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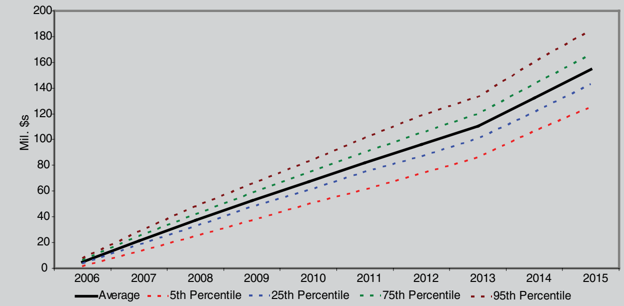

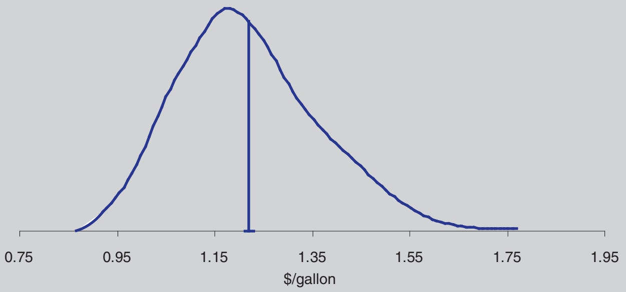

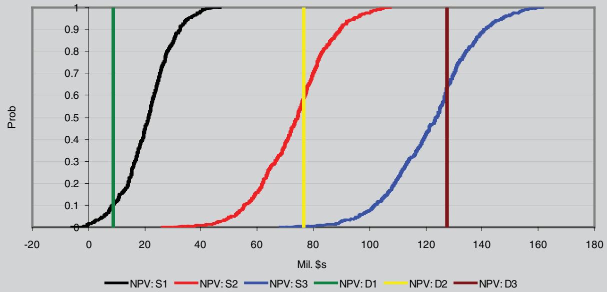

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*The authors are, respectively, Regents Professor and Senior Faculty Fellow, Research Associate, Professor and Extension Economist, Associate Professor and Extension Economist, Assistant Professor and Extension Economist, and former Graduate Assistant all of the Department of Agricultural Economics at Texas A&M University.

An Ethanol Plant in Missouri. Source: J. Marc Raulston.

Recent resurgence of interest in ethanol production by rural development groups, politicians, and grain producers can be attributed to many different factors such as depressed commodity prices, rising gasoline prices, shifts in environmental policy, and a push towards national fuels self-sufficiency. Grain producers in many regions are considering the development of ethanol plants to help overcome low crop prices. Bryan and Bryan International (2006) report that in 2005 there were 95 ethanol plants in the US with a combined production capacity of 4,336 MMGPY[1]. Kenkel and Holcomb (2006) expect the trend of privately owned plants to continue as plants expand into feedstock deficit regions.

Expansion to feedstock deficit regions will likely reduce the profitability of ethanol plants as feedstock costs increase and also will likely increase their risk. Like all agribusinesses, ethanol plants face the full range of risk on economic variables, such as: input price, product price, fuel costs, rate of inflation, and interest rates. The price of the feedstock for an ethanol plant is dependent upon national and international supply and demand conditions so it is certainly subject to risk. The price of ethanol has ranged from less than a dollar a gallon two years ago to over $3.60 per gallon in 2006, demonstrating a significant amount of variability. The price of fuel (natural gas and electricity) used by an ethanol plant has also experienced considerable variability over the past few years. Due to the risk faced by an ethanol plant, a comprehensive feasibility study should explicitly consider the risk for inputs, such as: corn, electricity, natural gas, production costs, and operating interest rate; and the risk for output prices, such as: ethanol and dry distillers grains (DDGS).

The literature on ethanol plants and production contains numerous examples of feasibility studies that ignore risk, *e.g*. Bryan and Bryan International (2001), Van Dyne (2002), Long and Creason (1997), Whims (2004), Tiffany and Eidman (2003), Shapauri, *et al*. (2002), and Fruin, *et al* (1996). Gill (2002) and Herbst (2003) both incorporated risk into ethanol plant feasibility analyses. Failure to incorporate input cost and output price risk tends to mislead potential investors and policy makers interested in helping grain producers through investment in ethanol plants.

The objective of this study is to demonstrate the benefits of quantifying the economic viability of a proposed agribusiness under risk relative to a feasibility study which ignores risk. To achieve this objective, the economic viability of a 50 MMGPY ethanol facility in Texas is analyzed over a 10-year period in two ways: with no risk and with historical risk for prices and costs.

Review of Literature

Much of the ethanol literature comes from the 1980's, a boom period for development of ethanol plants, and from the current era, namely 2002 to present. Topics covered in the literature range from the structure of the industry, production technology, ethanol policy, feasibility studies, economic impact studies, and economies of scale (Van Dyne (2002), Bryan and Bryan International (2001, 2003, 2006), Long and Creason (1997), Gill (2002), Herbst (2003), Tiffany and Eidman (2003), Shapauri, *et al*. (2002), Whims (2004), and USDA (2006)).

The use of ethanol as a fuel additive for internal combustion engines dates back to the 1920's, when Standard Oil marketed, what in today's notation would be, E25 (gasoline with 25-percent ethanol, by volume) in the Baltimore area. In 1938, an 18 MMGPY alcohol plant was constructed and operated in Atchison, Kansas, supplying over 2,000 service stations across the Midwest. After WWII, efforts to sustain U.S. ethanol production failed with the increased availability of less expensive fuels derived from petroleum and natural gas (DiPardo, 2001).

