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Investment analysis of deferring a farmer owned ethanol plant: using real options

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Investment analysis of deferring a farmer owned ethanol plant – using real options

by

Ramanathan Shunmugavelu

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

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2003

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This is to certify that the master's thesis of
Ramanathan Shunmugavelu
has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

To my father

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1. INTRODUCTION

Over the past decade, there has been a growing interest among United States (US) farmers in owning and operating businesses that further process farm commodities. For example, farmers are creating businesses that convert crops to fuels or process meats and dairy products for higher value specialty markets. Ventures of this type are frequently referred to as farmer owned, value-added (FOVA) businesses. The key driver behind the development of FOVA businesses is to create and capture value through further processing or through product and market development.

One of the most active industry segments for FOVA businesses is biofuels. A significant investment in plants that produce fuel ethanol from corn has occurred over the past decade. There is also an emerging industry that processes vegetable oils and fats into biodiesel/fuel. Both the ethanol and biodiesel/fuel industries have been strongly influenced by public policies that either require the use of these products by consumers or offer financial incentives for investors and consumers.

Although FOVA businesses are a relatively new phenomenon, farmers' creation of businesses to provide services and bargaining power is not. For well over a century, supply and marketing cooperatives have played a key role in commodity merchandising, provision of farm inputs and financing. Cooperatives support farmers in coordinating the purchase of supplies or the marketing of farm produce, thereby improving efficiencies. They increase the

bargaining power of farmers and enable farmers to venture into fields such as processing or value addition that may not be possible by farmers individually. Overall, cooperatives help in improving the net incomes and, ultimately, the economic well being of farmers. In addition, they also strengthen democratic decision-making and leadership development. About 50 percent of the farm cooperatives in the US primarily marketed farm products (USDA, 2001). Marketing cooperatives accounted for 68 percent of the gross business volume of all cooperatives. The dairy and the grain/oilseed sectors accounted for the largest proportion of such cooperatives.

Key Issues in the Success of FOVA Businesses

The process of establishing a FOVA business and making it a success is not easy task. The major issues that contribute to the success of the project include (1) getting the cooperation of members (2) obtaining capital to start the project (3) managing business risks that arise due to changes in markets and those political or policy situations that affect the market of the end product directly.

The first issue is very typical of FOVA businesses. Strong leadership is needed to transform the business idea into reality. Transforming a business idea into a project can take a long time and can be best understood by looking at a real example. Northeast Missouri Grain Processors, Inc. (NMGP) was formed to produce ethanol from corn. The business idea started in 1994 from a discussion of farmers who were also the board members of the Missouri Corn Growers Association. These farmers visited some of the successful ethanol producing cooperatives in Minnesota and North Dakota and wanted to replicate this experience. In

March, 1995 the group filed incorporation papers and at the same time initiated a feasibility study. In September, 1995 the report was reviewed. The positive review helped NMGP to proceed further with site selection. By early September, 1997 the cooperative had a completed business plan. From December 1997 to April, 1997 about 25 meetings were conducted as a part of membership drive. The Board decided that to be a member, one must be a bona fide corn producer and make a minimum investment and supply a specific number of bushels of corn to the plant. A unit of stock was priced \$ 2,500 and required an annual supply of 1,000 bushels of corn. Groundbreaking for the project was held during April, 1999 (USDA, 2001) and the plant began operations in April, 2000 (Great River Economic Development Foundation, 2000). In this case, it took six years to transform the business idea to an operating project.

The second issue is obtaining capital to start a FOVA business. The total capital needed is dependent upon the nature of business, capacity of the project and the seasonality of the commodities used. Typically for many FOVA businesses, the initial composition of capital is 40 percent equity and 60 percent debt. For an investment of \$ 50 million, equity of \$ 20 million is needed. Assuming a 1,000 member involvement in the project, each one needs to contribute \$ 20,000. In addition to equity, farmers also need to commit to providing inputs as seen in the above NMGP example. In addition to equity, the FOVA business is responsible for a debt of \$ 30 million. Lenders look for adequate cash flows and positive net worth before making a commitment in a project. A thorough investment analysis is needed before farmer investors or lenders commit their money.

The third issue, managing business risks – price and production risks, is common to all businesses. However, FOVA businesses are also extremely affected due to changes in political or policy situations. For instance, passing of a particular bill may open up the market for the end product, thereby create a stronger demand for the product.

All the three issues discussed above are inter-related. A change in the political or policy situation that affects the project favorably increases the net present value of the project, thereby increasing the investor returns and improving the membership commitment. A project with a negative net present value now may turn positive in the future or vice versa due to such policy changes. It is difficult to accurately forecast such changes in political or policy situation. Given the long period required to establish a FOVA business, the stake of the farmers and the potentially large impact of policy or regulatory changes, one of the major concerns for producers is how to properly incorporate them into the decision making process.

Investment Analysis of FOVA Businesses

A traditional investment analysis can incorporate probabilities for changes in the political or policy situation and then estimate the net present value. Such a traditional investment analysis has just two outcomes, either invest now if the net present value is positive or do not invest if the value is negative. This approach ignores an important basic feature of project investments i.e. these investments can be postponed. Project investments have three basic features. Project investments are irreversible, can be postponed and their outcomes cannot be determined with certainty. An investment decision is irreversible because committing to an investment kills the option of waiting to invest in the future. The option of waiting is

definitely worth something especially if a major change in political or policy situation is expected. Real options, an alternative investment analysis methodology, can incorporate all these features of project investments directly into an analytical framework.

Real options is a theoretical framework and a set of techniques that apply the theory and the methodologies developed for the financial options markets to the fields of corporate finance (Antikarov). An investment opportunity is akin to a call option. By paying an option value one can buy a call option. The holder of the option has the right but not an obligation to buy the asset. The holder of the call option, by paying an exercise price, can exercise the option and buy the asset. Similarly the investors have the option to invest now or in the future. They can exercise the option by paying the exercise price - the investment expenditure, in return for the asset that has a value - the project. The strike price is akin to the gross value of the project. The payoff, then, is the strike price less the exercise price or the net present value of the project.

The following simple example, adapted from Dixit and Pindyck (1994), compares investment analysis using the traditional net present value method with the real options method.

Assume that a group of farmers are considering a 40 million gallon per year ethanol production project with the following, simple specifications/costs:

- Investment cost: \$ 50 million for a plant with an economic life of 20 years.
- Cost of capital: 8 percent.

- Expected impact of policy change: If a major pending bill is passed (assumed to be a 0.5 probability) then the price of ethanol will be \$ 1.2 per gallon, otherwise it will be \$ 1 per gallon.
- Expected annual revenue: \$ 44 million (expected price per gallon of ethanol - \$1.1, based on a 0.5 probability of the price being at \$ 1.2 and a 0.5 probability of the price being at \$ 1).
- Annual expenses: \$ 40 million.

Based on these assumptions, the expected NPV can be calculated as

$$NPV = \sum_{t=0}^n \frac{CF_t}{(1+r)^t} \quad (1.1)$$

Where 'CF' is the net cash flow for each year

't' = 0 to n (number of periods)

'r' = cost of capital

In the above example,

$$CF_0 = \$ -50 \text{ million}$$

$$\text{Net cash flow per year } CF_1 - CF_{20} = \$ 44 \text{ million} - \$ 40 \text{ million} = \$ 4 \text{ million.}$$

So,

$$NPV = \$ -50 \text{ million} + \sum \frac{\$ 4 \text{ million}}{(1+.08)^{20}} = \$ -10.7 \text{ million.}$$

Based on the expected NPV for this project, the conclusion is do not invest, since the NPV is negative.

The same problem can also be analyzed using a real options approach. In our above example, using a traditional capital budgeting approach, the choices an investor has are to invest now or do not invest on the project. Real options widens the scope of the choices. The choices under real options would be to be to invest now or wait for some period of time until the status of RFS is known and analyze the investment at a later date. Real options can value waiting. The value for waiting arises from uncertainty in the payoff and the possibility to postpone the investment.

Suppose in the above example, using the real options, an investor decides to wait for one year, then the NPV can be calculated as

$$NPV = 0.5Max\left[\sum\frac{CF1_t}{(1+r)^t},0\right]+0.5Max\left[\sum\frac{CF2_t}{(1+r)^t},0\right] \quad (1.2)$$

0.5 is the probability assumed for passing RFS

'CF1' is the net cash flow for each year if the RFS is passed

'CF2' is the net cash flow for each year if the RFS is not passed

't' = 1 to n (number of periods)

$$\begin{aligned} NPV &= 0.5Max\left[\frac{-50}{1.08} + \sum\frac{(48-40)}{(1+0.08)^{20}},0\right]+0.5Max\left[\frac{-50}{1.08} + \sum\frac{(40-40)}{(1+0.08)^{20}},0\right] \\ &= 0.5 [\$ 28.5 \text{ million}] + 0.5[\$ 0 \text{ million}] \\ &= \$ 14.3 \text{ million} \end{aligned}$$

The above equation indicates that the investor has the option to wait, learn about the outcome of the pending bill and invest only if the pending bill is passed. The right hand side of the above equation indicates that there are two possible outcomes, each with its own probability.

In the first outcome, the annual revenue is assumed to be \$ 48 million, corresponding to the price when the bill is passed. This results in a positive net value of the project: \$ 28.5 million. In the second outcome, the annual revenue is assumed to be \$ 40 million, corresponding to the price when the bill is not passed. This results in a negative value of the project. Hence it will not be undertaken. Using the respective probabilities, the NPV of the project is \$ 14.3 million.

The difference between the NPV estimated using the traditional discounted cash flow method and that using the real options gives the premium for the real options, the value for waiting. In this case the value for waiting is \$ 25 million (highly unrealistic!). As long as the option value is greater than the net present value, it is worthwhile to wait. During the waiting period, the farmers can continue with equity drive, site selection, etc., that are not cost intensive. If the option value is less than the NPV and the NPV is positive, then it is worthwhile to invest immediately rather than to wait.

As demonstrated above, real options would seem to be an appropriate tool to analyze investments in FOVA businesses such as biofuels because these projects are affected, in many cases, by changes in political or policy situations. Although theoretical approaches on real options are well developed, application approaches are not. Even if some application techniques are available, their complexity often frustrates practitioners (Antikarov). For example, application of the concept of real options in FOVA businesses is practically non-existent.

Objectives of the Study

The specific problem the thesis will address is how to analyze the investment, using real options, in an ethanol plant, given the uncertainty of a policy change that would significantly influence demand. The specific objectives for the thesis are to:

- (1) estimate the value of delaying an ethanol production project up to one year - using real options
- (2) compare and analyze the value of the project estimated using real options with the value of the project estimated using a traditional cash flow method especially on how they differ over a one year time period.
- (3) Interpret the option value from an investor's point of view

The remainder of the thesis is organized into six sections. The first section describes the ethanol industry including the production process. The second section reviews the literature available on real options. The third section discusses the methodology adopted to calculate the value of a project using real options and discusses an appropriate method for the study. The fourth section discusses the findings of the traditional discounted cash flow analysis including sensitivity analysis. The fifth section discusses the outcome of the real options valuation and compares the findings with that from the traditional discounted cash flow method. The last section presents the summary and conclusions and identifies opportunities for further research.

2. ETHANOL INDUSTRY

Ethanol is a colorless, volatile, inflammable liquid. It can be used as a solvent, an intoxicating agent and a fuel. In the US, it is mainly used as an additive in the automotive fuel. Ethanol is used to increase the oxygen level in gasoline to reduce the impact of automotive emission and to improve the air quality. Until recently, the primary oxygenating agent in gasoline was methyl tertiary butyl ether (MTBE). Recently MTBE has been found to contaminate drinking water. Consequently, there have been attempts to replace MTBE with some other additives, especially ethanol (DiPardo). Ethanol is also used in gasoline in a higher proportion at 10 and 85 percents as it reduces greenhouse gas emissions (DiPardo). Ethanol also increases the octane rating and has anti-knocking properties when added to gasoline. There are some negative qualities of ethanol. Ethanol has high Reid vapor pressure, a measure for volatility, that limits its use under high temperatures. In addition, it also absorbs moisture and hence cannot be transported through pipelines. This affects the way blenders handle, store and transport ethanol.

Production of Ethanol

Ethanol is produced from the fermentation of sugar by enzymes of a specific yeast. Theoretically, any material rich in sugar can be used for the production of ethanol. Sugar cane is a common material used in the production of ethanol in many countries. In the US, corn is the major raw material used. Ethanol can be produced using a dry or a wet milling process. The main difference between the two processes is in the initial treatment of the grain and the feed co-products. In the dry milling process, corn is ground and mixed with water to

form mash. The mash is cooked and enzymes are added to convert starch to sugar. Then yeast is added to ferment the sugars, producing a mixture of ethanol and solids. Ethanol is later distilled and dehydrated. Solids are then dried to produce distillers dried grain with solubles (DDGS). The co-product - DDGS is used as a protein supplement in animal feed. In the wet milling process, the corn is steeped in water to separate the grain into its components namely starch, fiber, gluten and germ. The starch is then processed into ethanol similar to the dry milling process. There are a host of co-products from wet milling process namely corn gluten meal from gluten and corn oil, corn gluten feed from germ (Shapouri, Gallagher, Graboski, 2002 and Renewable Fuels Association, 2002). Most of the co-products from the wet milling process are used as animal feeds.

