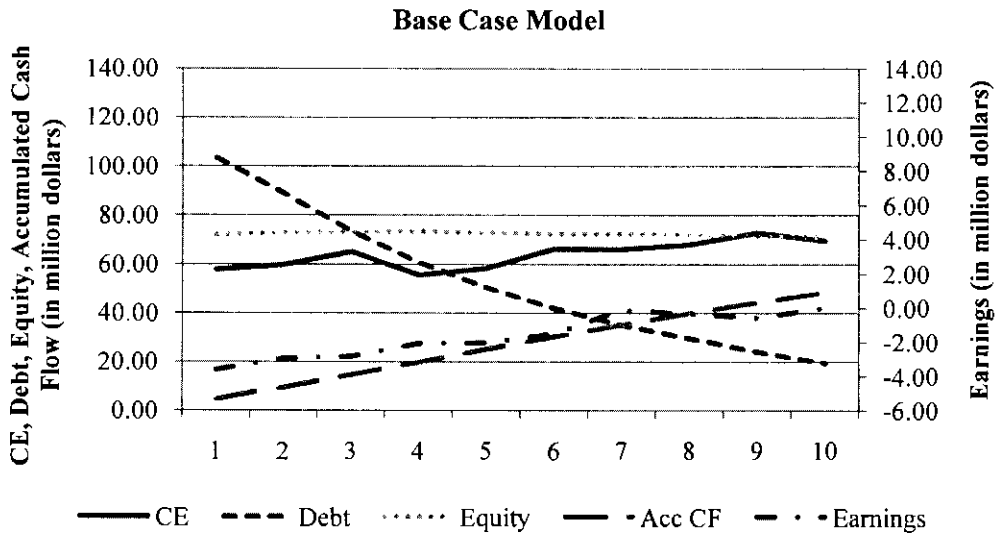
Table 10. Five-Year Data Series Certainty Equivalent Values over the 10-year Period (Values in Million Dollars)

Year	Base Case	Frac--No Sweep	Frac--30% Sweep
1	57.77	61.5	61.43
2	59.71	58.7	61.19
3	65.08	59.7	66.29
4	55.55	58.4	65.30
5	58.28	68.9	80.01
6	66.21	78.4	94.02
7	66.14	92.4	132.36
8	68.02	96.9	124.34
9	72.86	103.1	119.17
10	69.58	108.1	118.17
Mean	63.92	78.61	92.23
St Dev	5.75	19.84	28.87
Min	55.55	58.41	61.19
Max	72.86	108.10	132.36
Range	17.31	49.69	71.17
Overall Risk of Bankruptcy	42.1%	41.7%	40.7%
Overall Variance of ROA	0.001	0.003	1.995

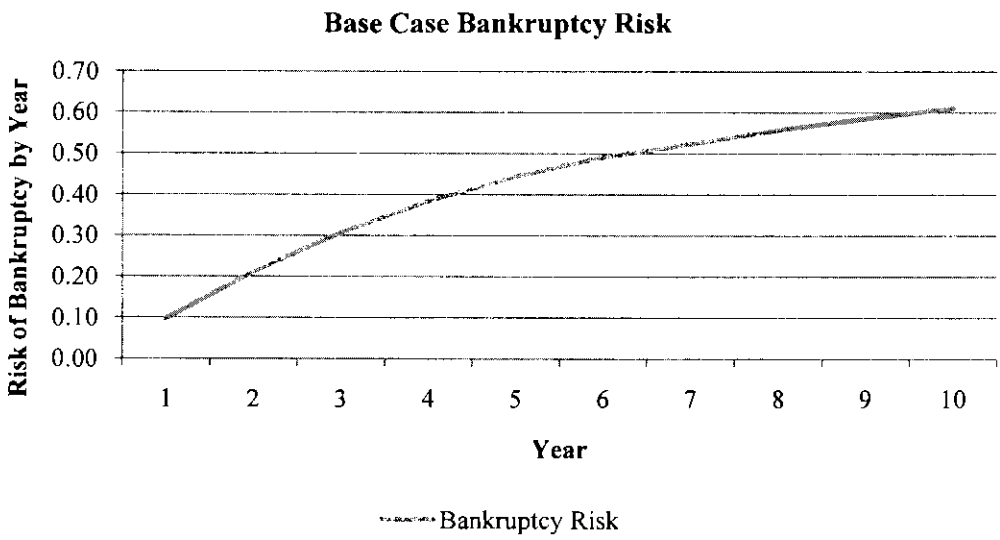
Base Case

When using the shorter time series of data, an ethanol producer's profit potential decreases due to higher input prices and lower output prices the ethanol industry has faced in recent years. However, in the base case, the firm certainty equivalent does not fall