Most all economic feasibility studies for proposed ethanol plants ignore price and cost risk. For example, a recent study by Bryan and Bryan International (2001) analyzed the economic viability of a 15 MMGPY facility in Dumas, Texas, and included the operational and construction costs for additional facility sizes, including 30 and 80 MMGPY facilities. However, like other ethanol feasibility studies, they ignored ethanol and DDGS price risk and simply increased their assumed prices received at a fixed rate of inflation over time[2]. Risk on corn price and energy cost was ignored in their study and operating costs were simply indexed up over the study period to account for inflation. USDA (2006) recently analyzed the economic feasibility of ethanol production from several feedstocks without incorporating the effects of price and cost risk.

In contrast to other ethanol plant feasibility studies, Gill (2002) and Herbst (2003) incorporated price and cost risks into their studies. Their

An Ethanol Plant in Brazil. Source: James Richardson.

feasibility studies incorporated price and cost risk by simulating spreadsheet feasibility models using Monte Carlo techniques. Gill's (2002) emphasis was on analyzing the economic viability of ethanol plants for alternative levels of state subsidies for ethanol production in Texas. Herbst (2003) estimated the economic variability of ethanol production if the plants used corn vs. sorghum and were located in different regions of Texas. Due to incorporating risk into their studies, the results were presented in terms of the probability that the firm will be an economic success and the probability of annual cash flow deficits.

Methodology

Over the past 10 years there has been a resurgence in the interest in Monte Carlo simulation (Richardson (2006), Winston (1996), and Vose (2000)). The reduced cost of computers, wide spread use of Excel and the availability of simulation add-ins for Excel has made this methodology affordable to business. Monte Carlo simulation offers business analysts and investors an economical means of conducting risk-based economic feasibility studies for new investments and a non-destructive means of stress testing existing businesses.

Stochastic Simulation

Ignoring risk in the feasibility analysis of a project only provides a point estimate for key output variables (KOVs) instead of probability distributions that show the risks of success and failure (Pouliquen (1970), Reutlinger (1970), and Hardaker, *et al.* (2004)). Following the examples of Richardson and Mapp (1976), Pouliquen (1970), Reutlinger (1970), and Richardson (2006), a stochastic simulation model of a proposed ethanol production facility in Texas is developed and applied to demonstrate the benefits of Monte Carlo simulation for feasibility studies of agribusinesses.

Pouliquen (1970) defines the benefits of stochastic simulation as providing decision makers the extreme values for KOVs of interest and their relative probabilities with a weighted estimate of the relationships between unfavorable and favorable outcomes. In addition to the analysis of risk and how it affects the feasibility of a project, Pouliquen (1970) suggested that the completed feasibility simulation model can be used to analyze alternative management plans if the investment is undertaken.

Richardson (2006) outlines the steps for developing a production-based investment feasibility simulation model. First, probability distributions for all risky variables need to be defined, parameterized, simulated, and validated. Secondly, the stochastic values from the probability distributions are linked to the accounting relationships needed to calculate production, receipts, costs, cash flows, and balance sheet variables for the project. Stochastic values sampled from the probability

An Ethanol Plant in Iowa. Source: George Knapek.

distributions thus make the financial statement variables stochastic. By stochastically sampling the probability distributions many times (say, 500 iterations) the model generates empirical estimates of probability distributions for unobservable KOVs such as present value of ending net worth, net present value, and annual cash flows, so investors can evaluate the probability of success for a proposed project.

Due to the annual nature of grain feedstocks for an ethanol plant, the Monte Carlo feasibility model is an annual model. In addition to the stochastic variable part of the model, it has all of the accounting equations for an income statement, a cash flow statement, and a balance sheet. The parts of the model are described in the following sections.

Stochastic Variables

Stochastic variables in the ethanol model are annual prices for: corn, ethanol, dry distillers grain (DDGS), electricity, natural gas, gasoline, operating interest rate, and inflation rate on production costs. Ethanol and DDGS prices affect cash receipts while the other stochastic variables affect costs of production and all of these variables affect net cash income, cash reserves, net worth, and ultimately net present value.

The stochastic variables were simulated using the multivariate empirical (MVE) distribution (Richardson, Klose and Gray, 2000) to account for the correlation among the variables. Historical data for the 1989-2005 period were used to estimate the parameters for the MVE distribution. Parameters for the MVE distribution are: deviations from mean or trend expressed as a fraction (the stochastic component), correlation matrix (the multivariate component), and the projected means for the 10 year planning horizon (the deterministic component).

Historical corn and DDGS prices were obtained from the United States Department of Agriculture (USDA), Economic Research Service, Feed Grains Data Delivery Service for 1989 through 2005. Ethanol prices were collected from *Hart's Oxy-Fuel News* from 1989 to 2005. Historical annual gasoline, industrial electricity, and natural gas prices were obtained from the United States Department of Energy. Historical operating interest rates and the index of prices paid (PPI) were obtained from FAPRI.

The stochastic components for ethanol, DDGS, corn, gasoline, natural gas, and electricity were their residuals from trend expressed as a fraction of the forecasted value. The random components of PPI and interest rates were the residuals from their mean expressed as a fraction of the means. The local prices of corn in Texas were simulated by adding a stochastic wedge to national corn prices based on the historical difference between national and state annual average prices. The correlation matrix used to simulate the MVE distribution for the random variables was calculated using the unsorted residuals from trend or mean.