A few years back, wet and dry milling processes shared equally the total production of ethanol. Over the past five years, dry milling technology has improved significantly resulting in the reduction of capital and operating costs. Consequently, most new ethanol plants employ dry milling technology. In 2002, dry milling facilities accounted for about 60 percent of the total production (Renewable Fuels Association, 2003).

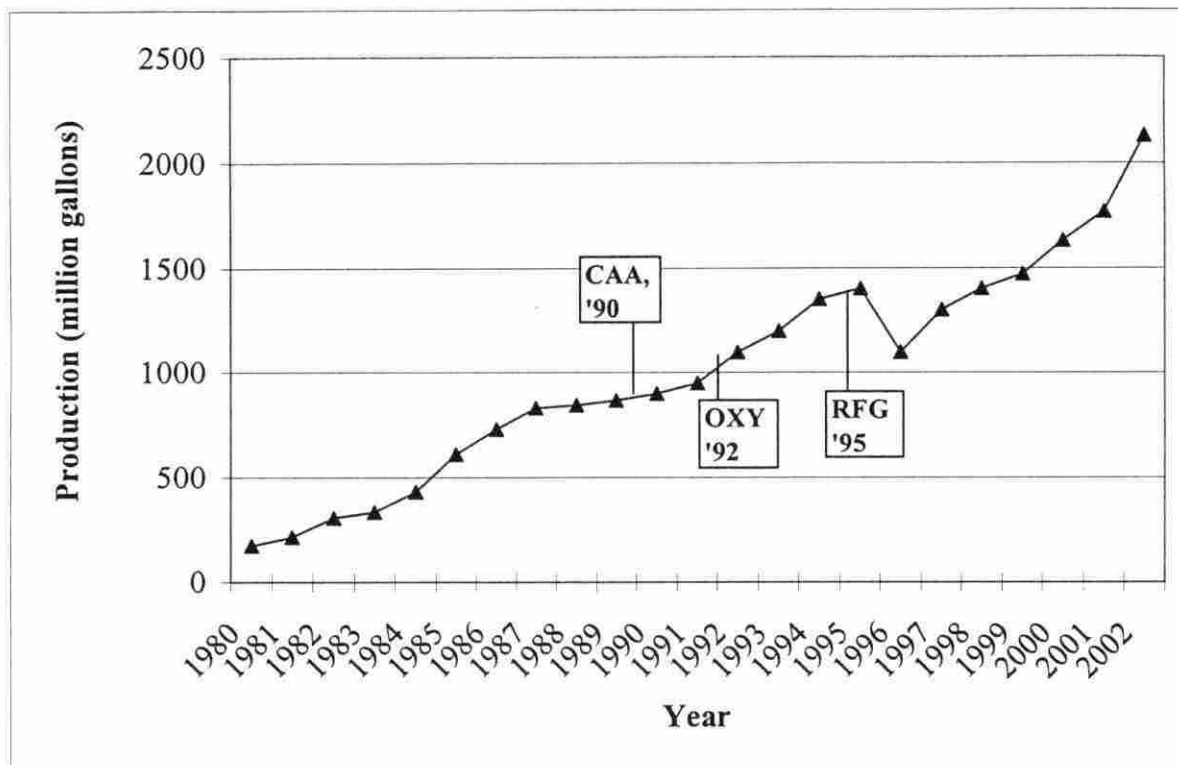
In the US, the ethanol industry is highly concentrated in a few states and with a few investors. The states of Illinois, Iowa, Minnesota and Nebraska have about three fourths of the total ethanol production capacity (Renewable Fuels Association, 2003). The largest eight companies have a market share of 71 percent, largest four have 58 percent of the market. Archer Daniels Midland, the largest producer of ethanol, has a share of 41 percent (US General Accounting Office, 2002). This profile is slowly changing. About three fourths of

the plants being constructed are owned by farmers (Renewable Fuels Association, 2003). The majority of farmer owned plants are smaller capacity dry mills dispersed throughout rural areas.

Government Support to Produce and Use Ethanol

The ethanol industry, as stated earlier, has been highly influenced by government policies. The Clean Air Act had a major impact on the increase in production. In 1990, under the Clean Air Act Amendments, Congress mandated changes in fuel composition through two programs – the Oxygenated Fuels Program and the Reformulated Gasoline Program. The Oxygenated Fuels Program took effect in 1992 and mandated the use of oxygenated fuels in specific regions of the US. Thirty-nine metropolitan areas were originally selected under the program, though currently less than half remain in the program (Sparks Companies and Kansas State University, 2002). The purpose of this program is to reduce the carbon monoxide content during winter months to a minimum of 2.7 percent oxygen by weight in these specific regions. The Reformulated Gasoline Program (RFG) is primarily targeted at reducing ground-level ozone pollution. It took effect in 1995. Specific regions including areas in and around Baltimore, Chicago, Hartford, Houston, Los Angeles/San Diego, New York/Philadelphia and San Diego came under RFG program (US General Accounting Office, 2002; Sparks Companies and Kansas State University, 2002). Gasoline sold in these regions is required to have a minimum average oxygen content of 2 percent by weight.

These programs significantly supported the production and use of ethanol. The graph, below, shows the production of ethanol over the last two decades along with major policies related to ethanol. The abrupt drop in ethanol production in 1996 was due, in part, to a surge in the price of corn.



Source: US Energy Information Administration, Renewable Fuels Association

Figure 1. Production of Ethanol since 1980

It is evident that whenever there was a major policy change, ethanol production appears to have responded. During the late 1980s, the ethanol production reached a low compound annual growth rate of 2.7 percent. After the Clean Air Act Amendments in 1990, the growth rate increased. From 1992 to 1995, giving a two-year lag for the response, the compound annual growth rate increased to 8.4 percent. The period 1997 – 2002 witnessed the combined

effect of Oxygenated Fuels Program (OXY '92, as mentioned in the graph) and Reformulated Gasoline Program (RFG '95). The compound annual growth rate during this period increased to 20.0 percent.

Recognizing the importance of ethanol, as well as the intense lobbying effort of farmer and established ethanol producers, federal and state governments have been supporting production of ethanol through various tax incentives. Currently, there are three tax incentives for the production and use of ethanol (Sparks Companies and Kansas State University, 2002). The first one is the exemption of 10 percent ethanol blends from the federal excise tax on each gallon of fuel. This amounts to \$ 0.53 per gallon of ethanol. In addition, ethanol-gasoline blends consisting of 7.7 percent and 5.7 percent, corresponding to 2.7 and 2.0 percents of oxygen also receive prorated exemption. The second incentive is income tax credits associated with ethanol. There are three categories within income tax credits. The first category is similar to the excise tax exemption. Alcohol blenders receive an income tax credit of \$ 0.53 per gallon of ethanol used to produce fuel. The second category is a straight alcohol credit. It applies to mixtures of 85 percent or more alcohol. The tax credit is again \$ 0.53 per gallon of ethanol used. The third category is the small ethanol producer's credit. The credit is \$ 0.10 per gallon of ethanol produced, used or sold for use as motor fuel. This credit is limited to 15 million gallons of annual alcohol production. The third incentive is a new federal tax deduction for individuals or businesses that purchase vehicles using clean-fuels. In addition, there are incentives in the form of the Federal Bioenergy Program and Federal Biomass Energy Programs through US Department of Agriculture and Department of Energy for research on and production of biofuels. In addition, the government supports the domestic

production of ethanol by imposing an import tax of \$ 0.53 per gallon (US General Accounting Office, 2002).

As of July 2001, sixteen states provided additional incentives, chiefly in the form of state excise tax exemptions or producer credits. For instance Iowa pays an incentive of \$ 0.01 per gallon of ethanol in the form of excise exemption and on the other extreme, Wyoming pays a producer payment of \$ 0.40 per gallon of ethanol produced (Sparks Companies and Kansas State University, 2002).

Pending Bills on Ethanol Industry

The Renewable Fuels Standard (RFS) is the major bill that would significantly affect the demand for ethanol. The RFS essentially replaces the air quality standards with a simple requirement that renewable fuels will be part of US energy supplies. The proposed start date for the RFS is January 2004. Should the RFS pass in its current form, the use of renewable fuels (largely ethanol and to a lesser extent biodiesel) is expected to gradually increase two fold to 5 billion gallons a year by 2012. This could increase corn utilization in ethanol by 1 billion bushel per year by 2012 (Energy Information Administration, 2002). This would also affect the prices of ethanol, corn and related co-products.

In mid-2003, there were 15 other bills pending at various stages of passage. These bills aim at promoting energy security and energy conservation or providing more incentives or providing environmental protection or eliminating MTBE. A few of them propose increasing tax incentives or providing producer credit (Renewable Fuels Association, 2003). All these

bills could have an impact in the future demand and production of ethanol. There is no study that has dealt with the impact of all these bills. It is also not known if these bills would be passed and if they do when they would become effective. The key point remains that the demand for ethanol and its cost of production will continue to be influenced by political action in the foreseeable future.

3. LITERATURE REVIEW

Trigeoris (2001) and Schwartz and Trigeoris (2001) give the history and overview of real options. The initial part of the literature review is the summarized version of their overview. Dean (1951), Hayes and Abernathy (1980) and Hayes and Garvin (1982) have argued that the traditional discounted cash flow method often undervalued investment opportunities. The assumptions of the discounted cash flow analysis lead to its limitations (Dixit and Pindyck, 2001). It assumes that the project is reversible, that is, assets can be sold easily once an investment is made. The second assumption is that, if the project is irreversible, then it is a now or never proposition. It also assumes that the construction or operation of the project will begin at a fixed point in time, and it is usually the present. Discounted cash flow analysis assumes that once a decision to invest is made, the project starts initial activities and generates cash flows without any provision for contingencies.

Origin of Real Options

In order to correctly use cash flow methods, one must estimate the discount rate, the future cash flows, the project's impact on other assets of the firm and estimating the firm's impact on future investment opportunities or the time-series link among projects. All the problems except the last one can be handled with proper capital budgeting techniques. The last problem is a serious one, for which discounted cash flow will not help much. The last problem is similar to a series of options. A firm has to decide how and when it is going to invest. An option valuation is a much better tool to analyze this rather than a discounted cash

flow. Trigeoris and Mason (1987) explained that option valuation is like an economically corrected version of decision tree analysis. And it is better suited to value a variety of corporate options. Teisberg (1995) provided a comparison of discounted cash flow, decision tree analysis and real options.

The major conclusion of these studies is that real options is potentially a better tool compared to traditional discounted cash flow analysis. The traditional analysis has limitations in incorporating some realistic, but complex issues. Using a real options approach to value projects has some important advantages. It takes into account all the flexibilities that the project has. It uses all the information contained in the market prices. It also allows, using the powerful analytical tools developed in contingent claims analysis, to determine both the value of the project as well as optimal exercise point.

Pricing real options, of course, originated from the concept of pricing financial options. Black and Scholes (1973) and Merton (1973) are the pioneers in developing the theory for option pricing. Cox, Ross and Rubinstein (1979) developed a simplified binomial approach to value options. The basic premise of option valuation comes from the fact that an option can be combined with an equivalent portfolio of traded securities to make it risk neutral. Mason and Merton (1985), and Kasanen and Trigeoris maintain that real options can be valued in a manner similar to the valuation of financial options.

Initial attempts to apply real options theory were made by Brennan and Schwartz (1985) to value natural resources - mines. The spot price of the commodity was assumed to follow

geometric Brownian motion. This helped the direct application of financial option pricing to value real assets. The assumption that the commodity spot price followed geometric Brownian motion had some disadvantages. Specifically, the assumption of Brownian motion implies that the volatility of all futures returns is the same as the volatility of the spot prices. However, this is not the reality. The volatility changes significantly depending upon the maturity of the option. Geometric Brownian motion implies that the variance of the distribution of spot prices grows linearly with time. In reality, supply and demand adjust with respect to the changes in prices.

In most capital investments, the sources of uncertainty arise from non-traded state variables such as the policy risk facing the project as expressed by the volatility of the project value. Cox, Ingersoll and Ross (1985) used the inter-temporal capital asset pricing model and derived a fundamental partial differential equation that can be used to value projects whose uncertainties are from non-traded state variables. They, among others, suggest that any contingent claim on an asset, whether traded or not, can be priced in a world with systematic risk by replacing the actual growth rate with a certainty-equivalent rate and then behaving as if the world were risk-neutral.

This study focuses on application of real options to defer a project investment. There is limited literature available on the applications of real options. The option to defer has been examined by McDonald and Siegel (1986). They present a case in which they assume both the present value of benefits and the investment cost follow geometric Brownian motion. They also assume that the present value could jump discretely to zero. Then they go on to

present examples of the option values of the project for a wide variety of parameters. They assume a one-time lump sum investment. The standard deviations of the project they have used range from 0.10 to 0.30. Though it is an application of real option, they have not focused on any particular industry in their example. Of course, the major limitation of the study is the assumption that the present value and investment of the project follow geometric Brownian motion.

The other major paper that focuses on application of real options on investment is by Majd and Pindyck (1987). The major difference between this paper and the earlier described above is the duration of the investment process. Majd and Pindyck focus on a sequential investment typically over a five or six year period. This is particularly relevant for industries that have a longer horizon to complete a project, such as mining. A major feature of such projects is that the pattern of expenditures can be adjusted in response to the changes in the environment.

Merton (2001) mentions that studies have been done in developing models in pharmaceutical, power and movie industries. Copeland and Antikarov (2001) present a list of companies that have employed real options. The majority of the firms are petroleum companies, especially in oil exploration and development.

