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Including Risk in Economic Feasibility Analyses: The Case of Ethanol Production in Texas

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The widespread use of personal computers and spreadsheet models for feasibility studies makes risk-based Monte Carlo simulation analysis of proposed investments a relatively simple task. Add-in simulation packages for Microsoft® Excel can be used to make spreadsheet models stochastic. Rather than basing investment decisions on point estimates, investors can easily estimate the implied distributions of returns for uncertain investments and calculate the risk of an investment as well as the probability of success. The benefits of using Monte Carlo simulation to analyze a risky investment are demonstrated using an ethanol plant as an example.

Key Words: economic feasibility analysis, ethanol feasibility, risk management, stochastic simulation

Business analysts around the world have been relying on Microsoft® Excel to conduct economic feasibility analyses of prospective investments for more than 15 years. The widespread availability of microcomputers and the ease of using spreadsheet models to answer "what if" questions is largely responsible for the popularity of Excel among business analysts. Numerous textbooks used in business schools rely on Excel to demonstrate the basic concepts involved in business analysis (e.g., Keller and Warrack, 1997; Ragsdale, 2001; Weida, Richardson, and Vazsonyi, 2001; Wilson and Keating, 2002).

Over the past 10 years, the interest in Monte Carlo simulation has increased (e.g., Winston, 1996; Thompson, 2000; Vose, 2002; Aven, 2005; Richardson, 2006). The reduced cost of computers, widespread use of Excel in business, and the availability of simulation add-ins for Excel has made Monte Carlo simulation practical for business analysis. 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 under risk.

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Deterministic investment feasibility analyses that ignore risk provide only a point estimate for key output variables (KOV) instead of estimates for probability distributions that show the chances of success and failure (Pouliquen, 1970; Reutlinger, 1970; Hardaker et al., 2004). According to Pouliquen (1970), Monte Carlo simulation provides decision makers with extreme values of relevant KOVs and their relative probabilities with a weighted estimate of the relationships between unfavorable and favorable outcomes. In addition to analysis of risk and how it affects the feasibility of a project, he suggested that a completed feasibility simulation model can be used to analyze alternative management plans if the investment is undertaken.

User-friendly simulation add-ins for Excel, such as Simetar, @Risk, and Crystal Ball, are available for converting deterministic Excel spreadsheet models into Monte Carlo simulation models. Despite this availability, agribusiness feasibility studies done using Excel generally ignore risk (e.g., Bryan and Bryan International, 2003; Van Dyne, 2002; Long and Creason, 1997; Fruin, Rotsios, and Halbach, 1996; Tiffany and Eidman, 2003; Whims, 2004; Shapouri, Gallagher, and Graboski, 2002).

The objective of this article is to demonstrate the benefits of using Monte Carlo simulation techniques, instead of conventional deterministic spreadsheet analysis, to measure the economic viability of a risky investment. First, relevant literature on ethanol production in the U.S. is reviewed briefly. Then the Monte Carlo simulation techniques for analyzing the economic viability of a proposed 50 million gallon per year (MMGPY) ethanol plant in Texas are described in detail. Results for both a deterministic and a Monte Carlo simulation feasibility analysis are presented to demonstrate the benefits of including risk as a factor in a feasibility analysis.

Feasibility of Ethanol Production in the U.S.

Recent interest in ethanol production among rural development groups, politicians, and grain producers can be attributed to many different factors: depressed commodity prices, rising gasoline prices, shifts in environmental policy, and a push towards national fuel self-sufficiency. Grain producers in many regions are considering the development of ethanol plants to help overcome low crop prices. Bryan and Bryan International (BBI) (2006) reported that in 2005, there were 95 ethanol plants in the US with a combined production capacity of 4,336 MMGPY.

Much of the literature on the economic feasibility of ethanol production in the U.S. comes from the 1980's, a boom period for the development of ethanol plants, but more recently, topics covered include the structure of the industry, production technology, ethanol policy, feasibility studies, economic impact studies, and economies of scale (e.g., Van Dyne, 2002; Bryan and Bryan International, 2001, 2003, 2006; Long and Creason, 1997; Gill, 2002; Herbst, 2003; Tiffany and Eidman, 2003; Shapouri, Gallagher, and Graboski, 2002; Whims, 2004; Shapouri, Salassi, and Fairbanks, 2006).

Almost 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 ethanol facility in Dumas, Texas, including the operational and construction costs for additional 30 and 80 MMGPY facilities. However, they ignored ethanol and dry distillers grain (DDGS) price risk and simply increased their assumed prices at a fixed rate of inflation over time.[1] Instead of accounting for risk on corn price and energy cost, they simply indexed operating costs over the study period to account for inflation. Similarly, Shapouri, Salassi, and Fairbanks (2006) analyzed the economic feasibility of ethanol production from several feedstocks, and like BBI, they did not incorporate price and cost risk.