Projected means for the stochastic variables over the 2006-2015 study period came from several sources. Projected annual prices for corn, DDGS, interest rates and PPI rates of inflation came from the January 2006 FAPRI Baseline. Annual average prices for electricity, gasoline, and natural gas were projected using their 2005 prices and FAPRI's projection for annual rates of change in the prices of fuel. Annual average prices for ethanol were assumed to be either \$1.80/ gallon, \$2.20/ gallon, or \$2.50/gallon throughout the planning horizon. The pessimistic price projection of \$1.80/gallon is slightly higher than the average price in 2004 of \$1.72. The optimistic price scenario of \$2.50/ gallon is consistent with prices the first half of 2006, while the \$2.20/gallon represents a more moderate price projection.

The Economic Model

Pro forma financial statements in the economic model link the annual stochastic variables to assumed production and cost coefficients for simulating annual cash flows and net present value over a 10 year planning horizon. The following sections describe the pro forma financial statements and the order of calculations in the economic model.

Income Statement

Total annual receipts were calculated by summing the stochastic annual ethanol and DDGS receipts and interest earned on ending cash balances. Receipts for ethanol equals production times the stochastic price of ethanol.

The plant is projected to run half of the first year and near full capacity in the remaining years of the planning horizon (plus five percent denaturant). Because of stochastic down time for maintenance, the plant will not run at 100 percent capacity. To account for the stochastic down time, the production capacity was adjusted using a GRKS distribution[3].

The GRKS distribution used a minimum days down of 10 and a maximum of 20 with a middle value of 15; these parameters were reduced 50% for the first year. Corn used by the plant equaled stochastic production divided by 2.75 gallons per bushel[4] so corn purchased is a stochastic variable. Annual DDGS receipts were computed by multiplying quantity of corn purchased by the DDGS per bushel of corn coefficient, 18 lbs/bushel[5], and the DDGS stochastic price. Interest earned on beginning year cash balances was included in the income statement and was calculated using the stochastic operating interest rate minus the historical difference between savings and operating interest rates times the positive cash balances.

The cost of corn used for the fermentation process was the product of the stochastic price of corn and the stochastic quantity of corn purchased. Per gallon variable production costs for the first year ($0.93/gallon) come from a recent BBI (2003) plant handbook and were inflated using stochastic annual inflation rates, and multiplied by the volume of anhydrous ethanol produced per year to compute total variable costs[6]. Electricity and natural gas costs were calculated based on input requirements for a 50 MMGPY plant (BBI, 2003) and the stochastic annual prices for these inputs[7]. Start-up expenses of buying initial inventories of supplies and corn along with the cost of hiring and training employees was included at $9 million.

Total annual costs were computed by summing annual corn costs, variable costs, electricity and natural gas costs, loan interest costs, and deprecation expense. Depreciation expense was calculated using MACRS on the plant, annual capital improvements, and capitalized start up costs. Net income (losses) equaled the total annual receipts minus total annual costs.

Matt Sederstrom (2006) of Fagen, Inc. reported that the cost to build a 50 MMGPY plant requires $1.75 per gallon of capacity. The $95 million of capital

Iowa corn. Source: George Knapek.

includes construction and land costs. The present analysis assumed that 50 percent of the total capital requirements were borrowed and the remaining 50 percent were contributed by owner/investors. The 8-year loan on the plant was amortized using a fixed interest rate of 9.5 percent.

An operating loan equal to 15 percent of total annual variable costs was used in the model and the cost of the loan was calculated using a stochastic interest rate. Stochastic operating interest rates were used for short-term loans to finance cash flow deficits over the 10 year analysis period.

Cash Flows Statement

Beginning cash equaled the positive ending cash balances in the balance sheet from the previous year. In year one beginning cash balance was zero for the plant. The sum of annual beginning cash balance and net cash income (plus depreciation) equals total annual cash inflows. Annual cash outflows were calculated by summing the principal payments for the initial capital loan, repayments of cash flow deficits, income taxes and dividends.

A corporate business structure was assumed when calculating federal income taxes for the proposed plant. For the purposes of this study, 35 percent of positive net income is paid as a dividend each year[8]. Total cash inflows minus annual total outflows equaled ending cash balance before borrowing. If the ending cash balance was negative, then the firm must borrow funds to make ending cash balance equal zero. Loans to cover cash flow deficits were assumed to be one year extensions of the operating loan and must be fully repaid the next year.

Balance Sheet

Value of total assets was calculated annually using ending cash balances, land value[9], and book value for plant, and equipment adjusted for the MACRS depreciation table for a 15-year recovery period (Smith, *et al*., 1998). Total liabilities equaled long-term liabilities (the current ending balance of the original loan) plus current year cash flow deficits. Net worth was computed by subtracting total liabilities from total assets. Net worth is used in two forms: a) nominal or current dollar terms, and b) real dollars, for which the nominal values have been discounted using a discount rate of 25 percent.

The probability of economic success was calculated using the net present value (NPV):

$$NPV = -BeginningEquity + \sum_{t=1}^{10}\left(\frac{Dividends_t + \Delta AnnualNetWorth_t}{(1+0.25)^t}\right)$$

If the NPV is positive, the firm has a rate of return greater than the discount rate, i, or 0.25, and is considered to be an economic success (Richardson and Mapp, 1976). In stochastic simulation, the model recorded a one for iterations when the firm had a positive NPV and a zero otherwise. The probability of economic success was calculated as the sum of 1's for the NPV counter variable divided by the number of iterations.