below zero over the ten-year period, while a negative certainty equivalent was seen when using the total-year data series. The mean certainty equivalent value over the ten-year period is considerably higher than when using the total-year data series. A benefit to lenders and potential investors in this base case is that the variance of returns on assets is very low for the ten-year period. This indicates variability in returns is low, which is attractive to risk averse firms, lenders, and individual investors.



Panel A



Panel B

Figure 19. Five-year data series base case.

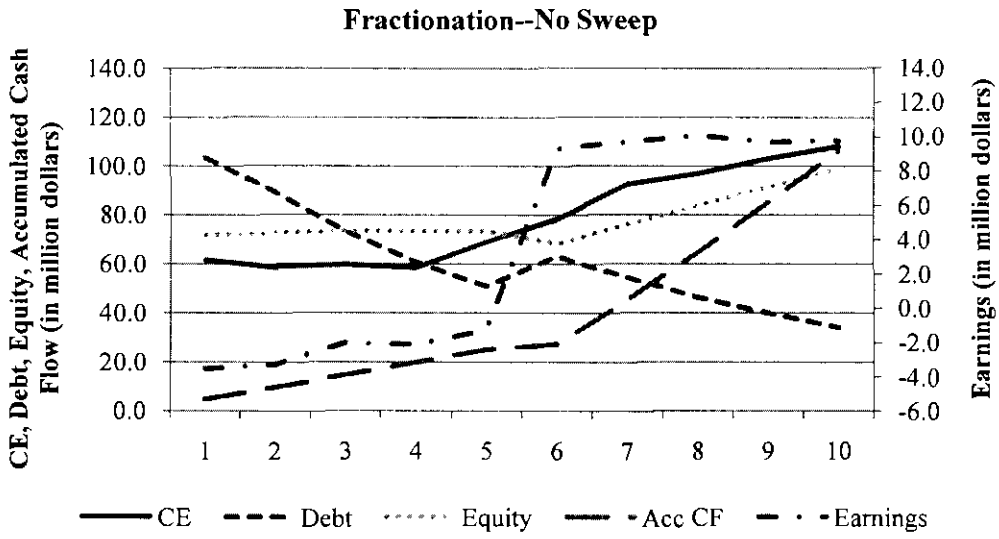
Bankruptcy risk is higher with the shortened data series. The reason for this is the higher corn price relative to ethanol price which creates multiple years of negative earnings. In addition, equity has no opportunity for growth, and would likely be used to continue operations. Furthermore, investors cannot be paid with negative earnings, which will not attract individuals who may wish to invest in an ethanol plant given decreased profitability. This situation reflects recent financial stress faced by ethanol firms who have had difficulty attracting investors or procuring financing.