In contrast to other ethanol plant feasibility studies, Gill (2002) and Herbst (2003) used Monte Carlo simulation techniques to incorporate price and cost risk. Gill analyzed the economic viability of ethanol plants for alternative levels of state subsidies for ethanol production in Texas. Herbst estimated the economic variability of ethanol production using corn or sorghum and whether plants were located in different regions of Texas. Because they incorporated risk into their studies, their results presented (a) the probability of economic success and (b) the probability of positive annual cash flow.

Monte Carlo Simulation for Feasibility Analyses

Richardson (2006) outlined the steps for developing a production-based investment feasibility simulation model. First, probability distributions for all risky variables must be defined, parameterized, simulated, and validated. Second, the stochastic values from the probability distributions are used in accounting equations to calculate production, receipts, costs, cash flows, and balance sheet variables for the project. Stochastic values sampled from the probability distributions make the financial statement variables stochastic. Third, the completed stochastic model is simulated many times (i.e., 500 iterations) using random values for the risky variables. The results of the 500 samples provide information used to estimate empirical probability distributions for unobservable KOVs (e.g., present value of ending net worth, net present value, and annual cash flows) so that investors can evaluate the probability of success for a proposed project. Fourth, the analyst uses the stochastic simulation model to analyze alternative management scenarios and provides the results to decision makers in the form of probabilities and probabilistic forecasts for the KOVs.

The steps for developing a Monte Carlo simulation model for an investment feasibility study are presented in this section. Due to the annual nature of corn production, the model for a proposed ethanol plant is assumed to be annual. The equations for the ethanol feasibility model are the accounting identities necessary to calculate an income statement, cash flow statement, and a balance sheet.

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

Stochastic Variables

Stochastic variables in a Monte Carlo simulation model are variables the decision maker is unable to forecast with certainty. Such variables have two components: the deterministic component, which can be forecasted with certainty, and the stochastic component, which cannot be forecasted with certainty. For example, the forecast for a stochastic variable, Y, can be represented as $\tilde{Y} = \hat{Y} + \tilde{e}$, where $\hat{Y}$ is the deterministic component and $\tilde{e}$ is the stochastic component, the latter of which is forecasted by simulating values from a probability distribution. Deterministic feasibility studies use the $\hat{Y}$ values as the forecast and assume $\tilde{e}$ is zero. Monte Carlo simulation feasibility studies estimate parameters for the $\tilde{e}$ distributions based on historical data and simulate a large number of samples to generate a probabilistic forecast of $\tilde{Y}$.

Stochastic variables in the ethanol model used in this study include annual prices for corn, ethanol, DDGS, electricity, natural gas, and gasoline, as well as interest rates, inflation rate for production costs, and number of days per year the plant is down. The stochastic variables were simulated using the multivariate empirical (MVE) distribution described by Richardson, Klose, and Gray (2000) to account for the correlation among the variables. Historical data for 1989–2005 were used to estimate the parameters for the MVE distribution. Parameters for the MVE distribution include projected annual mean prices in the FAPRI November 2006 Baseline (deterministic component), historical deviations from trend forecasts expressed as a fraction (stochastic component), and the correlation matrix for the deviations from trend (the multivariate component).

Equations (A.1)–(A.11) in the Appendix provide detail about how the random variables were simulated. Equations (A.1)–(A.8) were simulated as an MVE distribution, defined by the fractional deviations from trend (S_i), cumulative probabilities ($F(S_i)$), and correlated uniform standard deviates (C_i), where i indicates the row of the correlation matrix. Equations (A.9) and (A.10) are linearly dependent on the stochastic prime interest rate, thus making operating and certificates of deposit (CD) interest rates stochastic. The last stochastic variable, down time (A.11), is the number of days per year the plant is not operating and is simulated using a GRKS distribution.[2] The GRKS distribution assumed a minimum days down of 10 and a maximum of 20 with a middle value of 15.

Historical corn and DDGS prices were obtained from the United States Department of Agriculture, Economic Research Service, Feed Grains Data Delivery Service for 1989 through 2005 (USDA, 2006). Ethanol prices were collected from Hart's Oxy-Fuel News from 1989 to 2005. Historical annual wholesale gasoline, industrial electricity, and natural gas prices were obtained from the United States Department of Energy (USDE, 2006). Historical operating interest rates and the

[2] The GRKS distribution is a two-piece normal distribution with 50% of the weight below the middle value and 2.5% less than the minimum, and 50% above the middle value and 2.5% above the maximum. The distribution is used in place of a triangle distribution when one knows only minimum information about the random variable and the minimum and maximum are uncertain (Richardson, 2006).

index of prices paid (PPI) were obtained from the 2006 *Economic Report of the President*. 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.