Model Assumptions

The assumptions used in the model to simulate a 50 MMGPY ethanol plant are summarized in this section in terms of a gallon of ethanol produced. Ethanol yields 2.75 gal/bu of corn, DDGS yields 18 lb/bu of corn, and variable costs were: denaturant (gasoline) $0.0762/gal, enzymes cost $0.04/gal, chemicals cost $0.04/gal, maintenance materials $0.02/gal, labor $0.05/gal, and miscellaneous and water treatment costs $0.03/gal (BBI 2003). To incorporate the effect of an uncertain rate of inflation for variable costs, the initial costs were inflated each year using stochastic inflation rates. Natural gas and electricity costs per gallon were simulated using their respective stochastic prices and energy requirements of 0.038MCF/gal and 0.80 Kwh/gal, respectively (BBI, 2003). Capital requirements including construction and startup costs are $87.5 million (Sederstrom, 2006), and annual capital replacement costs totaling $875,000, or 1 percent, per year. It was assumed that the 50 MMGPY facility would be operated at half of year 1 and 100 percent of capacity in years 2-10 for the deterministic model and stochastically it will operate at half capacity in year 1 and about full capacity in years 2-10.

All of the input/output coefficients were the same for the deterministic and the Monte Carlo feasibility analyses. The annual values for all stochastic variables were held constant at their mean values in the deterministic analysis.

A minimum ethanol price of $1.80 was assumed in the model and a minimum wholesale gasoline price of $1.25 was assumed. The minimums were used to reflect the recent prices for petroleum and ethanol.

The model described in this section was programmed in Microsoft© Excel using standard accounting identities and equations. The financial model was made stochastic

Table 1: Results of Deterministic and Stochastic Ethanol Plant Models for Three Assumed Ethanol Price Scenarios.

	$1.80/Gallon	$2.20/Gallon	$2.50/Gallon
Deterministic Model			
PVENW (mil $s)	17.25	31.89	42.79
NPV (mil $s)	8.71	76.62	127.46
ROI (%)	26.5	51.7	70.6
Variable Cost in 2007 ($/gallon)	1.2158	1.2158	1.2158
Monte Carlo Feasibility Model			
PVENW			
Mean (mil $s)	20.03	31.27	41.77
Standard Deviation (mil $s)	1.90	2.60	3.02
Coefficient of Variation (%)	9.47	8.30	7.23
Minimum (mil $s)	14.67	20.87	29.83
Maximum (mil $s)	24.87	39.04	50.74
Net Present Value (NPV)			
Mean (mil $s)	20.94	73.14	122.07
Standard Deviation (mil $s)	9.05	13.20	15.49
Coefficient of Variation (%)	43.34	18.04	12.69
Minimum (mil $s)	(5.87)	26.33	67.95
Maximum (mil $s)	46.86	106.96	161.69
Return on Investment (ROI)			
Mean (%)	31.3	50.7	68.8
Standard Deviation (%)	3.3	3.3	5.5
Coefficient of Variation (%)	1054.8	921.4	792.5
Minimum (%)	21.1	31.5	46.7
Maximum (%)	39.5	64.9	85.3
Variable Costs in 2007			
Mean ($/gallon)	1.2190	1.2190	1.2190
Standard Deviation ($/gallon)	0.1440	0.1440	0.1440
Coefficient of Variation (%)	11.81	11.81	11.81
Minimum ($/gallon)	0.9115	0.9115	0.9115
Maximum ($/gallon)	1.7694	1.7694	1.7694
Prob (NPV<0) (%)	1.6	0	0
Prob (Economic Success) (%)	98.4	100	100
Prob (Stoch VC > Deter VC)	46.8	46.8	46.8

using Simetar©, an add-in for Excel (Richardson, Schumann and Feldman, 2006). Simetar© was used to estimate the parameters for the multivariate empirical probability distribution, and Simetar© simulated the model using a Latin hypercube sampling procedure for sampling random variables.

Results

Results of the economic feasibility analysis for a 50 MMGPY ethanol plant in the Texas Panhandle were summarized in Table 1. The results were presented in terms of the present value of ending net worth (PVENW), the net present value (NPV), variable costs per gallon and the probability of economic success. The feasibility of the plant was tested under three different ethanol price scenarios. The annual mean prices used for Scenarios 1 - 3 were, respectively, $1.80/gallon, $2.20/gallon, and $2.50/gallon of ethanol.

The cost of production did not change with scenarios. The deterministic variable cost per gallon of ethanol with credits for DDGS was $1.216 in