Numerical Techniques

As discussed earlier, there are disadvantages in directly applying the financial option theory to value real options. The chief one is the assumption of geometric Brownian motion of the variables. This assumption may not be applicable for projects. Hence an alternative valuation technique, using numerical methods, started to attract researchers. There are two categories

of numerical techniques. The first category approximates the stochastic process directly and uses Monte Carlo simulations. The second category approximates partial differential equations.

Cortazar (2001) gives a comparison of numerical techniques. He starts by saying that most real projects are complex and cannot be solved using analytical approaches. Hence numerical techniques offer a better way to value these complex, real projects. The three major numerical techniques are binomial trees, Monte Carlo simulations and finite difference methods. As mentioned above, the binomial tree method was originally developed by Cox, Ross and Rubinstein (1979). One major limitation of the binomial tree method is the need to assume that uncertainty, at any time, can be represented by two distinct states. The advantage of using a binomial tree is that it is easy to understand and apply. It can also be used to value American options - options that can be exercised anytime until expiry. Most real options are American options.

Monte Carlo simulation, as developed by Boyle (1977) is an excellent alternative, where assumptions regarding uncertainty or price movements are not necessary. But the original approach cannot be used for American options. Recently modified Monte Carlo simulation approaches have been suggested for valuing American options.

The finite difference method is the third numerical valuation technique. This method was originally developed by Schwartz (1977). This method approximates the partial difference equation that represents the valuation equation. The finite difference can either follow an

implicit or explicit method. Details of finite difference methods are explained in the next section.

Application of Real Options in FOVA Businesses

The literature on applications of real options in FOVA businesses is practically non-existent. One of the papers on this topic is a case study of a cooperative investing in a corn based tortilla chips project authored by Bailey and Sporleder (2000). This is the only published real options analysis that is available on corn processing. As a new generation cooperative gets up-front capital commitment by members, the authors argue that the capital decision should be made in phases rather than in one initial go or no-go decision. Investment in two phases helps the cooperative to buy the land during the first year and if the commitment of members and all other necessary issues are sorted out then it can go ahead with further investment in the second year. They analyze this for two different plant sizes. The authors use the Black-Scholes options valuation method assuming an ad hoc project volatility. They use this approach mainly because of its simplicity. Their major conclusion is that real options can be used to value such flexibilities as two stage investment that a traditional discounted cash flow analysis can not do. This is very much needed for a new generation cooperative, as a stage-wise implementation of the project is a normal process. They also conclude by stating “if the overall application of real options is in its relative infancy then the use of real options applied to cooperatives is barely past conception” (Bailey and Sporleder, p18).

A second study on real options in agriculture, more specifically on cooperatives, is by Sporleder and Zeuli (2000). This study analyzes a farmer’s options to invest now or wait and

invest later on a new generation cooperative that would process tomatoes into paste. The study focuses on theories related to real options and compares it over traditional net present value method. They state that the uncertainty can stem from technical factors, input costs and external factors. Once again, the authors propose the use of the Black-Scholes method to value the option. They conclude that the presence of uncertainty increases the value of waiting. They also conclude that as the variance in the net value of the project increases, the value to wait increases. They argue that real options provides the value of the project over a time horizon, which can not be done using the traditional net present value method. Real options also helps value uncertainties. Finally, real options can use the same theory that has been developed for financial call option. Most of the theoretical conclusions drawn in this study have been dealt with in earlier studies. The most interesting part is that the concept of real options can be used by cooperative members to measure the value of waiting.

The third paper by Turvey (2001) is based on a previously written case study of a biotechnology and seed company, Mycogen. The company is at a turning point and analyzes which direction it should take. It can grow adopting one of the following strategies: mergers and acquisitions buying highly contested assets at high prices or continue its earlier approach. The earlier approach followed either by networking and accessing strategic assets through alliances or focusing on internal growth. Using the qualitative aspects of real options, the author provides a candidate solution to Mycogen's problem. He analyzes the uncertainties facing the company and concludes that they are inter-related. Hence the growth of Mycogen is driven by a series of options, one option leading to new and different options, termed as compound options. The author concludes that uncertainties and expected cash flows are also

inter-related. The company should rank the different paths depending upon the uncertainties and the expected cash flows for each path and go for the best path.

Key Issues from the Review

As seen from the literature review, it is amply clear that none of the papers have dealt with the issue on which this thesis focuses. The closest is the paper by Bailey and Sporleder (2000) where the cooperative has to value the option of waiting for one year after investing on the land. Here the authors have chosen the Black-Scholes method to value the option because of its simplicity. In fact all the application papers mentioned in the review employ Black-Scholes methodology. As discussed earlier, it is doubtful if the project values would follow geometric Brownian motion. Instead a numerical technique is definitely better suited to value such options though it is more complicated than the Black-Scholes method.

The other key issue that remains open is the estimation of project volatility. Most papers have assumed an ad-hoc volatility from 0.10 to 0.30. In the corn processing paper by Bailey and Sporleder (2000), the authors assume a volatility of 0.20. There is limited evidence of a practical method to value project volatility. As Copeland and Antikarov (2001) mention, estimation of project volatility is frequently made incorrectly due to simplistic assumptions. This topic is dealt with in detail in the next section.

Resolving the method for valuation and estimation of volatility are, then, the key issues that face the application of real options. The next section focuses on several approaches for resolving these issues.

4. METHODOLOGY

The key question of the study, as discussed in the introductory section, is how to analyze the investment in an ethanol plant, given the situation of a pending policy outcome such as RFS. The expected outputs of the study are the net present value of the project and option value of the project over a one-year time period. The net present value can be obtained from a standard discounted cash flow analysis. The option value of the project involves several steps. Copeland and Antikarov (2001) advocate a four-step process to value real options. The first step computes the base case present value using traditional discounted cash flow method. The second step models the uncertainty. This step is to estimate how the present value develops over time. The third step identifies and incorporates managerial flexibilities and the fourth step conducts the real options analysis/valuation.

In this study there were three steps followed. The first step was maintained as above: a standard discounted cash flow analysis was done on the ethanol project. The second step modeled and incorporated uncertainties and also calculated the project volatility. In this step, price volatilities were built in and volatility of the project was calculated using Monte Carlo simulation. The final step valued the real options using the finite difference method. The paragraphs that follow start with a description of step three and then go on to describe steps one and two.

Finite Difference Method

As discussed in the earlier section, a real option is similar to a financial call option. In a financial call option, the holder that buys the option paying an option value and receives the right but not an obligation to buy the underlying asset. The option value of the financial option is calculated generally using a Black-Scholes formula. One of the major assumptions in this approach is that the price of the underlying asset follows a geometric Brownian motion. This assumption may not be applicable to project situations. Hence a numerical technique is a more appropriate method to value real options of projects. This is mainly due to the fact that numerical methods do not assume any particular price movements. This study adopted Monte Carlo simulation to determine the volatility of the project and used the finite difference method to value the real options.

Process of Deriving the Finite Difference Equation

The basic premise of option valuation comes from the fact that an option can be combined with an equivalent portfolio of traded securities to make it risk neutral. Cox, Ingersoll and Ross (1985), among others, suggest that any contingent claim on an asset, whether traded or not, can be priced in a world with systematic risk by replacing the actual growth rate with a certainty equivalent rate and then behaving as if the world were risk-neutral. Typically, a partial differential equation is used to solve for option valuation. The partial differential equation basically describes the changes in option values to the changes in the underlying asset value. In finite difference method this partial differential equation is approximated. The finite difference method is not intuitive.

The partial differential equation (Hull, 2002 and Cortazar, 2001) used in the approximation is

$$\frac{\partial H}{\partial t} + rV \frac{\partial H}{\partial V} + \frac{1}{2} \sigma^2 V^2 \frac{\partial^2 H}{\partial V^2} = rH \quad (4.1)$$

where H = option value of the project

t = time

V = Gross project value

σ = volatility (standard deviation in one year)

of the project value

r = risk-free interest rate

The finite difference method employs a grid approach to approximate the above differential equation to arrive at the option values. The grid has time and project values as the x-axis and y-axis respectively. The notation $H_{i,j}$ denotes the option value at i^{th} time ($i=1, \dots, M$) and j^{th} project value ($j=1, \dots, N$) on the grid. Suppose 'i' is from 1 to 12 (M) and 'j' is from 1 to 20 (N), and each interval on x-axis (δt) is 1 month and each interval on y-axis (δV) represents \$ 10 million, then the grid would appear as follows:

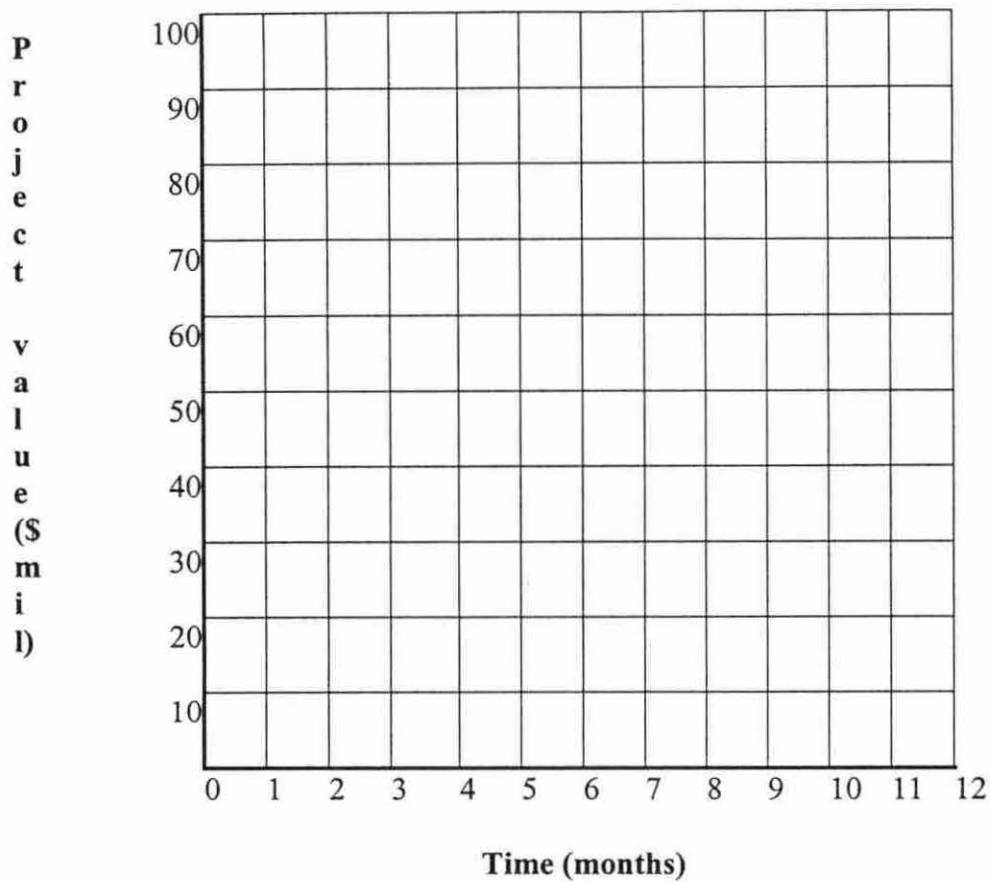


Figure 2. The Option Valuation Grid

Given this grid, $H_{5,7}$, for example, indicates the option value at the end of fifth month and when the project value is \$ 70 million ($j\delta V$ or 7×10).

The first, second and the third terms on the left hand side of the partial differential equation are approximated to find the change in option value for a unit change in project value and for a unit change in time period and the rate of change in option value for a unit change in project value respectively. The type of approximation used determines the type of finite

difference method. The approximation can be forward if the past option values are used to estimate the future option values. It can be backward if the future option values are used to estimate the past option values. In the implicit type, the forward approximation is used and in the explicit type, the backward approximation is used. These two types are discussed in the next sub-section.

The backward approximation of the first, second and third terms of the partial differential equation are given below. The first term is approximated as:

$$\frac{\partial H}{\partial V} \cong \frac{H_{i+1,j+1} - H_{i+1,j-1}}{2\delta V} \quad (4.2)$$

The second term is approximated as:

$$\frac{\partial H}{\partial t} \cong \frac{H_{i+1,j} - H_{i,j}}{\delta t} \quad (4.3)$$

The third term is approximated as:

$$\frac{\partial^2 H}{\partial S^2} \cong \frac{H_{i+1,j+1} + H_{i+1,j-1} - 2H_{i+1,j}}{\delta S^2} \quad (4.4)$$

These terms are then substituted in the differential equation and rearranged to obtain the finite difference equation as described in the next sub-section. Once the option values are known at some nodes, the approximated equation can be used to estimate the option values at other nodes.

Types of Finite Difference Methods

Depending upon the approximation, there are two different finite difference methods for valuing options. The implicit finite difference solves for the current option value based on

past option values, i.e., forward approximation, and the explicit finite difference solves for the current option value based on future option values, i.e., backward approximation. This is amply clear in the following equations as adapted from Hull (2002) and Cortazar (2001).