Fractionation Model

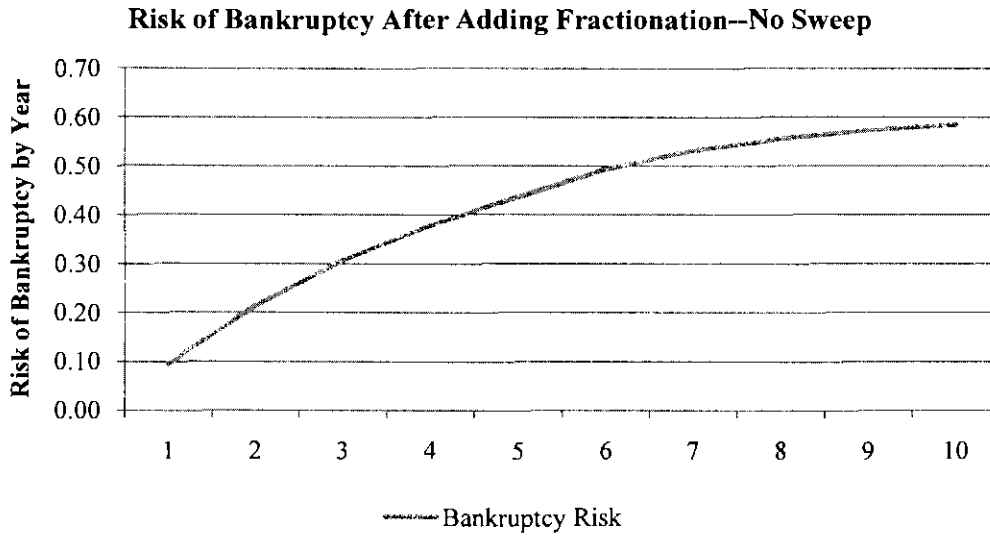
The fractionation model indicates that the ethanol firms perform well by investing in fractionation, given current input and output prices. Panel A in Figure 20 shows how earnings increases dramatically after the investment is made. In addition, the certainty equivalent, equity, and accumulated cash flows increase after investing in fractionation. The results indicate the firm is able to accumulate sufficient cash to invest, even when faced with unprofitability in the firm's early years.

The certainty equivalent's ending value is higher when using the five-year data series, than with the total-year data series.

A difference to note when using the five-year data series is that the risk of bankruptcy falls when the firm has the opportunity to invest in new technology, as noted in Table 10. Using the total-year data series, the risk of bankruptcy increased for the firm investing in fractionation. Variance of ROA is lower when using this data series than in the previous data series' analysis.



Panel A



Panel B

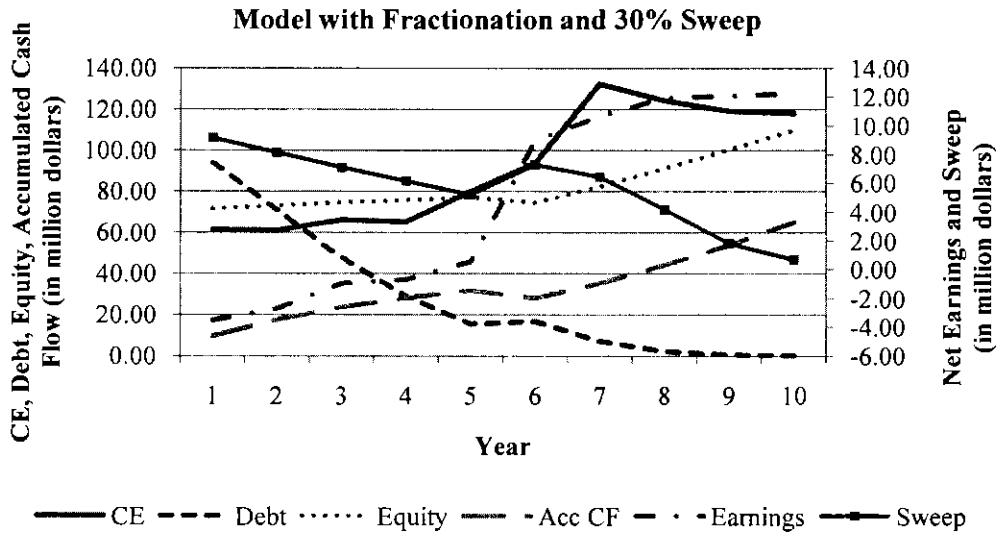
Figure 20. Five-year data series fractionation investment.