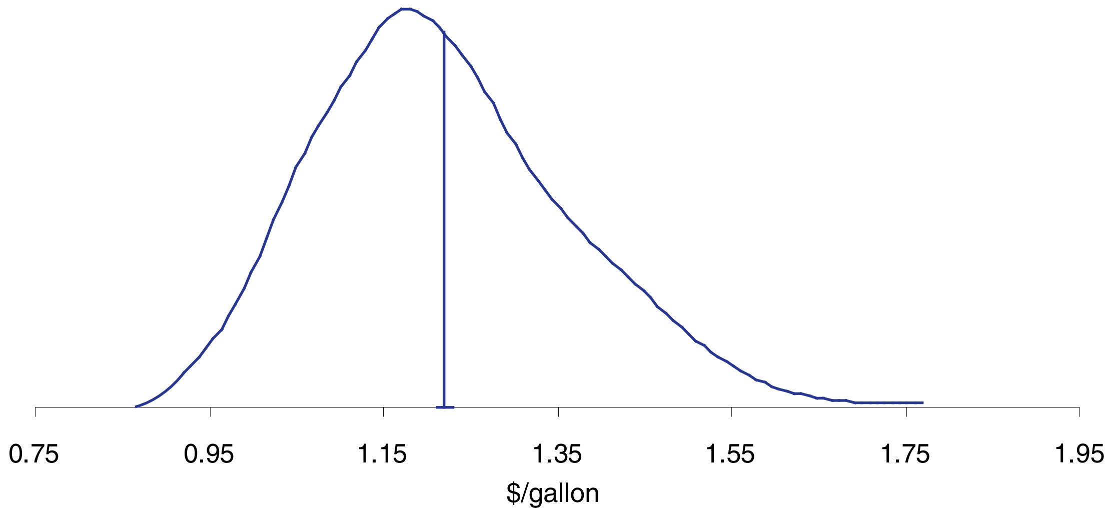

Figure 1: Probability Density Function of the Variable Cost per Gallons of Ethanol, with DDGS Credit for (2007).

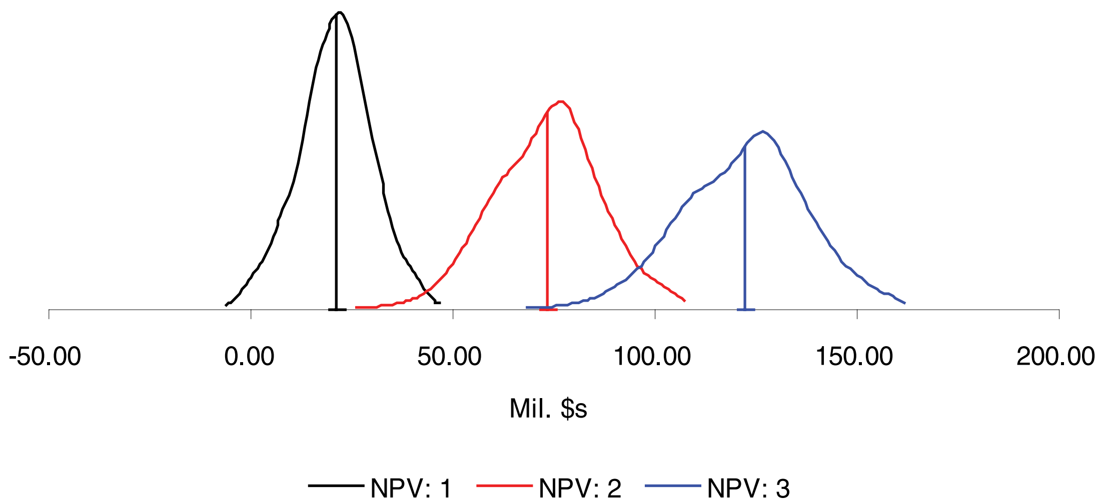

Figure 2: The Probability Density Functions of NPV for Scenarios 1, 2 and 3.

2007. The stochastic average variable cost per gallon was $1.219, with a standard deviation of $0.144 and a coefficient of variation (CV) of 11.81 percent. The minimum and maximum variable costs were $0.912 and $1.769, respectively. Figure 1 presents the probability density function (PDF) chart of the variable cost in 2007 for the stochastic scenarios. The deterministic cost of production (the vertical line at $1.21/gallon in Figure 1) is 52 cents less than the maximum and 30 cents greater than the minimum due to the skewed nature of production costs.

Based on the assumptions for the 50 MMGPY plant a deterministic feasibility study would report PVENW values of $17.25, $31.89, and $42.79 million for ethanol price Scenarios 1, 2, and 3, respectively. Deterministic NPVs for Scenarios 1, 2, and 3, were $8.71, $76.62, and $127.46 million, respectively. Rate of return on investment (ROI) was 26.5, 51.7, and 70 percent for the three scenarios.

The Monte Carlo feasibility study resulted in average PVENW values that were similar to the deterministic study for all three price scenarios; however, the risk analysis produced estimates of the variability on PVENW, NPV, and ROI. For Scenario 1, the deterministic PVENW was $17.25 million and the risk study reported a mean PVENW of $20.03 million. The NPV for the deterministic and stochastic analysis were $8.71 million and $20.94 million, respectively, for Scenario 1 and the stochastic analysis projected NPV would have