Projected means for the stochastic variables over the 2007–2016 study period came from several sources. Projected annual mean prices for ethanol, corn, DDGS, interest rates and PPI came from the FAPRI November 2006 Baseline. Annual average prices for electricity, gasoline, and natural gas were projected using their 2005 prices and the FAPRI projection for annual rates of change in the price of fuel.

The stochastic variables were simulated for 500 iterations to validate the stochastic part of the model. Student-*t* tests, at the alpha equal 0.05 level, were performed for all random variables to determine whether they statistically reproduced their respective means in each year of the planning horizon. Box's *M* test was performed on the simulated values to determine whether they statistically reproduced their historical covariance matrix at the alpha equal 0.05 level. Student-*t* tests were performed on the simulated values to determine whether their observed correlation was statistically equal to their respective historical correlation coefficients at the alpha equal 0.05 level. All of the tests failed to reject their null hypotheses, meaning that the stochastic variables statistically reproduced their assumed means and their historical variability and correlation.

The Economic Model

Equations in the pro forma financial statements (income statement, cash flow, and balance sheet) for a deterministic economic feasibility spreadsheet model comprised all of the equations for the Monte Carlo simulation model. The stochastic variables in equations (A.1)–(A.11) were used as exogenous variables in the pro forma financial statement equations to incorporate risk into the model. The equations for the proposed ethanol plant are summarized in the Appendix as equations (A.12)–(A.46).

Receipts

Ethanol production (A.12) is a function of engineered capacity minus lost production when the plant is down for repairs. Gasoline required (A.13) to denature the ethanol was assumed to be 5% of ethanol production. Gross ethanol production (A.14) is the sum of ethanol production and gasoline required. Ethanol receipts (A.15) are the product of the stochastic price for ethanol and gross ethanol production.

Corn used (A.16) by the plant equals stochastic ethanol production divided by 2.75 gal./bu.,[3] so corn purchased was a stochastic variable. Annual DDGS receipts (A.17) were computed by multiplying quantity of corn purchased by the DDGS per

[3] Tiffany and Eidman (2003) used 2.75 gal./bu. for a corn to ethanol conversion rate. Whims (2004) used 2.65 gal./bu. for ethanol. Shapouri, Gallagher, and Graboski (2002) used 2.64 gal./bu. for ethanol.

bushel of corn coefficient, 18 lbs./bu.[4] and the DDGS stochastic price. Interest earned on beginning year cash balances (A.18) was included in the income statement and was calculated using the stochastic operating interest rate for certificates of deposit times the positive ending cash balances in the previous year. Total receipts (A.19) equal the sum of ethanol receipts, DDGS receipts, and interest earned on positive cash balances.

Expenses

The cost of corn (A.20) used for the fermentation process is the product of the stochastic price of corn in Texas and the stochastic quantity of corn purchased. Gasoline cost (A.21) is the product of stochastic price of gasoline and gasoline required. Natural gas (A.22) and electricity (A.23) costs were calculated based on input requirements for a 50 MMGPY plant (BBI, 2003) and their stochastic annual prices for these inputs.[5] Other production costs in addition to those accounted for explicitly in the model come from the BBI (2003) plant handbook adjusted for inflation. Other costs (A.24) were calculated using the base cost per gallon adjusted annually for the stochastic annual inflation rates, multiplied by the volume of anhydrous ethanol produced. Total variable cost (A.25) is the sum of costs for corn, gasoline, natural gas, electricity, and other costs, all of which are stochastic.

Christianson (2006) reported that the cost to build a 50 MMGPY plant was $2.20/gal. of capacity. The $110 million of capital requirements included construction and land costs. The present analysis assumed that 50% of the total capital requirements were borrowed and that the remaining 50% were contributed by owner/investors. The 8-year loan on the plant was amortized using a fixed interest rate of 9.5% to calculate annual interest payments (A.26) and principle payments (A.36) for the plant loan. These calculations are deterministic because a fixed interest mortgage was assumed for the plant. If the mortgage had a variable interest rate, these calculations would be stochastic as well.

An annual operating loan equal to 15% of total variable costs was assumed for the model, and the operating loan interest cost (A.27) was calculated using a stochastic interest rate. Stochastic operating interest rates were also used for annual loans to refinance cash flow deficits (A.28). Total interest cost (A.29) is the sum of interest on the plant loan, an operating loan interest payment, and interest on carryover loans.