The equation for implicit finite difference approximation is

$$a_j H_{i,j-1} + b_j H_{i,j} + c_j H_{i,j+1} = H_{i+1,j} \quad (4.5)$$

where $H_{i,j}$ = option value at i^{th} time and $j\delta V$ (if $j=7$ and

$\delta V = 10$, then $j\delta V = 70$) project value

$$a_j = \frac{1}{2} r j \delta t - \frac{1}{2} \sigma^2 j^2 \delta t \quad (4.6)$$

$$b_j = 1 + \sigma^2 \delta t + r \delta t \quad (4.7)$$

$$c_j = -\frac{1}{2} r j \delta t - \frac{1}{2} \sigma^2 j^2 \delta t \quad (4.8)$$

r = risk-free interest rate

δt = time interval

σ = volatility (standard deviation in one year)

of the project value

The option value at the fifth month is calculated using the option values of the fourth month – a forward induction approach. In this case, a, b and c are weights given to the option values of the previous months.

The equation for explicit finite difference approximation is

$$H_{i,j} = a_j^* H_{i+1,j-1} + b_j^* H_{i+1,j} + c_j^* H_{i+1,j+1} \quad (4.9)$$

where $H_{i,j}$ = option value at i^{th} time and $j\delta V$ (if $j=7$ and

$$\delta V = 10, \text{ then } j\delta V = 70)$$

$$a_j^* = \frac{1}{1+r\delta t} \left(-\frac{1}{2} rj\delta t + \frac{1}{2} \sigma^2 j^2 \delta t \right) \quad (4.10)$$

$$b_j^* = \frac{1}{1+r\delta t} (1 - \sigma^2 j^2 \delta t) \quad (4.11)$$

$$c_j^* = \frac{1}{1+r\delta t} \left(\frac{1}{2} rj\delta t + \frac{1}{2} \sigma^2 j^2 \delta t \right) \quad (4.12)$$

r = risk-free interest rate

δt = time interval

σ = volatility (standard deviation in one year)

of the project value

The option value at the fifth month is calculated using the option values of the sixth month – a backward induction approach. Consequently, a^* , b^* and c^* are weights given to the option values of the following months.

Solving for the Option Values

To solve for the option values, the values at the right (zero time to maturity or in the above grid, when $i=12$), bottom (when the project value is zero) and top (when project value is at the maximum) edges of the grid should be solved first as follows:

The value of the call option at zero time to maturity is

$$H_{N,j} = \max(j\delta V - I, 0) \quad (4.13)$$

where δV = interval in project value or

$j\delta V$ = maximum project value on the grid

I = investment expenditure

($H_{N,j}$ is the net present value of the project if it is positive or zero)

The value of the call option when the project value is zero is

$$H_{i,0} = 0 \quad (4.14)$$

The value of the call option when the project value is at the maximum is

$$H_{i,M} = j\delta V - I \quad (4.15)$$

In other words, the assumption is that one exercises the option when the project value is at the maximum.

After the values at the edges are calculated, either implicit or explicit equations can be used to solve for values at other nodes on the grid. If the implicit approach is followed, there will be a set of simultaneous equations to be solved. If the explicit approach is used, the option value at each node can be calculated using three values from the future time period. The implicit approach is more efficient. It converges to the solution of the differential equation depending upon the project and time intervals used. The disadvantage is that, depending upon the grid size, many simultaneous equations need to be solved. The explicit approach is simpler.

Log Transform Approach

In the finite difference method, it is possible for a_j^* or b_j^* or c_j^* to be negative. A negative value could lead to difficulties in option valuations including negative option values. Hull (2002) mentions that it is computationally more efficient to use log-transformation. Hence a $\ln V$ (log of project value), rather than V , would be more appropriate in the finite difference method. Using $Z = \ln V$, the finite difference equation for the explicit method becomes

$$H_{i,j} = \alpha_j^* H_{i+1,j-1} + \beta_j^* H_{i+1,j} + \gamma_j^* H_{i+1,j+1} \quad (4.16)$$

$$\text{where } \alpha_j^* = \frac{1}{1+r\delta t} \left(-\frac{\delta t}{2\delta Z} (r - \sigma^2 / 2) + \frac{\delta t}{2\delta Z^2} \sigma^2 \right) \quad (4.17)$$

$$\beta_j^* = \frac{1}{1+r\delta t} \left(1 - \frac{\delta t}{\delta Z^2} \sigma^2 \right) \quad (4.18)$$

$$\gamma_j^* = \frac{1}{1+r\delta t} \left(\frac{\delta t}{2\delta Z} (r - \sigma^2 / 2) + \frac{\delta t}{2\delta Z^2} \sigma^2 \right) \quad (4.19)$$

r = risk-free interest rate

δt = time interval

σ = volatility (standard deviation in one year)

of the project value

Z = log of the gross project value

In this study, the log transform, explicit approach was used so that the outcome is more efficient. The option values were calculated for a time period of one year, divided into twelve equal units representing months. Once the option values were calculated they were compared with the boundary condition. Each value of $H_{N-1,j}$ was compared with $j\delta V-I$. If $j\delta V-I$ is

greater than $H_{N-1,j}$ then an early exercise was preferred and the final option value was adjusted to represent $j\delta V-I$. This step represents the American option meaning that the option can be exercised at any time before the total time frame of one year.

Inputs Needed to Calculate the Option Value

The inputs needed to calculate the option values using equation 4.16 are the (1) risk free interest rate (2) time interval (3) gross value of the project and (4) volatility of the project. The first two inputs are assumed inputs. The inputs that need to be calculated are the gross value of the project and the volatility of the project. The gross value of the project was calculated using a traditional discounted cash flow method as described in the paragraphs that follow. The project volatility was estimated using a Monte Carlo simulation.

Discounted Cash Flow Model of the Project

The discounted cash flow analysis was performed using a multi-year financial model of the ethanol plant. The model combines technical, financial and price information and generates income and expense statement, balance sheet and cash flows and gross present value of the project over a twenty year time horizon.

Most assumptions on technical and financial aspects were adapted from the USDA's 1998 Ethanol Cost-of-Production Survey (Shapouri, Gallagher and Graboski, 2002). Price assumptions are discussed under a separate sub-section – Price Simulations. Standard yield rates were assumed for ethanol and DDGS; ethanol in terms of one bushel of corn and DDGS in terms of one gallon of ethanol. The gross value of the project was needed for the

calculation of option value. Hence the investment expenditure was not part of the gross value calculation. At the last stage of the option value calculations investment expenditure was accounted for. The investment expenditure is the exercise price in real options. If the real option is exercised, then an investment decision has been made.

As indicated earlier, the inputs needed to calculate the option values are the gross value of the project and the project volatility. Once the gross value was calculated as discussed in this sub-section, the project volatility was calculated as detailed in the paragraphs that follow.

Calculating the Project Volatility

Copeland and Antikarov (2001) mention some of the common mistakes in calculating the project volatility. One major mistake is using the output price volatility or volatility of stock price as a surrogate for project volatility. Another mistake is attempting to include too many uncertain factors in the analysis. They advocate limiting the sources of uncertainty as most of the volatility of a project can be traced to two or three sources.

Project volatility can be defined as the standard deviation of project value in a unit time. The unit time in this study is considered to be one year. A simple method to calculate the project volatility, as given below, is to calculate the standard deviation of 'r' in the following equation:

$$PV_t = PV_0 e^{rt} \quad (4.20)$$

where PV_t = Present Value of the Project at time 't'

PV_0 = Present Value of the Project at time '0' i.e, now

r = rate of return

t = time period

The above equation can be rewritten as

$$rt = \ln\left(\frac{PV_t}{PV_0}\right) \quad (4.21)$$

For $t=1$, the above equation becomes

$$r = \ln\left(\frac{PV_1}{PV_0}\right) \quad (4.22)$$

The standard deviation of 'r' when $t=1$ is, then, the volatility of the project. The procedure given above is similar to the one suggested by Hull (2002) for estimating the volatility of prices that is discussed later in this section. Two financial models were specified. One reflected prices and costs during the base year. The second model was set up to calculate the present value of the project one year later, PV_1 . All the model inputs at time $t=1$ were similar to the model inputs at time $t=0$ except for the prices of ethanol and corn. It was assumed that both these prices would gradually increase reflecting the gradual increase in the use of ethanol that would result from the implementation of the proposed Renewable Fuels Standard. The actual prices used in the model are provided in the later sections.

In the above equation, the subject of interest is the standard deviation of 'r' and not 'r' itself. As mentioned earlier, the standard deviation of 'r', the volatility, is an input for option value calculation. The volatility of the project is the result of the combination of volatilities of the

prices. Volatilities of prices were calculated based on the historical data of the last ten years. These price volatilities and various other inputs were combined with the future prices to simulate the future price paths. As a result, each iteration in the simulation used a different price path and the project volatility was calculated at the end of the simulation.

Price Simulation

The model used Monte Carlo simulation using @RISK, Excel add-in software to simulate price paths. @RISK uses the distribution type of the variable and some minimum inputs, such as the expected value and the standard deviation, and simulates random values for the variable. Additional inputs such as correlation among the prices, changes in volatilities refined the simulation paths. These were estimated using the last ten-year average monthly prices. The sources of the data were Nebraska Ethanol Board for ethanol prices, Economic Research Service, USDA for the prices of DDGS and Iowa Department of Agriculture and Land Stewardship for the prices of corn. Following Hull (2002), price volatilities were estimated as:

$$\hat{\sigma} = \frac{s}{\sqrt{\tau}} \quad (4.23)$$

$$\text{where } s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (u_i - \bar{u})^2} \quad (4.24)$$

$$u_i = \ln\left(\frac{S_i}{S_{i-1}}\right) \quad (4.25)$$

τ = length of time interval in years

S_i = price at the i^{th} time

The above formula is similar to the one that estimates the project volatility. The standard deviation of 'u_i' per unit time is the volatility of prices.

In addition, annual volatilities, using one year data at a time, were calculated. Using ten years of data, there were ten annual volatilities. Using these ten annual volatilities, the annual standard deviation (volatility) of volatilities was estimated. The manually input expected prices, annual volatilities and the standard deviations of volatilities were then used to simulate the prices. The expected prices were based on the studies as described later in this section. The @RISK software used the expected prices, combined them with the volatilities and the standard deviations of volatilities and simulated the price paths for analysis.

Normality of prices was an assumption made in simulation. To test the normality assumption, Shapiro-Wilk goodness-of-fit (W) tests were conducted on the average prices and the annual volatilities. The Shapiro-Wilk W test was used, because the number of observations in each case was less than 2,000. A specification of standard deviation of prices was made to select the values within a band. In addition, correlations between ethanol and DDGS, ethanol and corn, and DDGS and corn were also estimated. The correlations were also used to restrict the prices in each iteration.

Such a detailed price specification resulted in price paths that are more realistic than typical price paths assumed in many future cash flow studies. Figure 3 provides an example of two randomly simulated price paths used in actual analysis.

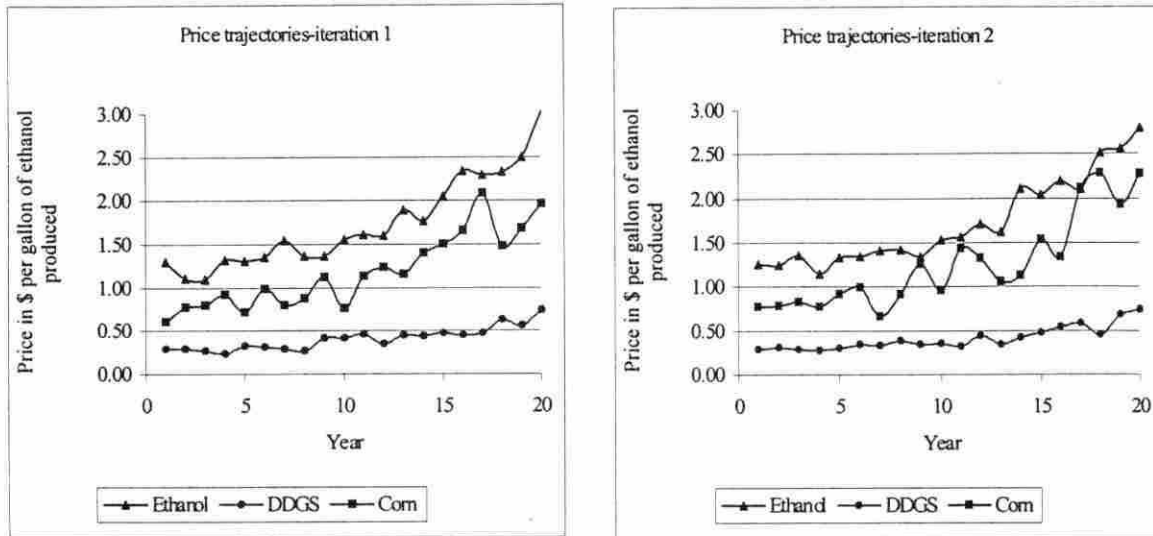


Figure 3. Examples of Simulated Price Trajectories

The initial prices for the simulations were based on the currently available information on prices for ethanol, DDGS and corn. However, one major challenge in the model was deciding on the future, expected prices. Even the current prices of ethanol are not publicly available unlike those of corn. Information on forecast prices of ethanol was much more difficult to obtain. Preparing a separate model for forecasting the price of ethanol was not within the scope of this thesis. As a consequence, existing studies on forecast price paths were analyzed and the most appropriately forecast prices were used for simulations. The paragraphs that follow describe the studies that were analyzed to source expected future prices.