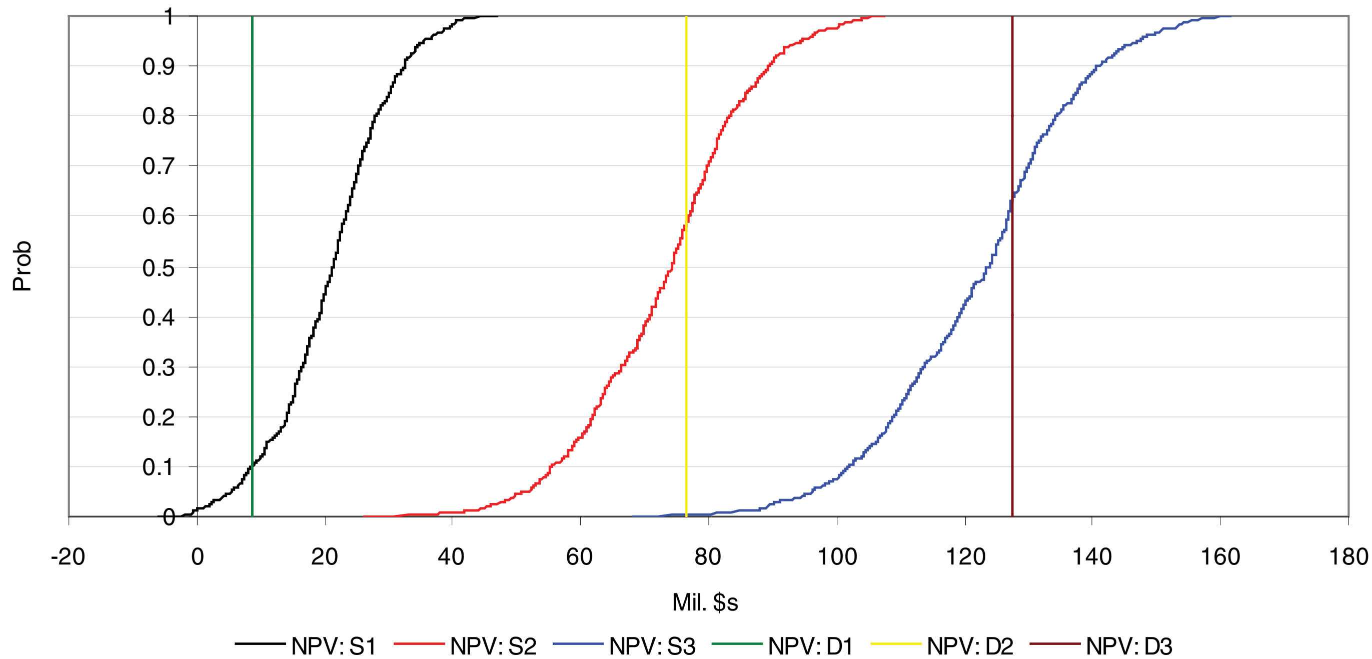

Figure 3: The Cumulative Distribution Functions for the Deterministic and Stochastic results for Scenarios 1, 2 and 3.

a minimum and maximum of -$5.87 million and $46.86 million, respectively. By only analyzing the deterministic NPV, one misses the range of possible outcomes and could make a bad business decision.

For Scenario 2 ($2.20/gal), the PVENW for the deterministic analysis was $31.89 million and $31.27 million for the Monte Carlo analysis. The NPV for the deterministic and stochastic studies were $76.62 million and $73.14 million, respectively, and the stochastic analysis has a minimum and maximum NPV of $26.33 million and $106.96 million, respectively, for an $80 million range.

Under Scenario 3 ($2.50/gal) the PVENW for the deterministic study was $42.79 million and $41.77 million for the stochastic model. The NPV for the deterministic results was $127.46 million and $122.07 million for the stochastic analysis and the stochastic minimum and maximum NPVs were $67.95 million and $161.09 million, respectively for a $93 million spread.

The simulation risk analysis showed an average ROI for Scenario 1 of 31.3 percent, slightly higher than the deterministic ROI of 26.5 percent (Table 1). For Scenarios 2 and 3 the average ROI from the risk analysis was 50.7 and 68.8 percent, both less than there respective deterministic results. More importantly the risk analysis indicated that investors could expect considerable variability in ROI. Under Scenario 2 the ROI could range from 31.5 percent to 64.9 percent with a 55 percent chance of the ROIs exceeding 50 percent. Under Scenario 1 there was a 34 percent chance that ROI would be less than 30 percent.

By examining the simulated values for NPV over all iterations simulated, the model indicated the probability that NPV would be negative. For Scenario 1 the probability of a negative NPV was 1.6 percent (Table 1). For Scenarios 2 and 3 the probability of a negative NPV equaled zero. As a result the probability of economic success is 98.4 percent for Scenario 1 and 100 percent for Scenarios 1 and 3, based on the probability of returning a return greater than the 25 percent discount rate.

Figure 2 presents the probability density function (PDF) charts of NPV distributions for the three stochastic scenarios and the deterministic NPV for the no-risk scenarios. The deterministic NPVs are depicted as vertical lines in the three PDFs. The assumption that ethanol price has a minimum of the $1.80/gal is responsible for the narrow dispersion of the PDF for Scenario 1.

Figure 3 presents a cumulative distribution function (CDF) chart of the simulated NPV distributions under the three price scenarios. The three vertical lines in the CDF chart represent the deterministic NPVs for the three scenarios. The line