Fractionation with 30% Sweep

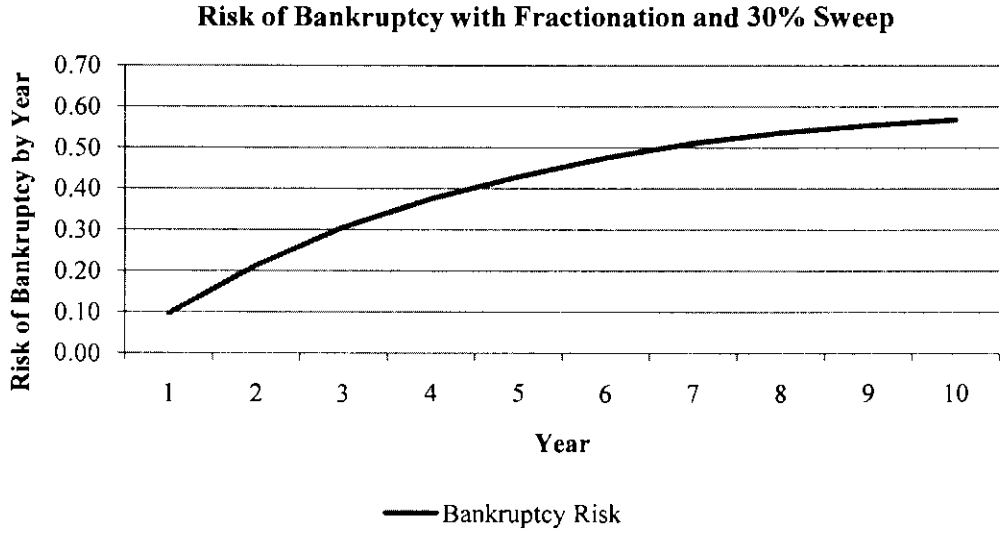
The graph in Panel A of Figure 21 indicates the firm again invested in fractionation after Year 5. The certainty equivalent increased more in Year 7 than Year 6, indicating additional debt payments help the firm achieve greater wealth in future years.

While stressful financial times due to low earnings exist, the firm is still able to invest in dry fractionation. A higher sweep percentage should show that the firm must wait before investing because cash is not available for investment.

As seen when using the total-year data series, bankruptcy risk is lowest with the sweep in place, primarily due to a more rapid decrease in the leverage ratio.



Panel A



Panel B

Figure 21. Five-year data series fractionation investment with sweep.

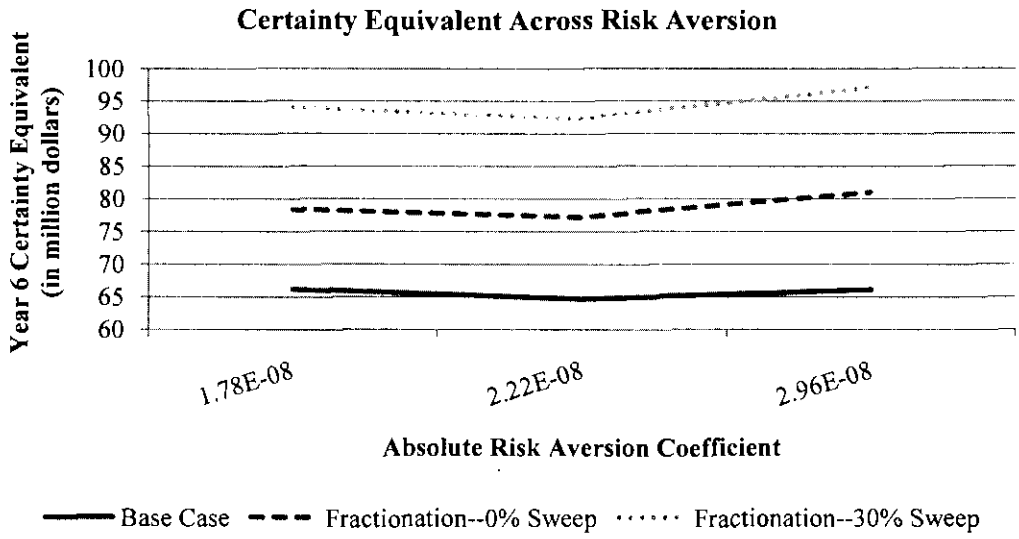


Figure 22. Certainty equivalent values across varying levels of risk aversion.

The certainty equivalent is highest for the firm investing in fractionation when subject to the sweep. This result is reasonable because a firm will expect higher compensation for taking the risk associated with the sweep. A difference when using the shortened data series is that fractionation has a higher certainty equivalent than the base case for each level of risk aversion. In addition, all certainty equivalent values are higher in Year 6 with the shortened data series for each level of risk aversion, indicating higher earnings and equity levels.