One study that provided a future price path for ethanol is Dipardo's Outlook for Biomass Ethanol Production and Demand (DiPardo). This study used the National Energy Modeling System to analyze prices under various technological scenarios, assuming either a

continuation of the federal ethanol subsidy through 2020 or expiration of the subsidy in 2008. The National Energy Modeling System forecasts energy markets for a period of twenty years. The model forecasts the production, imports, conversion, consumption and prices of energy. The Petroleum Market Model is a component of the National Energy Modeling System. The Petroleum Market Model includes forecasting ethanol supply. Unfortunately the focus of the study is the impact of technology on ethanol production and does not incorporate the impact of the Renewable Fuels Standard.

The second and perhaps more useful study is by Gallagher et al on the effects of growing markets and Renewable Fuels Standards on additives markets and ethanol industry. This study compares the baseline markets with two scenarios. The first scenario is the growth of the additive markets under RFS. The second one examines a national ban on MTBE but without the RFS. A simulation methodology is followed by the authors to analyze the effects on the markets. A proportional costing method is used, that is, all costs are proportional to crude petroleum input. The excise tax and the ethanol subsidy are also included. The authors also assume that support payments would continue to be made in the future. Regulatory and environmental constraints are also added to the model. The authors conclude that most of the refinery gasoline and additive prices would be lower in the year 2015 than in the year 2000. As ethanol and corn prices are the most relevant to this thesis, only those are discussed in the paragraph that follows.

The actual output of ethanol in 2000 was 1.65 billion gallons. Gallagher et al estimate ethanol production under the baseline would be 4.41 billion gallons in 2015. Compared to

this, estimated output in 2015 under scenario 1 (RFS) and under scenario 2 (MTBE ban, no RFS) is 5.00 and 4.54 billion gallons respectively. Under scenario 1, ethanol production is 13.4 percent greater than under the baseline. Under scenario 2, ethanol production increases by 2.9 compared to the baseline. The price of ethanol was \$ 1.58 per gallon in 2000. In 2015, under baseline, it is estimated to be \$ 2.06 (in 2000 prices). Under scenario 1, it is estimated to be \$ 2.27 and under scenario 2, it is \$ 2.09 per gallon. Compared to the baseline price, the ethanol price under scenario 1 is 10.2 percent higher and under scenario 2 it is 1.5 percent higher. This study also estimated the price of corn. From the actual price of \$ 1.73 per bushel in 2000, price increase to \$ 2.10 in 2015 under baseline. In the case of scenarios 1 and 2, they are \$ 2.17 and \$ 2.11 per bushel respectively.

The third study by Sparks Companies and Kansas State University (2002) is a report on establishing an ethanol production plant. This study analyzed investment using the traditional return on investment method. The study analyzed the last ten-year average prices of ethanol from 33 locations. Unfortunately the actual price data are not available in the report. The study found a high correlation between ethanol prices and prices of conventional gasoline. The study developed a model to forecast the prices of ethanol based on the forecast price of conventional gasoline. The forecast price of gasoline was sourced from Annual Energy Outlook 2002 prepared by Department of Energy. The model also includes a random factor variable to indicate unforeseen problems in production as happened in 1996. The model forecasts a price of \$ 1.27 per gallon of ethanol in 2003 and \$ 1.44 in 2010.

The Sparks Companies and Kansas State University (2002) also forecast the prices of DDGS up to 2010. The model to forecast DDGS prices is based on the forecast corn prices. The forecast prices of DDGS range from \$ 96 to \$ 101 per ton.

For the forecast prices of corn, there are a number of sources. The major one is “Effects on the Farm Economy of a Renewable Fuels Standard for Motor Vehicle Fuel” (USDA, 2002). The study projects grain ethanol production using the volume of renewable fuels specified in RFS and making adjustment for biodiesel and biomass-ethanol. Biomass-ethanol projections are sourced from Annual Energy Outlook 2002 and biodiesel projections are sourced from Congressional Budget Office. The study assumes that grain ethanol would be produced from either corn or sorghum. The future share of corn in producing ethanol is assumed to be similar to the current share of 93 percent. The study concludes, that, from 2006 onward, ethanol production under the RFS scenario will be higher than baseline condition and this is reflected in the prices of corn. The forecast prices range from \$ 2.20 per bushel of corn in 2003 to \$ 2.60 in 2011.

To sum up, DiPardo’s study uses National Energy Modeling System, but does not incorporate the impact of RFS. The study by Gallagher et al is closer to the central idea of this thesis, that is, to analyze the impact of RFS. This study includes estimation of prices under a baseline and two scenarios that incorporate implementation of the RFS. But the study does not provide time series data. This is the only comprehensive study available on the gasoline and its additive markets. The major limitation is that the study uses 2000 price for ethanol as a base, which was about 37 percent higher than it is now. Sparks companies and

Kansas State University have developed a gasoline based ethanol pricing model that also includes a dummy variable for production related problems as happened in 1996. This is the only study that estimates the prices of DDGS. The USDA study specifically focuses on the impact of RFS on the prices of corn and other agricultural produce. Here again, the baseline and RFS scenario prices are estimated separately.

Given this information availability, the ethanol prices estimated in the study by Gallagher et al were used for this thesis after making adjustments for the prices. The initial price was brought down to the 2002 level. In the case of DDGS, the only estimates available were from Sparks Companies and Kansas State University study. Hence this was used. In the case of corn, the USDA study seemed more appropriate, recent and provided time series. Hence it was used. As indicated earlier, these are just the expected prices. The actual prices varied in each iteration depending upon the volatilities, standard deviation of volatilities and correlation specifications as discussed above. Actual expected prices used in the study are given in the later sections.

Conclusion

To estimate the option values, the gross present value of the project and the project volatility were the key inputs. A standard discounted cash flow analysis was done to calculate the gross present value of the project. In the second step, the project volatility was estimated using Monte Carlo simulation. The specifications for the Monte Carlo simulation included the expected prices, price volatilities, volatility of volatilities and correlations among ethanol, DDGS and corn prices. The outcome of the combined price volatilities was the key to

estimate the project volatility. The price volatilities and the correlations were estimated using the last ten year average monthly prices of ethanol, DDGS and corn. The project volatility was then used to estimate the options value for a time period of one year. The option valuation was done using log form, explicit finite difference method. Once the option values were calculated, they were compared with the boundary condition and the final option values were adjusted for early exercise of the option.

5. FINDINGS OF DISCOUNTED CASH FLOW ANALYSIS

The first step followed in this study was a standard discounted cash flow analysis of an ethanol plant investment. The inputs that go into the standard cash flow analysis were grouped into technical, financial and price assumptions. The outputs were the income and expense statement, balance sheet and cash flow analysis including the present value of the project. The paragraphs that follow describe, in detail, the inputs and the outputs of the financial model.

Inputs of the Model

Technical assumptions: The rated capacity of the plant was assumed to be 40 million gallons of ethanol per annum and the economic life is assumed to be 20 years. In the second year of operation the plant would utilize 40 percent of the rated capacity to reflect construction and start up delays. From the third year onwards, production was assumed to be 100 percent of the rated capacity. The ethanol yield from a bushel of corn was assumed to be 2.606 gallons. It was assumed that for every gallon of ethanol produced, 6.5081 lbs of DDGS would be produced.

Financial assumptions: The total investment expenditure for a 40 million gallon per year ethanol plant was assumed to be \$ 50 million. It was assumed that the plant would be financed entirely by debt. This simplification was made mainly to price the capital and to avoid the complexity of deciding the dividend structure for the owners' equity. The term of

the loan was assumed to be 15 years with an interest rate of 6 percent per annum. It was also assumed that whenever there is an operational deficit, the plant would borrow money at a short-term rate of 3 percent per annum. The short term was assumed to be 6 months. If there were surplus cash, then the plant would invest money on a short-term basis. The plant is assumed to have a salvage value of 10 percent. The income tax rate was assumed to be 30 percent.

Price assumptions: The prices mentioned here are for the baseline case, when the project begins at time zero. The initial price (price during year 1) of ethanol was assumed to be \$ 1.15 per gallon based on the 2002 average price adjusted for 2003. For other years, as indicated in the previous section, the price was assumed to follow a linear trend based on Gallagher's study. Every year the price was increased by 0.545 percent in the form of trend. This worked out to be \$ 1.16 ($1.15 + (1.15 \times 1 \times .00545)$) in year 2 and \$ 1.17 ($1.16 + (1.16 \times 2 \times .00545)$) in year 3 and so on. The calculations for DDGS were also similar. A linear trend was assumed. The actual prices of corn were sourced from USDA study as mentioned in the previous section. The prices in years 1, 5, 10, 15 and 20 are given in Table 1:

Table 1. Projected Prices of Ethanol, DDGS and Corn

	Year 1	Year 5	Year 10	Year 15	Year 20
Ethanol (\$/gallon)	1.15	1.22	1.47	2.02	3.14
DDGS (\$/ton)	96.00	100.88	119.81	160.31	241.02
Corn (\$/bushel)	2.20	2.45	2.83	3.78	5.68

Outputs of the Model

Table 2 presents a representative income statement for year 10, assuming baseline prices:

Table 2. Projected Income and Expenses in Year 10

	Amount(\$)	Percentage	
<u>Income</u>			
Ethanol	57,119,769	78.9	
Co product – DDGS	14,164,240	19.6	
Co product - CO2	1,086,152	1.5	
Total income	72,370,161	100.0	
<u>Expenses</u>			
Production expenses			
Corn	44,611,198	62.7	74.6
Electricity	1,860,453	2.6	3.1
Fuels	5,118,732	7.2	8.6
Water	213,902	0.3	0.4
Enzymes and yeast	3,611,021	5.1	6.0
Chemicals	1,431,795	2.0	2.4
Denaturants	1,238,217	1.7	2.1
Waste management	283,545	0.4	0.5
Maintenance	1,447,571	2.0	2.4
Total production expenses	59,816,346	84.0	100.0

... Table 2 continued

Table 2. (Continued)

	Amount(\$)	Percentage	
Labor, administration and other expenses			
Labor costs	3,516,952	4.9	49.2
Administration expenses	1,959,942	2.8	27.4
Other costs	1,671,423	2.4	23.4
Total labor, admin and other expenses	7,148,317	10.0	100.0
Depreciation	2,201,864	3.1	
Interest expenses - Long term + short term	2,008,869	2.8	
Total expenses	71,175,396	100.0	

From the above, it is clear that ethanol alone accounts for more than three fourths of the total income. Ethanol and DDGS constitute almost the total income. Production expenses account for 84.0 percent of the total expenses. Labor, administration and other expenses account for another 10.0 percent. Depreciation and interest expenses constitute the remaining 6.0 percent. Corn alone accounts for three fourths of the production expenses. Labor accounts for nearly half the labor, administration and other expenses. The composition of income and expenses do not change much from year to year. So an analysis at any year would not change the above results significantly.

All the prices and expenses except for ethanol, DDGS and corn, used in the calculations are in terms of dollars per gallon of ethanol. The explanations for the calculations in the income

and expense statement in year 10 are as follows (a 4 decimal point price is used in calculations, hence manual calculations do not match those shown here):

- Income from ethanol: The opening and closing stocks remain the same, so the production and sale quantities were the same at 40 million gallons. The projected price of ethanol in year 10 is \$ 1.47 per gallon. The realized value net of 2.75 percent sale commission works out to \$ 57.1 million.
- Income from DDGS: The sale quantity of DDGS is 118,300 tons. Based on the unit price of \$ 119.81, the sale value is \$ 14.2 million.
- Income from carbon dioxide: Based on a value of \$ 0.0266 per gallon of ethanol, the sale value of carbon dioxide is about \$ 1.1 million.
- To produce 1 gallon \$ 1.08 worth of corn is needed. To produce 40 million gallons of ethanol, \$ 43.2 million worth of corn is needed. In addition given the assumed inventory requirements, an additional quantity of corn needs to be purchased. This works out to a total of \$ 44.6 million.
- Expenses of other inputs for producing one gallon of ethanol are given in Table 3:

Table 3. Cost of Other Inputs Per Gallon of Ethanol Produced

Inputs	Cost per gallon of Ethanol Produced (\$)
Electricity	\$ 0.0465
Fuels	\$ 0.1280
Water	\$ 0.0053
Enzymes and yeast	\$ 0.0883
Chemicals	\$ 0.0343
Denaturant	\$ 0.0301
Waste management	\$ 0.0071
Maintenance	\$ 0.0362
Labor	\$ 0.0879
Administration	\$ 0.0490
Other costs	\$ 0.0418

Detailed income and expense statement and cash flow statement are provided in Appendix I.

The following figure helps in understanding the income flow from the project.