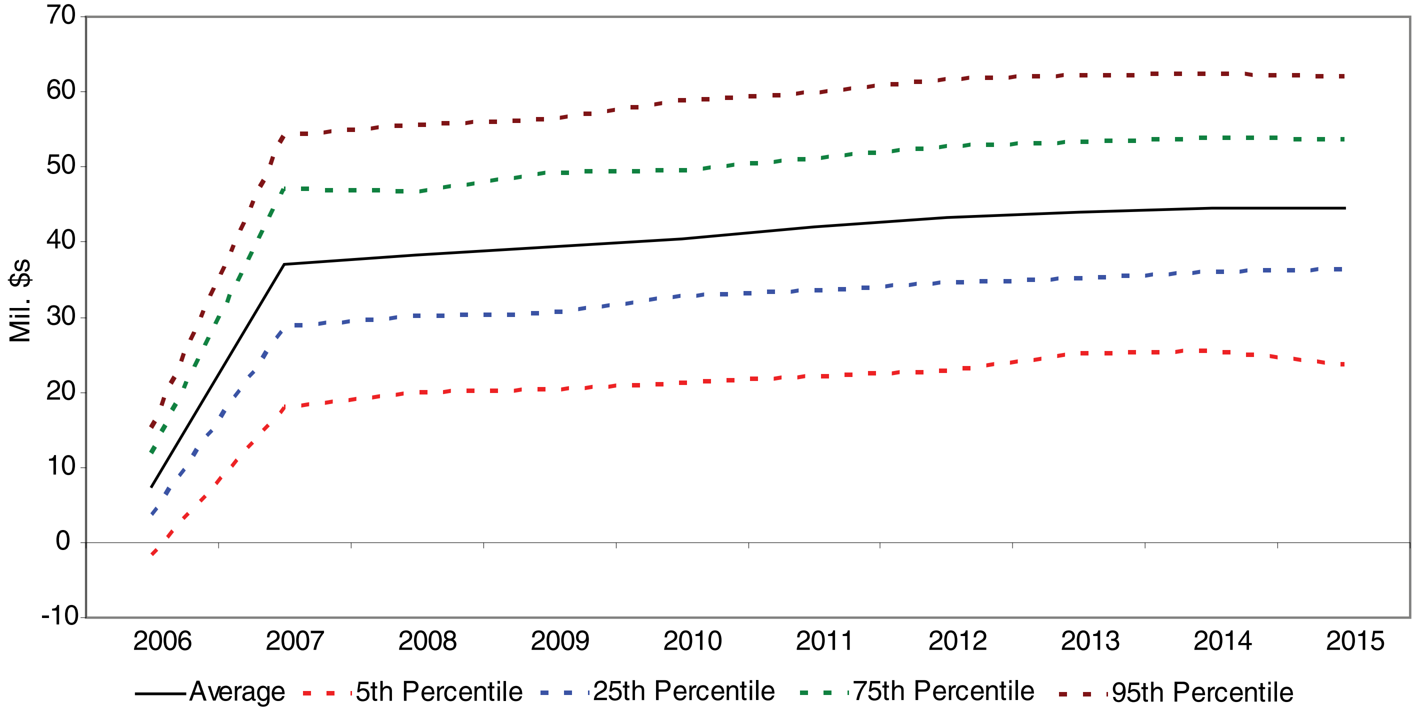

Figure 4: A Fan Graph of Annual Net Cash Income for Scenario 2

for the deterministic NPV crosses the CDF for its associated stochastic scenario at different points for each scenario. Scenario 1's deterministic NPV crosses the CDF at the 10 percent level because there is an assumed minimum price for ethanol of $1.80 and the simulated ethanol price does not fall below $1.80. In Scenarios 2 and 3 the deterministic NPV line crosses the associated CDF at approximately the 60 percent level indicating that the deterministic analysis has a positive bias. The probability distributions and the CDFs for NPV generated by the Monte Carlo model provide a great deal more information about the economic viability of the proposed business than the deterministic analysis.

Figure 4 presents a fan graph of the annual net cash income (NCI) under Scenario 2 for the 10-year planning horizon. The fan graph illustrates the range of possible NCI for each year of the planning horizon. The top line represents the 95-percentile line while the bottom line represents the 5-percentile line. This means 90 percent of the time annual NCI falls between these lines so the two lines represent a 90 percent confidence interval for NCI in each year. The middle line is the average. The lines second from the bottom and top represent the 25 percentile and 75 percentile lines, respectively; so they represent the 50 percent confidence interval for annual NCI. The fan graph shows a positive trend in NCI and has relatively little change in the overall NCI variability over the 10-year period. Figure 5 presents a fan graph of the Ending Cash for Scenario 2 over the 10-year planning horizon and shows a positive trend in cash reserves but with increasing variability over time.

Conclusions

The purpose of this paper was to demonstrate the usefulness of Monte Carlo simulation for evaluating the economic viability of a proposed agribusiness. A simulation model of a 50 MMGPY ethanol plant in the Texas Panhandle was developed based on accepted input/output coefficients and investment costs. Stochastic values for costs and prices were incorporated into the model using historical risk for these variables, thus facilitating a simulation risk analysis of the business.

The simulation model was developed using standard accounting principles and pro forma financial statements. Key output variables for the analysis were variables of interest to potential investors, namely: present value of ending net worth (PVENW), net present value (NPV), rate of return to investment (ROI), probability of economic success, and annual cash flows. Additional output variables of interest to investors, such as financial ratios, can be reported for a Monte Carlo simulation model.