Summary

The results show that while ethanol producers are able to build equity, prices received for ethanol and co-products and paid for corn have a major impact on whether the firm earns enough profit to set aside extra cash for investment. Imposing the 30% free cash flow sweep can help the firm accumulate equity in the long run and earn higher profits

because debt is retired early. The sweep causes the firm's certainty equivalent to be higher than without the sweep at all levels of risk aversion, which should encourage a firm to accept a lender's desire to impose the sweep. Tiffany and Eidman (2004) also determined that a sweep was beneficial to an ethanol firm's long-term success because of fast debt pay-down. However, cash is difficult to accumulate with the sweep in place, thus challenging the optimal investment timing. Rather than waiting until Year 6 to invest, an ethanol firm could attempt to invest in dry fractionation as soon as cash becomes available.

Imposing higher values for the free cash flow sweep percentage may show a delay in investment, but would likely not prohibit investment entirely, unless the value reaches 100% of free cash flow. A multitude of alternative levels of the sweep's percentage is one area in which to expand this study. A lender would use this to determine the point at which a sweep would push the firm into bankruptcy or an inability to invest in new technology rather than help reduce debt.

Chapter Six summarizes and discusses conclusions from the thesis and suggests areas for further study.

CHAPTER 6. SUMMARY AND CONCLUSIONS

This chapter summarizes the problem statement, objectives, and results of the thesis, and suggests areas for further study.

Summary of Problem Statement and Objectives

The biofuels industry is constantly evolving to improve efficiency, remain profitable, and satisfy ever-changing demands for "greener" energy. As the United States moves toward more "environmentally-friendly" fuels, efficient ethanol production becomes more important because the evaluation of biofuels contribution to greenhouse gas (GHG) emissions may include both direct and indirect emissions such as producing and transporting the biomass from field to plant. New rules proposed in California may limit the amount of corn ethanol that can be sold in that state because it does not reduce net GHG emissions enough in a full lifecycle analysis.

Dry fractionation is one technology that can help ethanol producers achieve higher levels of efficiency and increase profits. However, tight credit markets and decreasing profitability pose difficulties for firms trying to maintain adequate equity or new investment. Ethanol producers also face difficulty procuring outside investment capital during stressful financial periods. While dry fractionation can help a firm improve its financial standing, investors become nervous about investing in a struggling industry. In addition, lenders require extra debt payments in high-cash flow years, which further strain the firm's ability to retain equity.

The purpose of this thesis was to determine an ethanol producer's ability to maintain sufficient cash flow and equity for investment in such technology subject to lender constraints and individual firm levels of risk aversion.

Summary of Results

A certainty equivalent model was used to determine an ethanol-producing firm's ability to maintain adequate equity for investment in fractionation during stressful financial times, subject to lender-imposed sweeps and risk aversion. Results of the study indicated that while firm profits are low due to high corn prices and low ethanol prices, ethanol producers could retain adequate cash flows and equity to invest in dry fractionation technology. The investment increased firm profits and allowed the firm to increase its equity position relative to debt.

With the imposition of a sweep, long-term equity growth reached higher levels than without the sweep in place. The sweep allowed firm equity to increase faster in later years as debt decreased at a faster rate. However, the optimal sweep percentage is difficult to determine. Many different percentages could be used, but market conditions, the type of business, and individual firms' risk aversion play an important part in determining the optimal sweep percentage. Firm earnings also reached higher levels because interest on debt fell as debt was paid. In addition, having the sweep in place lowered the overall risk of bankruptcy but increased the variance of return on assets.

Varying levels of risk aversion had little effect on the firm's certainty equivalent. However, slight differences were observed between more risk-neutral and more risk averse firms. A more risk-neutral firms' certainty equivalent value was higher than that for more risk averse firms indicating risk-neutral firms receive a higher payment for their willingness to assume some risk. The lender-imposed sweep showed that for a given level of risk aversion, a firm's certainty equivalent is higher to compensate for the additional risk.

An ethanol producer may use this information to plan investment in new technology, specifically dry fractionation. However, while obvious benefits exist from investing, procuring debt and equity financing is difficult during stressful financial times. In addition, a firm must be willing to accept a lender-imposed sweep because it helps build long-term equity and maintain long-run viability. While ethanol producers' earnings are lower when using recent years' price data, the long-term outlook for ethanol producer profits is good, assuming corn and ethanol prices return to "normal" levels.