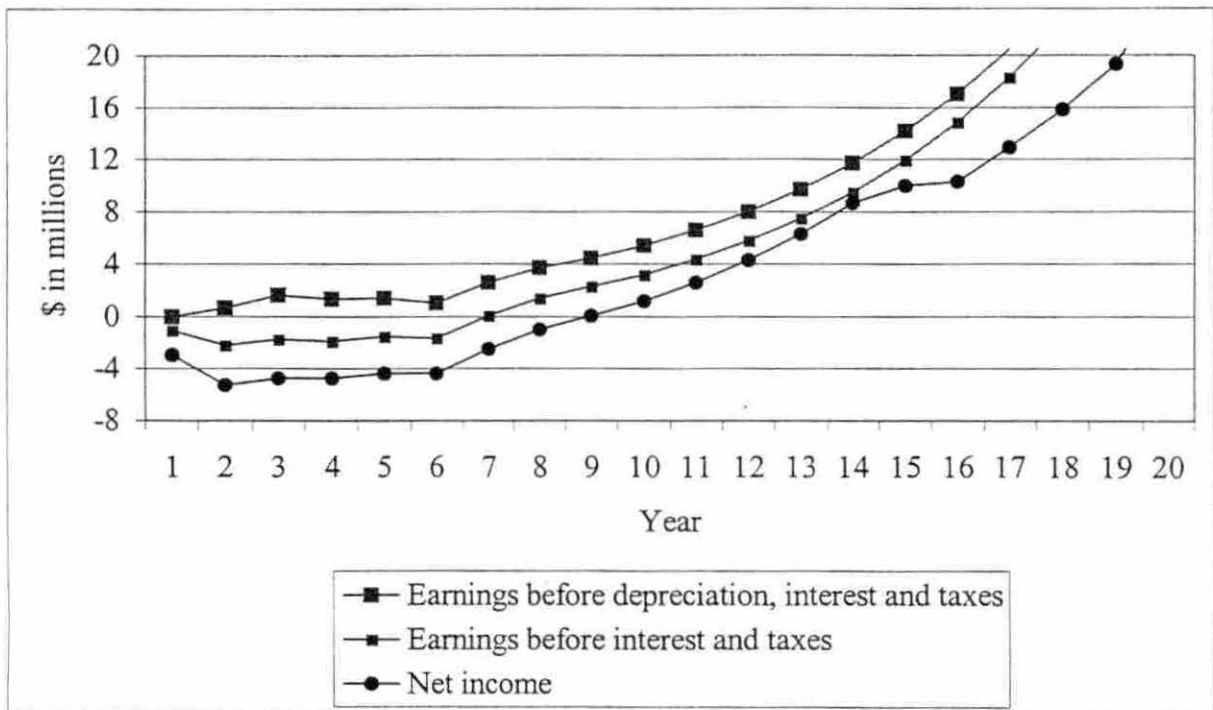


Figure 4. Income from the Project

From the above figure it is clear that the earnings before depreciation, interest and taxes are positive from year 2 onwards. All earnings measures do not increase until about the sixth year. If the depreciation is accounted for, then the earnings become negative till about the seventh year. Interest expenses are high due to the assumption of 100 percent debt. Taxes are low due to negative earnings especially during the initial period. Towards the end of the project, especially in the last five years, taxes increase significantly.

The present value for the project was estimated from the cash flow of the project. The present value of the project was estimated to be \$ 64.95 million. Based on a capital expenditure of \$ 50 million, the net present value of the project would be \$ 14.95 million.

A sensitivity analysis was done changing the prices of the key outputs: ethanol and DDGS and the key input: corn. The price of each of these was increased/decreased by 5 percent ignoring the correlation. The results are presented in Table 4:

Table 4. Sensitivity Analysis of the Present Value of the Project

Scenario	Change in the present value from the base case
Ethanol prices increased by 5 percent	+40.1
Ethanol prices decreased by 5 percent	-44.7
DDGS prices increased by 5 percent	+10.0
DDGS prices decreased by 5 percent	-10.1
Corn prices increased by 5 percent	-27.3
Corn prices decreased by 5 percent	+28.2

It is clear from the sensitivity analysis that changes in the prices of ethanol and corn had a major impact on the present value of the project. Ethanol prices had the largest impact on the value of the project. A 5 percent increase in the price of ethanol lead to a 40.1 percent increase in the present value. A 5 percent decrease in the price of corn resulted in a 28.2 percent increase in the present value. A 5 percent increase in the price of DDGS increased the present value by 10.0 percent. A price decrease had a greater impact than an increase in prices.

There are some limitations in this sensitivity analysis. First, while a five percent change may be possible from one year to another, it is unlikely that the change would continue for a

twenty year period as assumed here. Secondly, the prices are also correlated, especially those of DDGS and corn. So it is unlikely that the prices of DDGS and corn change in opposite directions.

Conclusion

This section discussed the inputs that go into and the outputs produced by the discounted cash flow model. The forecast prices of ethanol were based on the study by Gallagher et al and those of DDGS were based on “Corn Based Ethanol Costs and Margins” (Sparks Companies and Kansas State University, 2002). The forecast prices of corn were based on the “Effects on the Farm Economy of a Renewable Fuels Standard for Motor Vehicle Fuel” (USDA, 2002).

Ethanol and DDGS accounted for almost all the income and corn accounted for three fourths of the production expenses. Hence ethanol, DDGS and corn were the key outputs and input in the financial model. A sensitivity analysis changing the prices of ethanol, DDGS and corn was done. As expected, a 5 percent change in the prices of ethanol and corn affected the present value of the project much more than a 5 percent change in the price of DDGS.

The sensitivity analysis above clearly explained the effect of changing some of the key variables. However, many variables can change at the same time at any point in time during the entire period of the project. Some of these variables are also correlated. For instance, rarely does the price of DDGS go down when the price of corn goes up. Such complex

changes incorporated in the discounted cash flow analysis reveal much more than a single variable change. The next section discusses the results of such complex changes.

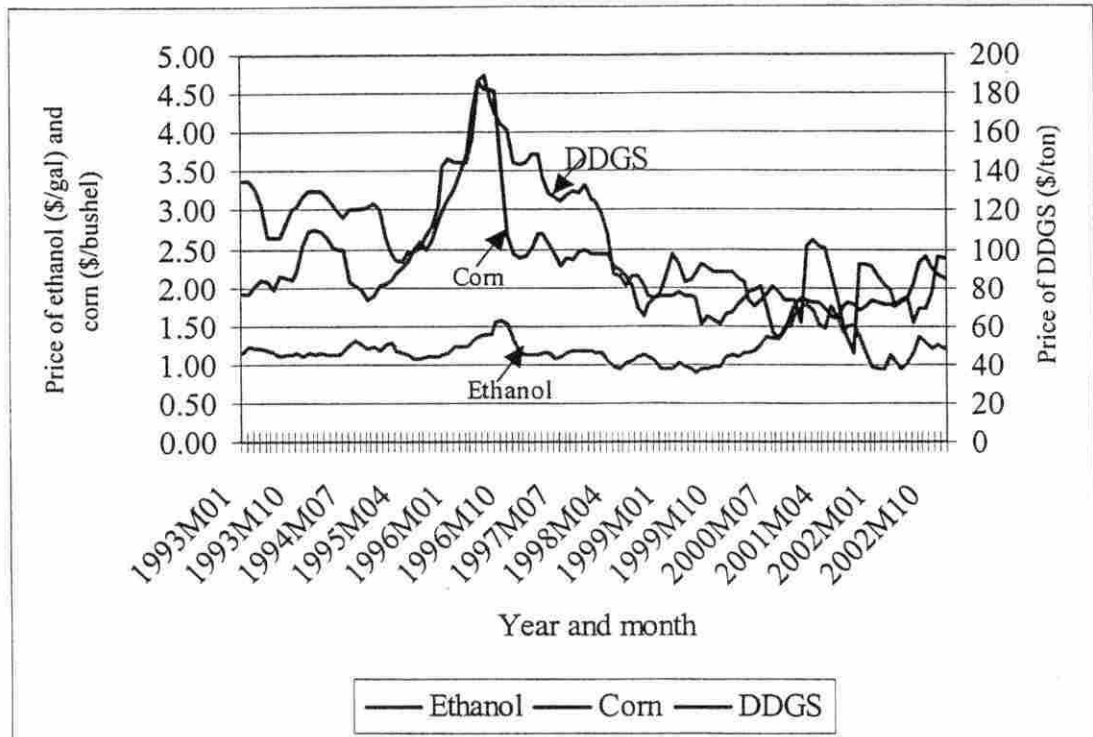
6. FINDINGS OF THE SIMULATION AND OPTION VALUATION

The project volatility, as stated earlier, was estimated using Monte Carlo simulation. The input specifications for the Monte Carlo simulation are price volatilities, volatility of price volatilities and the correlations among ethanol, DDGS and corn prices. This section discusses the inputs that went into the estimation of the project volatility and the option valuation and their outcomes.

Price Volatilities

The Monte Carlo simulation specification consists of the type of distribution to be used, the expected price and the volatility (standard deviation per year). Some other specifications are optional but make the simulation more realistic. The major one is the correlations among the variables. For instance assume that the prices of corn and DDGS have a high positive correlation between them. Specifying the correlation between these two prices will avoid generating a lower price for corn and a higher price for DDGS. Hence the simulation is more realistic.

The average monthly prices of the last ten years were analyzed to estimate the correlation among prices and volatilities of ethanol, DDGS and corn prices. The accompanying graph, Figure 5, depicts the average monthly prices for the last ten years. The prices are definitely not stable over the last ten years. The prices of ethanol, DDGS and corn seem to have some kind of correlation among each other. However, the prices of corn and DDGS seem to have a higher correlation than those of corn and ethanol.



Source:

- (1) Price of Ethanol - Average monthly price at Omaha, Nebraska, Nebraska Ethanol Board
- (2) Price of Corn - Iowa Department of Agriculture and Land Stewardship, Agricultural Marketing Division, Des Moines, Iowa
- (3) Price of DDGS - Economic Research Service, USDA

Figure 5. Average Monthly prices of Ethanol, DDGS and Corn

The correlation matrix, as given below in Table 5, confirms the observations made from the graph. The prices of corn and DDGS have a correlation of 0.7859, whereas that between the prices of corn and ethanol is 0.1208. The prices of ethanol and DDGS have a weak correlation.

Table 5: Price Correlation Matrix

	Ethanol	DDGS	Corn
Ethanol	1.0000	0.0775	0.1208
DDGS	0.0775	1.0000	0.7859
Corn	0.1208	0.7859	1.0000

Price volatility is defined as standard deviation per annum. Hence it is essential to understand the distribution of the prices. The distribution analysis of the average monthly prices is presented in Table 6. The mean of the last ten-year prices of ethanol is \$ 1.20 with a standard deviation of \$ 0.19. The median is \$ 1.16. The 75th and the 25th percentiles are \$ 1.26 and \$ 1.10 respectively. A test for normality of prices using Shapiro-Wilk W test resulted in a W of 0.8967 and the p-value of <0.0001. This indicates the normality of the prices. The assumption of normality is important for simulation specification.

Table 6. Key Features of Average Monthly Prices

	Ethanol	DDGS	Corn
Mean (\$)	1.20	106.31	2.24
Standard deviation (\$)	0.19	29.43	0.65
Median (\$)	1.16	101.40	2.07
75th percentile (\$)	1.26	127.00	2.47
25th percentile (\$)	1.10	83.25	1.81
Shapiro-Wilk W	0.8967	0.9566	0.8061
p-value (<)	0.0001	0.0042	0.0000

As discussed earlier, price volatilities were estimated from historical data using:

$$\hat{\sigma} = \frac{s}{\sqrt{\tau}} \quad (6.1)$$

$$\text{where } s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (u_i - \bar{u})^2} \quad (6.2)$$

$$u_i = \ln\left(\frac{S_i}{S_{i-1}}\right) \quad (6.3)$$

τ = length of time interval in years

S_i = price at the i th interval

Based on the last ten years of price data, the price volatility for ethanol was calculated as:

$$s = 0.03042$$

$$\tau = 0.08333$$

$$\hat{\sigma} = \frac{0.03042}{\sqrt{0.08333}} = 0.1054$$

The mean of the last ten-year prices of DDGS is \$ 106.31 with a standard deviation of \$ 29.43. The median is \$ 101.40. The 75th and the 25th percentiles are \$ 127.00 and \$ 83.25 respectively. A test for normality of prices using Shapiro-Wilk W test resulted in a W of 0.9566 and the p-value of 0.0042. This indicates the normality of the prices. Based on the last ten years of monthly price data, the price volatility for DDGS was calculated as:

$$s = 0.03942$$

$$\tau = 0.08333$$

$$\hat{\sigma} = \frac{0.03942}{\sqrt{0.08333}} = 0.1366$$

The ten-year mean for corn prices is \$ 2.24 with a standard deviation of \$ 0.65. The median price is \$ 2.07. The 75th and the 25th percentiles are \$ 2.47 and \$ 1.81 respectively. A test for normality of prices using the Shapiro-Wilk W test resulted in a W of 0.8061 and the p-value of 0.0000. This indicates the normality of the prices. Based on the last ten years of monthly price data, the price volatility for corn was calculated as:

$$s = 0.052339$$

$$\tau = 0.08333$$

$$\hat{\sigma} = \frac{0.052339}{\sqrt{0.08333}} = 0.1813$$

Instead of a static estimate of price volatility, a second specification for selecting different price volatility for each and every iteration was provided. In the beginning of this section, it

was discussed that additional specifications would make the simulation more realistic. This specification helps in randomly selecting the price volatility within a range. As in the case of volatility of prices, a volatility of (ten) annual price volatilities was calculated using the same formula. It was 0.0006 for the volatility of ethanol. With just ten observations it was not ideal to test the normality of the distribution of volatilities using the Shapiro-Wilk W test. The test revealed a W of 0.8810 with a p-value of 0.1279. The volatility of DDGS price volatilities was calculated to be 0.0048. The Shapiro -Wilk W test resulted in a W of 0.6792 with a p-value of 0.0006. The volatility of corn price volatilities was 0.0013 with a W of 0.7999 and a p-value of 0.0147. So the volatilities themselves can be said to follow a normal distribution in all the three cases, though the level of confidence for ethanol price volatility is less. In addition, a price band of one standard deviation was also specified to restrict the final price selection.