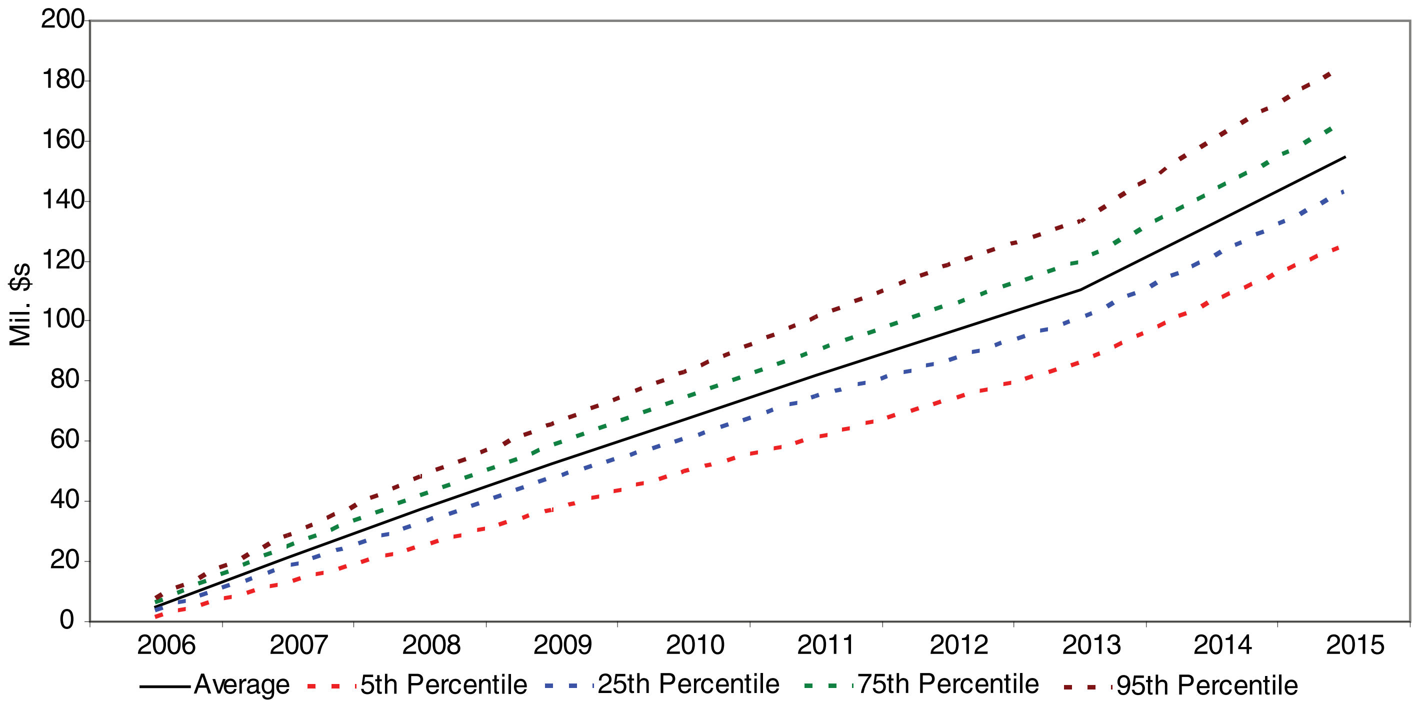

Figure 5: A Fan Graph of Annual Ending Cash for Scenario 2.

To demonstrate the usefulness of simulation risk analysis the results of three alternative scenarios were reported for a proposed ethanol plant. The pro forma financial statement simulation model was run two ways: deterministic and stochastic. The same parameters for the plant and means for the stochastic costs and prices were used for both methodologies. Both the deterministic and the simulation risk analysis results suggested that the plant could be economically viable under three ethanol price scenarios.

The results for the stochastic analysis provided more output to analyze. Mean values for PVENW and NPV were similar but the distributions of these variables for the simulation risk analysis showed a significant amount of variability for all of the key output variables. Point estimates do not give an indication of the risk a company faces when they are building a new plant or making other business decisions.

This paper demonstrated the advantages of simulation risk analysis to analyze the investment potential of a proposed agribusiness. The methodology can be easily applied to feasibility studies for a wide variety of agribusinesses. With the wide spread availability of micro computers, the use of spreadsheet models for business, and the ease of using simulation add-ins such as Simetar, models such as the one demonstrated here can be easily developed and used for business decision making in a risky environment.

Endnotes

[1] MMGPY denotes million gallons per year.

[2] Ethanol and DDGS prices had a downward trend for the seven year period prior to the BBI study.

[3] The GRKS distribution is a two piece normal distribution with 50 percent of the weight below the middle value and 2 percent less than the minimum, and 50 percent above the middle value and 2 percent above the maximum. The distribution is used in place of a triangle distribution when one knows only the minimum information about the random variable (Richardson, 2006).

[4] Tiffany and Eidman (2003) used 2.75 g/bu for a corn to ethanol conversion rate. Whims (2004) used 2.65 g/bu for ethanol. Shapuari, *et al*. (2002) used 2.64 g/bu for ethanol.

[5] The DDGS coefficient was 18 lb/bushel, meaning that 18 lbs of DDGS is derived from every bushel of corn used in ethanol production. Tiffany and Eidman (2003) used 18 lbs of DDGS per bushel of corn conversion rate. Whims (2004) used 15 lbs/bu for DDGS.

[6] Dale and Tyner (2006) reported that the cost per gallon to produce ethanol was $0.954 (with DDGS credit) for a 40 MMGPY plant. USDA (2006) reported that the average cost of production is $1.0719 (with DDGS credit) in 2005.

[7] Natural gas and electricity costs per gallon were based on their respective stochastic prices and energy requirements of 0.038MCF/gal and 0.80 Kwh/gal, respectively (BBI, 2003).

[8] A 35 percent dividend is a standard level of compensation for agribusiness firms organized as cooperatives (Smith *et al*., 1998). This level of compensation is expected to cover the dividend plus taxes assessed on members for undistributed earning for the cooperative.

[9] Land values were not appreciated as clean up costs at the end of the plants' useful life may offset any appreciation gained over the life of the investment.

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Agricultural and Food Policy Center
Department of Agricultural Economics
Texas A&M University
College Station, Texas 77843-2124

or call (979) 845-5913.