A more profitable investment opportunity may change cash flow, equity levels, and the sweep's importance. For example, if a firm determined that investing in equities rather than in new technology returned higher profits, future cash flows and ending equity may become more volatile, but would reach higher levels because the firm would not incur additional debt. Under this scenario, the firm will not be waiting to attain a certain debt to equity ratio and would choose to make an investment as soon as possible. However, the sweep will not allow a firm to make as large of investment with the additional debt payments. Assuming the firm is using excess cash to pay off debt and foregoing investment in profitable equities, the firm's long-run equity position will likely be lower due to the lost investments' compounding. A firm must look at opportunity costs before making an investment.

Areas for Further Study

Issues for further study include substituting technologies other than front-end dry-mill fractionation. Other economically feasible technologies include DDGS fractionation, which would produce higher yields of ethanol and increase plant profitability. In addition, extracting corn oil after front-end or DDGS fractionation is another potential revenue

source due to its use as biofuel or food. Firms can use this analysis to determine when they should switch from producing corn-based ethanol to other biomass-based ethanol to meet government guidelines on carbon emissions and if they should build new plants or convert existing plants.

A firm deciding whether to purchase a specific brand of fractionation technology could use this study to choose the best equipment manufacturer. Varying increased levels of ethanol production depending on specific manufacturers may create fine differences in profits or losses. Simulation allows the increase in ethanol production after implementing dry fractionation technology to take an expected increase in ethanol yield and compare it to other manufacturers' profit figures.

Other methods of determining the best investment include stochastic dominance. This analysis is a useful tool to determine the best of alternative investments based on risk by comparing the net present value (NPV) of alternative (or new) investments subject to risk aversion. Real options are useful when determining whether a firm should invest in new or alternative technologies, wait until economic conditions improve, or abandon expansion plans. With real options, a firm determines the optimal time to invest in a new technology given opportunities for profits or losses while accounting for uncertainty (Amram and Kulatilaka, 1999).

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APPENDIX A

Tables of values for total-year data series. All values are in million dollars. Acc. CF denotes accumulated cash flow, CE denotes certainty equivalent.

Table A1. Total-Year Data Series Base Case

Year	Debt	Equity	Earnings	Acc. CF	CE
1	103.36	68.64	-0.85	9.25	55.13
2	97.43	66.13	-0.57	18.27	38.30
3	87.52	64.83	-0.16	27.04	7.48
4	74.77	63.90	-0.03	35.85	-2.84
5	62.74	63.40	0.55	44.51	20.05
6	52.65	63.16	0.72	52.97	29.07
7	44.03	63.52	1.48	61.24	-5.32
8	36.53	63.92	1.58	69.38	40.10
9	29.92	63.83	0.87	77.10	20.33
10	24.02	63.75	0.88	84.55	45.39
Mean	61.30	64.51	0.45	48.02	24.77
Std. Dev.	28.49	1.69	0.82	25.44	20.53
Min	24.02	63.16	-0.85	9.25	-5.32
Max	103.36	68.64	1.58	84.55	55.13
Range	79.34	5.48	2.42	75.30	60.44

Table A2. Total-Year Data Series Fractionation

Year	Debt	Equity	Earnings	Acc. CF	CE
1	103.36	68.71	-0.76	10.21	53.14
2	97.51	66.17	-0.57	21.01	39.55
3	87.74	64.74	-0.31	31.59	17.18
4	75.11	63.93	0.08	41.06	1.21
5	63.11	63.18	0.11	49.10	4.84
6	73.27	53.53	6.22	49.40	21.44
7	63.03	57.26	6.99	61.57	26.92
8	53.11	61.83	7.18	73.21	30.50
9	44.72	66.52	6.85	83.93	50.16
10	37.64	71.26	6.86	93.89	63.75
Mean	69.86	63.71	3.26	51.50	30.87
Std. Dev.	21.83	5.23	3.76	27.02	20.75
Min	37.64	53.53	-0.76	10.21	1.21
Max	103.36	71.26	7.18	93.89	63.75
Range	65.72	17.73	7.94	83.69	62.53