Project Volatility

The price volatilities, volatility of volatilities and the correlation among prices were used as inputs in the simulation to estimate the project volatility. As discussed earlier, the project volatility is the standard deviation of the return of the project. The rate of return, r , was calculated using:

$$PV_t = PV_0 e^{rt} \text{ rewritten as} \quad (6.4)$$

$$rt = \ln\left(\frac{PV_t}{PV_0}\right) \quad (6.5)$$

For $t=1$, the above equation became

$$r = \ln\left(\frac{PV_1}{PV_0}\right) \quad (6.6)$$

From the above equation, it is obvious that to calculate the rate of return of the project, 'r', both the present value of the project at time 't' = 0 and the present value of the project at time 't' = 1 are needed. Some changes were made for the project if it started in year t=1. The project would take advantage of some of the additional information available at that time. These changes were assumed to be changes in the prices of ethanol and corn. A comparison of prices used in both the projects is given below in Table 7.

Table 7. Comparison of Projected Prices of Ethanol and Corn in Projects Starting at Year 0 and Year 1

	Year 1	Year 5	Year 10	Year 15	Year 20
Ethanol prices at t=0 (\$/gallon)	1.15	1.22	1.47	2.02	3.14
Ethanol prices at t=1 (\$/gallon)*	-	1.23	1.50	2.10	3.27
Corn prices at t=0 (\$/bushel)	2.20	2.45	2.83	3.78	5.68
Corn prices at t=1 (\$/bushel)*	-	2.49	2.98	4.03	6.03

* To compare the prices of the same year, year 1 of the project starting at t=0 was compared with year 0 of the project starting at t=1

As evident from the above table, the prices were gradually increased in the second project (t=1) to reflect the gradual increase in the proposed Renewable Fuels Standard.

The subject of interest is the standard deviation of the return, 'r', i.e., the volatility of the project and not the return of the project. Hence the results of the present values of both the projects and the return of the project are not discussed here. The simulation generated the volatility of the project: 0.22. This volatility is much higher than the volatilities of the prices. The estimated project volatility was then used to calculate option values using an explicit finite difference methodology.

Option Valuation

As discussed in the section Methodology, the log transform approach was used to estimate the option value. Using $Z = \ln V$, the finite difference equation used was

$$H_{i,j} = \alpha_j^* H_{i+1,j-1} + \beta_j^* H_{i+1,j} + \gamma_j^* H_{i+1,j+1} \quad (6.7)$$

$$\text{where } \alpha_j^* = \frac{1}{1+r\delta t} \left(-\frac{\delta t}{2\delta Z} (r - \sigma^2 / 2) + \frac{\delta t}{2\delta Z^2} \sigma^2 \right) \quad (6.8)$$

$$\beta_j^* = \frac{1}{1+r\delta t} \left(1 - \frac{\delta t}{\delta Z^2} \sigma^2 \right) \quad (6.9)$$

$$\gamma_j^* = \frac{1}{1+r\delta t} \left(\frac{\delta t}{2\delta Z} (r - \sigma^2 / 2) + \frac{\delta t}{2\delta Z^2} \sigma^2 \right) \quad (6.10)$$

r = risk-free interest rate

t = time interval

σ = volatility (standard deviation in one year)
of the project value

The input specifications for the option valuation are:

$i =$	1 to 10 (1 to M)
$j =$	1 to 12 (1 to N)
$r =$	0.0425
$\sigma =$	0.22
$\delta Z =$	1.6094
$\delta t =$	0.0833
$\ln(I) =$	3.9120

- 'M' denotes the number of intervals in the project value. The option values were estimated for the project values ranging from \$ 50 million to \$ 100 million with an interval of \$ 5 million.
- 'N' denotes the number of time intervals. The option values were estimated over a one year period for each of the 12 months.
- 'r' is the bank lending rate charged to the least risky clients, as a surrogate to risk-free interest rate.
- ' σ ' is the volatility of the project, that is calculated from the Monte Carlo simulation.
- ' δZ ' is $\ln(\delta V)$ and δV is the interval in the present value, 5 (\$ 5 million); hence δZ is $\ln(5)$ or 1.6094
- ' δt ' denotes the time interval in years, $\frac{1}{12}$ or 0.083
- 'I' is the investment expenditure, 50 (\$ 50 million), hence $\ln(I)$ is 3.9120

Using the formula, as given above,

The table above is the finite difference grid with options values. This grid is derived from an equivalent grid that calculates options values in terms of a log transformation. The first column shows the project value in \$ millions. The rest of the columns show option values for different time periods. The last column is the option value after one year or when the time remaining is zero. When the project value is \$ 65 million (project value \$65 million is the closest to the project value estimated in section 5), at the time of maturity (time remaining is zero), the option value is \$ 15 million. This is the same as the net present value of the project. So at the time of maturity of the option, the option value is the same as the project's net present value. This is straight forward from the call option formula, $\text{Max}(V-I,0)$.

As the time to maturity increases, the gap between the net present value and the option value widens. For instance, when the time remaining is one month, for the same project value, the option value is \$ 15.2 million. This is \$ 0.2 million more than that in the following month. When the time to maturity is 12 months, the option value for the same project value is \$ 17.6 million. The option value to wait increases at an increasing rate as the project value increases. This is depicted in Figure 6.

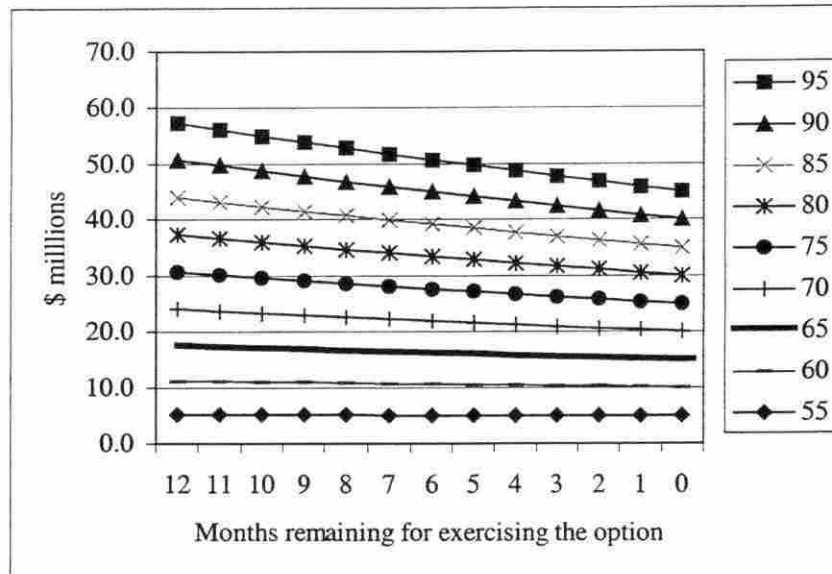


Figure 6. Option Values for Various Project Values Across One Year

The above figure shows the option values for different time periods and for different project values. At the right-most part of the graph is the value of the option when the time remaining is zero. This is always the same as the project's net present value. As the time to exercise increases the option value increases at an increasing rate. Further, it can also be concluded that the rate increase is higher for projects with higher values.

Conclusion

The major outcome of this section is the option value for the project. To estimate the option value of the project, the project volatility was needed. To calculate the project volatility, volatilities of ethanol, DDGS and corn prices needed to be calculated along with their

correlations. It was found that the correlation between DDGS and corn to be 0.7859. The ethanol price had a weak correlation with that of DDGS and corn. The prices of ethanol, DDGS and corn and their volatilities also follow a normal distribution, but the confidence level for the volatility of ethanol prices is less. Using these inputs, a Monte Carlo simulation of 1,000 iterations resulted in an estimated project volatility of 0.22.

The option values for different project values were calculated using a log form, explicit, finite difference grid. The grid reveals that the option value is the same as the net value of the project when the time remaining for exercising the option is zero. As the time remaining increases, the option value also increases. When the time remaining is twelve months, the gross option value for a \$ 65 million project value is \$ 17.6. It was also found that the option value increased at an increasing rate as the time remaining on the option and the project value increased. The interpretation of the option value is discussed in the next section.

7. SUMMARY AND CONCLUSIONS

Once the option value is estimated for the project, an interpretation is needed for the decision. Ultimately, it needs to be decided whether the project should be undertaken immediately or postponed or the project idea should be abandoned. There are additional questions that need to be answered if a decision to wait is made. These are: how long to wait before the project is started, can one expand the option time period up to two or three years and so on. This section discusses these issues. This section starts with a summary of all the key issues in this study and then interprets the option value.

The key question of this study is to analyze an investment of a FOVA business - an ethanol plant - using real options. The gross present value of the project was calculated to be \$ 64.95 million using a standard discounted cash flow analysis. The estimation of project volatility was done using a Monte Carlo simulation. The input specifications for the simulation were the volatilities of the prices, correlation among the prices along with the expected prices and the type of distribution. All the prices and the volatilities followed a normal distribution. The prices of corn and DDGS had a high correlation. The volatilities of the ethanol, DDGS and corn prices were 0.1054, 0.1366 and 0.1813 respectively. The study constructed two models – one for the project starting now and one for the project starting the next year after information on the passage of the RFS would have been received. Using 1,000 iterations and these two models, the project volatility was estimated to be 0.22.

Using this project volatility, the option values for a series of project values and time span were estimated. For a \$ 65 million project, the option value for a twelve month period is \$ 17.6 million. The option value has two components. They are the static net present value and the option premium (Trigeoris, 2001). The net present value of this project is \$ 15 million (\$ 65-50 million) and the option premium is \$ 2.6 million. The option premium, further, has two components i.e., the value to wait and competitive loss. An increase in time to defer reduces the static net present value. An increase in uncertainty - project volatility and time to defer increases the value to wait and hence the option premium. An increase in time to defer increases competitive loss and decreases the option premium. The combined effect of all the above on the gross option value is difficult to predict over a longer time period.

As this study focuses on immediate changes in the policy issue and the example used is Renewable Fuels Standard, it followed a one year time frame. Within one year, the static net present value is not affected significantly and the option premium keeps increasing. The static net present value remains at \$ 15 million and the option premium increases by \$ 200,000 per month on an average. The combined effect resulted in an option value of \$ 17.6 million. If the policy change requires a longer period for example or if the Renewable Fuels Standard would take longer than one year to implement, then the option valuation needs to be performed over a longer period of time.

Once the option value is estimated, it needs to be compared with the net present value. If the option value is greater than the net present value, then an early exercise is not optimal. So it

is better to wait. In this study the option value is \$ 17.6 million and the net present value is \$ 15 million. Hence it is optimal to wait.

There are a number of improvements that could be made to the present model used in this thesis. Within the static model, one of the limitations was the use of proportional costing. It is appropriate to use this method when all the inputs are exactly proportional to the output. However, some costs such as labor and administration do not vary exactly according to the output produced. It is possible to keep such fixed costs out of the proportional costing method. This would improve the static model especially when the output of ethanol changes.

In the log form finite difference methodology, the negative weights or probabilities are eliminated, but they become insensitive to project values. Even if the project values increase, the weights remain the same. So it may be possible to have option values inconsistent with project values depending upon the project volatility. This limitation needs to be probed further.

The major lesson learnt by doing this thesis was the understanding of the potential of real options in providing a different dimension to analyze investments. The concept of real options is more intuitive and more closely resembles the actual decision process. Another key insight is that real options is complementary to but does not replace traditional discounted cash flow method. So in creating a FOVA business, there are a number of key decisions that can be modeled as real options. In many situations the investment is made over a period of time rather than at one time. A FOVA business may acquire land first, then acquire equity

from farmers and possibly make other investments or decisions later. The application of real options is more appropriate when such uncertainties exist or when investments are made in stages.

The time required to create a FOVA business is also longer than a typical business mainly because of some time consuming activities such as the process of recruiting members and conducting an equity drive. Hence if a decision to wait is made, then the business can utilize the waiting period in these time consuming activities.

To sum up, many financial and managerial decisions associated with the creation of FOVA businesses are best modeled using real options. Although the use of real options in business is just in its infancy, improvements in estimating methods should bring the insight and valuations within the reach of FOVA managers and investors.

APPENDIX. Financial Statements

Projected Income and Expense Statement										
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Income										
Ethanol	-	17,689,454	45,070,617	46,363,888	47,374,621	48,665,579	50,256,944	52,174,246	54,449,043	57,119,769
Co product - DDGS	-	4,475,225	11,391,275	11,700,054	11,932,902	12,230,054	12,595,762	13,035,390	13,555,545	14,164,240
Co product - CO2	-	363,535	934,432	964,472	983,761	1,003,437	1,023,505	1,043,975	1,064,855	1,086,152
Total income	-	22,528,214	57,396,324	59,028,414	60,291,284	61,899,070	63,876,211	66,253,611	69,069,443	72,370,161
Production expenses										
Corn	-	14,208,968	36,311,808	37,890,582	38,679,969	40,258,744	40,258,744	41,048,131	42,690,056	44,611,108
Electricity	-	635,151	1,619,636	1,652,029	1,685,069	1,718,771	1,753,146	1,788,209	1,823,973	1,860,453
Fuels	-	1,747,515	4,456,164	4,545,288	4,636,193	4,728,917	4,823,496	4,919,966	5,018,365	5,118,732
Water	-	73,025	186,215	189,939	193,738	197,613	201,565	205,596	209,708	213,902
Enzymes and yeast	-	1,257,444	3,143,611	3,206,483	3,270,613	3,336,025	3,402,746	3,470,801	3,540,217	3,611,021
Chemicals	-	488,809	1,246,464	1,271,393	1,296,821	1,322,758	1,349,213	1,376,197	1,403,721	1,431,795
Denaturants	-	422,723	1,077,943	1,099,501	1,121,492	1,143,921	1,166,800	1,190,136	1,213,938	1,238,217
Waste management	-	96,801	246,843	251,780	256,815	261,952	267,191	272,535	277,985	283,545
Maintenance	-	494,195	1,260,198	1,285,402	1,311,110	1,337,332	1,364,079	1,391,361	1,419,188	1,447,571
Total production expenses	-	19,424,634	49,548,882	51,392,398	52,451,821	54,306,033	54,586,978	55,662,930	57,597,151	59,816,346
Gross profit	-	3,103,580	7,847,441	7,636,016	7,839,463	7,593,037	9,289,232	10,590,681	11,472,292	12,553,815
Labor, administration and other expenses										
Labor costs	-	1,200,674	3,061,718	3,122,953	3,185,412	3,249,120	3,314,102	3,380,385	3,447,992	3,516,952
Administration expenses	-	669,117	1,706,248	1,740,373	1,775,180	1,810,684	1,846,897	1,883,835	1,921,512	1,959,942
Other costs	-	570,617	1,455,074	1,484,176	1,513,859	1,544,136	1,575,019	1,606,519	1,638,650	1,671,423
Total lab, admin and other expenses	-	2,440,408	6,223,040	6,347,501	6,474,451	6,603,940	6,736,019	6,870,739	7,008,154	7,148,317
Earnings before depreciation, interest and taxes	-	663,172	1,624,401	1,288,515	1,365,012	989,097	2,553,214	3,719,942	4,464,138	5,405,498
Depreciation	1,101,456	2,869,680	3,403,639	3,148,479	2,912,285	2,693,858	2,491,730	2,304,902	2,214,146	2,201,864
Earnings before interest and taxes	(1,101,456)	(2,206,508)	(1,779,238)	(1,859,964)	(1,547,273)	(1,704,761)	61,483	1,415,040	2,249,992	3,203,634
Interest expenses - Long term + short term	1,844,620	3,033,835	2,953,491	2,869,147	2,775,695	2,678,379	2,549,629	2,392,792	2,213,565	2,008,869
Earnings before taxes	(2,946,076)	(5,240,344)	(4,732,729)	(4,729,111)	(4,322,969)	(4,383,140)	(2,488,145)	(977,752)	36,427	1,194,765
Other income										
Short term investment	-	-	-	-	-	-	-	-	-	-
State subsidy	-	-	-	-	-	-	-	-	-	-
Capital gain on salvage	-	-	-	-	-	-	-	-	-	-
Total other income	-	-	-	-	-	-	-	-	-	-
Qualified dividend	-	-	-	-	-	-	-	-	-	-
Taxable income	(2,946,076)	(5,240,344)	(4,732,729)	(4,729,111)	(4,322,969)	(4,383,140)	(2,488,145)	(977,752)	36,427	1,194,765
Taxes	-	-	-	-	-	-	-	-	-	-
Net income	(2,946,076)	(5,240,344)	(4,732,729)	(4,729,111)	(4,322,969)	(4,383,140)	(2,488,145)	(977,752)	36,427	1,194,765

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Income										
Ethanol	60,232,796	63,843,752	68,019,134	72,838,289	78,395,851	84,804,712	92,199,682	100,741,983	110,624,771	122,079,967
Byproduct - DDGS	14,871,096	15,687,588	16,627,355	17,706,563	18,944,358	20,363,412	21,990,588	23,857,748	26,002,743	28,470,614
Byproduct - CO2	1,107,875	1,130,033	1,152,633	1,175,686	1,199,200	1,223,184	1,247,647	1,272,600	1,298,052	1,324,013
Total income	76,211,767	80,661,373	85,799,122	91,720,538	98,539,408	106,391,307	115,437,917	125,872,331	137,925,567	151,874,594
Production expenses										
Corn	46,841,664	49,417,955	52,383,033	55,787,930	59,693,085	64,170,066	69,303,672	75,194,484	81,961,987	89,748,376
Electricity	1,897,662	1,935,615	1,974,327	2,013,814	2,054,090	2,095,172	2,137,075	2,179,817	2,223,413	2,267,881
Fuels	5,221,107	5,325,529	5,432,040	5,540,680	5,651,494	5,764,524	5,879,814	5,997,411	6,117,359	6,239,706
Water	218,180	222,544	226,995	231,535	236,165	240,889	245,707	250,621	255,633	260,746
Enzymes and yeast	3,683,242	3,756,906	3,832,045	3,908,685	3,986,859	4,066,596	4,147,928	4,230,887	4,315,505	4,401,815
Chemicals	1,460,431	1,489,640	1,519,433	1,549,821	1,580,818	1,612,434	1,644,683	1,677,576	1,711,128	1,745,350
Denaturants	1,262,982	1,288,241	1,314,006	1,340,286	1,367,092	1,394,434	1,422,322	1,450,769	1,479,784	1,509,380
Waste management	289,216	295,000	300,900	306,918	313,057	319,318	325,704	332,218	338,862	345,640
Maintenance	1,476,523	1,506,053	1,536,174	1,566,898	1,598,236	1,630,201	1,662,805	1,696,061	1,729,982	1,764,582
Total production expenses	62,351,006	65,237,484	68,518,952	72,246,568	76,480,896	81,293,633	86,769,710	93,009,843	100,133,653	108,283,475
Gross profit	13,860,761	15,423,889	17,280,170	19,473,970	22,058,512	25,097,674	28,668,207	32,862,489	37,791,914	43,591,119
Labor, administration and other expenses										
Labor costs	3,587,291	3,659,037	3,732,218	3,806,862	3,882,999	3,960,659	4,039,872	4,120,670	4,203,083	4,287,145
Administration expenses	1,999,141	2,039,124	2,079,906	2,121,504	2,163,935	2,207,213	2,251,357	2,296,385	2,342,312	2,389,159
Other costs	1,704,851	1,738,948	1,773,727	1,809,202	1,845,386	1,882,293	1,919,939	1,958,338	1,997,505	2,037,455
Total lab, admin and other expenses	7,291,283	7,437,109	7,585,851	7,737,568	7,892,320	8,050,166	8,211,169	8,375,393	8,542,900	8,713,758
Earnings before depreciation, interest and taxes	6,569,478	7,986,780	9,694,319	11,736,402	14,166,193	17,047,508	20,457,038	24,487,096	29,249,013	34,877,360
Depreciation	2,201,958	2,201,864	2,201,958	2,201,864	2,201,958	2,201,864	2,201,958	2,201,864	2,201,958	2,201,864
Earnings before interest and taxes	4,367,520	5,784,916	7,492,361	9,534,538	11,964,235	14,845,644	18,255,080	22,285,232	27,047,055	32,675,496
Interest expenses - Long term + short term	1,774,687	1,506,500	1,199,192	846,939	482,645	116,453	0	0	0	0
Earnings before taxes	2,592,833	4,278,416	6,293,169	8,687,599	11,481,590	14,729,190	18,255,080	22,285,232	27,047,055	32,675,496
Other income										
Short term investment	-	-	-	-	-	51,318	201,131	379,118	590,391	890,359
State subsidy	-	-	-	-	-	-	-	-	-	-
Capital gain on salvage	-	-	-	-	-	-	-	-	-	2,942,909
Total other income	-	-	-	-	-	51,318	201,131	379,118	590,391	3,833,268
Qualified dividend	-	-	-	-	-	-	-	-	-	-
Taxable income	2,592,833	4,278,416	6,293,169	8,687,599	11,481,590	14,780,508	18,456,211	22,664,350	27,637,447	36,508,764
Taxes	-	-	-	-	1,423,360	4,434,152	5,536,863	6,799,305	8,291,234	10,952,629
Net income	2,592,833	4,278,416	6,293,169	8,687,599	10,058,230	10,346,356	12,919,348	15,865,045	19,346,213	25,556,135

Projected Cash Flow Statement

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
From operating activities										
Net income	(2,946,076)	(5,240,344)	(4,732,729)	(4,729,111)	(4,322,969)	(4,383,140)	(2,488,145)	(977,752)	36,427	1,194,765
Depreciation	1,101,456	2,869,680	3,403,639	3,148,479	2,912,285	2,693,858	2,491,730	2,304,902	2,214,146	2,201,864
Net cash provided	(1,844,620)	(2,370,663)	(1,329,090)	(1,580,632)	(1,410,683)	(1,689,282)	3,585	1,327,150	2,250,573	3,396,629
Changes in working capital										
Decrease in accounts receivable	-	(712,788)	(1,103,188)	(51,471)	(39,684)	(50,463)	(62,001)	(74,499)	(88,181)	(103,306)
Decrease in inventories	-	(896,950)	(1,371,598)	(51,900)	(31,286)	(54,594)	(12,208)	(35,713)	(61,107)	(70,736)
Increase in accounts payable	-	1,583,897	2,456,417	153,881	86,590	154,631	19,693	87,749	161,225	185,560
Net change	-	(25,841)	(18,369)	50,510	15,620	49,573	(54,515)	(22,463)	11,937	11,518
Investing activities										
Fixed asset (purchase)/sale	-	-	-	-	-	-	-	-	-	-
Financing activities										
Long term debt	29,972,160	19,981,440	-	-	-	-	-	-	-	-
Repayment of long term debt	(1,287,687)	(2,223,406)	(2,356,810)	(2,498,219)	(2,648,112)	(2,806,999)	(2,975,419)	(3,153,944)	(3,343,180)	(3,543,771)
Equity	0	0	-	-	-	-	-	-	-	-
Dividend to shareholders	-	-	-	-	-	-	-	-	-	-
Net change	28,684,473	17,758,034	(2,356,810)	(2,498,219)	(2,648,112)	(2,806,999)	(2,975,419)	(3,153,944)	(3,343,180)	(3,543,771)
Net change in cash during the year	26,839,853	15,361,529	(3,704,269)	(4,028,341)	(4,043,175)	(4,446,707)	(3,026,349)	(1,849,256)	(1,080,670)	(135,624)
Cash at the beginning of the year	-	26,839,853	42,201,383	38,497,114	34,468,773	30,425,597	25,978,891	22,952,541	21,103,285	20,022,615
Add: Net change in cash after taxes	26,839,853	15,361,529	(3,704,269)	(4,028,341)	(4,043,175)	(4,446,707)	(3,026,349)	(1,849,256)	(1,080,670)	(135,624)
Cash at the end of the year	26,839,853	42,201,383	38,497,114	34,468,773	30,425,597	25,978,891	22,952,541	21,103,285	20,022,615	19,886,991
	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
From operating activities										
Net income	2,592,833	4,278,416	6,293,169	8,687,599	10,058,230	10,346,356	12,919,348	15,865,045	19,346,213	22,613,226
Depreciation	2,201,958	2,201,864	2,201,958	2,201,864	2,201,958	2,201,864	2,201,958	2,201,864	2,201,958	2,201,864
Net cash provided	4,794,791	6,480,280	8,495,127	10,889,463	12,260,187	12,548,220	15,121,306	18,066,909	21,548,171	24,815,090
Changes in working capital										
Decrease in accounts receivable	(120,168)	(139,112)	(160,541)	(184,930)	(212,844)	(244,955)	(282,069)	(325,156)	(375,385)	(434,170)
Decrease in inventories	(81,404)	(93,310)	(106,688)	(121,810)	(138,998)	(158,630)	(181,159)	(207,124)	(237,169)	(272,070)
Increase in accounts payable	212,507	242,568	276,327	314,470	357,801	407,277	464,029	529,413	605,048	692,880
Net change	10,935	10,146	9,098	7,730	5,960	3,692	801	(2,867)	(7,506)	(13,360)
Investing activities										
Fixed asset (purchase)/sale	-	-	-	-	-	-	-	-	-	4,935,360
Financing activities										
Long term debt	-	-	-	-	-	-	-	-	-	-
Repayment of long term debt	(3,756,398)	(3,981,781)	(4,220,688)	(4,473,930)	(4,742,365)	(1,940,891)	0	0	0	0
Equity	-	-	-	-	-	-	-	-	-	-
Dividend to shareholders	-	-	-	-	-	-	-	-	-	-
Net change	(3,756,398)	(3,981,781)	(4,220,688)	(4,473,930)	(4,742,365)	(1,940,891)	0	0	0	0
Net change in cash during the year	1,049,328	2,508,645	4,283,537	6,423,263	7,523,782	10,611,021	15,122,107	18,064,042	21,540,665	29,737,090
Cash at the beginning of the year	19,886,991	20,936,320	23,444,964	27,728,501	34,151,764	41,675,546	52,286,567	67,408,674	85,472,716	107,013,381
Add: Net change in cash after taxes	1,049,328	2,508,645	4,283,537	6,423,263	7,523,782	10,611,021	15,122,107	18,064,042	21,540,665	29,737,090
Cash at the end of the year	20,936,320	23,444,964	27,728,501	34,151,764	41,675,546	52,286,567	67,408,674	85,472,716	107,013,381	136,750,470

NPV

\$64,948,225

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