Table A3. Total-Year Data Series Fractionation with 30% Sweep

Year	Debt	Equity	Earnings	Sweep	Acc. CF	CE
1	97.38	68.63	-0.85	6.08	4.10	58.36
2	85.36	66.45	-0.22	5.90	8.95	42.39
3	69.43	65.80	0.56	5.58	13.98	11.77
4	51.31	65.80	1.04	4.92	18.39	-6.49
5	35.10	66.46	1.90	4.39	22.03	-9.09
6	34.18	60.88	6.73	5.62	18.50	45.63
7	21.87	65.77	8.79	5.54	24.23	56.25
8	12.09	71.59	9.39	4.79	30.16	74.55
9	5.37	77.66	9.11	3.27	36.61	73.62
10	1.78	84.02	9.23	2.25	43.31	86.23
Mean	41.39	69.31	4.57	4.83	22.03	43.32
Std. Dev.	33.58	6.80	4.42	1.23	12.11	33.92
Min	1.78	60.88	-0.85	2.25	4.10	-9.09
Max	97.38	84.02	9.39	6.08	43.31	86.23
Range	95.60	23.14	10.24	3.83	39.21	95.32

APPENDIX B

Tables of values for five-year data series. All values are in million dollars. Acc. CF denotes accumulated cash flow, CE denotes certainty equivalent.

Table B1. Five-Year Data Series Base Case

Year	Debt	Equity	Earnings	Acc. CF	CE
1	103.36	71.97	-3.61	4.69	57.77
2	88.90	73.03	-2.94	9.55	59.71
3	73.55	73.21	-2.83	14.71	65.08
4	60.75	73.38	-2.06	19.90	55.55
5	50.49	72.91	-2.03	25.21	58.28
6	42.05	72.41	-1.48	30.25	66.21
7	35.13	72.32	-0.11	35.20	66.14
8	29.59	72.20	-0.33	39.91	68.02
9	24.18	71.45	-0.55	44.35	72.86
10	19.41	71.32	0.03	48.49	69.58
Mean	52.74	72.42	-1.59	27.23	63.92
Std. Dev.	28.40	0.71	1.31	14.96	5.75
Min	19.41	71.32	-3.61	4.69	55.55
Max	103.36	73.38	0.03	48.49	72.86
Range	83.95	2.07	3.64	43.80	17.31

Table B2. Five-Year Data Series Fractionation

Year	Debt	Equity	Earnings	Acc. CF	CE
1	103.4	71.8	-3.5	4.7	61.5
2	89.0	72.7	-3.3	9.6	58.7
3	73.3	73.5	-2.0	14.7	59.7
4	60.7	73.4	-2.1	19.9	58.4
5	50.8	73.4	-1.3	25.0	68.9
6	63.1	68.4	9.3	27.3	78.4
7	54.3	76.0	9.7	45.1	92.4
8	46.5	83.9	10.1	64.6	96.9
9	39.9	91.5	9.7	85.2	103.1
10	34.1	98.8	9.8	106.1	108.1
Mean	61.51	78.33	3.63	40.23	78.61
Std. Dev.	21.75	9.87	6.44	34.38	19.84
Min	34.06	68.36	-3.54	4.73	58.41
Max	103.36	98.83	10.07	106.12	108.10
Range	69.30	30.47	13.61	101.40	49.69

Table B3. Five-Year Data Series Fractionation with 30% Sweep

Year	Debt	Equity	Earnings	Sweep	Acc. CF	CE
1	94.20	71.79	-3.54	9.16	9.50	61.43
2	71.10	73.12	-2.72	8.15	17.64	61.19
3	47.81	74.83	-0.97	7.11	23.77	66.29
4	29.24	75.85	-0.69	6.17	28.34	65.30
5	15.58	77.29	0.56	5.20	31.87	80.01
6	16.80	74.65	8.97	7.30	28.13	94.02
7	7.28	82.32	10.67	6.46	35.33	132.36
8	2.29	91.37	11.95	4.19	44.27	124.34
9	0.61	100.56	12.11	1.83	54.06	119.17
10	0.21	109.72	12.26	0.70	64.97	118.17
Mean	28.51	83.15	4.86	5.63	-1.01	92.23
Std. Dev.	32.53	13.07	6.83	2.70	16.28	28.87
Min	0.21	71.79	-3.54	0.70	-15.91	61.19
Max	94.20	109.72	12.26	9.16	35.81	132.36
Range	93.98	37.93	15.80	8.46	51.72	71.17