Annual depreciation (A.30) for the initial plant outlay (less land costs) and annual capital replacement outlay was calculated using the MACRS fractions for an asset with a 15-year life, given the relevant year for the calculation. Total expenses (A.31)

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[4] The DDGS coefficient was 18 lbs./bu., 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.

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

equal total variable costs plus interest and depreciation. Net return (A.32) was calculated as total receipts minus total expenses.

Cash Flows

The annual cash flows were calculated using equations (A.34)–(A.39). Cash inflows (A.34) equal net cash income (A.33) plus the positive cash reserves from the previous year (A.39). In a stochastic model, ending cash reserves can be positive or negative. Positive cash reserves are a cash inflow to the next year and earn interest (A.27), while negative cash reserves are cash flow deficits that require carryover financing the next year (A.28). Outflows in the cash flow statement (A.38) are dividends, principal payments, capital replacement, repayment of previous year cash flow deficits, and federal income taxes.

A corporate business structure was assumed for calculating federal income taxes (A.37). For the purposes of this study, 35% of positive net returns was paid as a dividend (A.35) each year.[6] Total cash inflows minus annual total outflows equaled ending cash balance before borrowing (A.39).

Balance Sheet

Value of total assets (A.40) was calculated annually using positive ending cash balances, land value,[7] and book value for plant and equipment adjusted for MACRS depreciation factors (Smith, Harmelink, and Hasselback, 1998). Total liabilities (A.41) equal long-term liabilities (the current balance for the plant loan) plus current cash flow deficits. Net worth (A.42) was computed by subtracting total liabilities from total assets. Net worth was used in two forms: nominal, or current, dollar terms and real dollars, for which the nominal values have been discounted using a rate of 7.5%. Debt to asset ratio (A.45) was calculated using nominal asset and debt values and insolvency was assumed if the ratio exceeded 75%.

The probability of economic success was calculated using the net present value (NPV), which was calculated with equation (A.43). A positive NPV value indicated that the firm had a rate of return greater than the discount rate, 0.075, and was therefore 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 "ones" for the NPV counter variable divided by the number of iterations.

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[6] A 35% dividend is a standard level of compensation for agribusiness firms organized as cooperatives (Smith, Harmelink, and Hasselback, 1998). This level of compensation is expected to cover the dividend plus taxes assessed on members for undistributed earning for the cooperative.

[7] Land values 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.

Model Assumptions

In terms of a single gallon of ethanol produced, this section outlines the assumptions made in our simulation of a 50 MMGPY ethanol plant. One bushel of corn yields 2.75 gallons of ethanol and 18 lbs. DDGS. The variable costs for making ethanol include enzymes at $0.04/gal., chemicals at $0.04/gal., maintenance materials at $0.02/gal., labor at $0.05/gal., and miscellaneous and water treatment costs at $0.03/gal. (BBI, 2003). Capital requirements including construction and startup costs were $110 million, plus a one-year loan to pay for $9 million worth of supplies, corn inventory, and training (Christianson, 2006). Annual capital replacement costs were $1.1 million, or 1%, per year of the initial capital outlay for the plant.

The most critical assumption for the ethanol plant was the annual mean prices for corn and ethanol. The FAPRI November 2006 Baseline projected prices for corn and ethanol in 2007–2016 were used as forecasted mean values for these stochastic variables. Ethanol prices were projected to decline steadily from $2.01/gal. in 2007 to $1.67 in 2016. Corn prices were projected to increase from $2.99/bu. in 2007 to $3.09 in 2011 and then decline gradually to $3.04 in 2015. Higher corn prices in the Baseline than the previous 10 years were due to increased demand for corn by ethanol producers.

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

The simulation model for the proposed ethanol plant was programmed in Microsoft® Excel using the accounting identities and equations in the Appendix. The deterministic simulation model was made stochastic using Simetar, an add-in for Excel developed by Richardson, Schumann, and Feldman (2006). Simetar was used to estimate the parameters for the multivariate empirical probability distribution and simulated the model using a Latin hypercube sampling procedure for simulating pseudo-random numbers.

Results

Results of the economic feasibility analysis for a 50 MMGPY ethanol plant in the Texas Panhandle are presented in table 1, which summarizes the deterministic and risk-based (or probabilistic) forecasts of six KOVs: variable cost per gallon, average net returns over 10 years, average ending cash reserves over 10 years, net present value, rate of return on investment (ROI), and present value of ending net worth (PVENW). For each of the KOVs, the deterministic forecast is a single point forecast while the stochastic analysis reports the mean, standard deviation, coefficient of variation, and minimum and maximum statistics, thus indicating the risk associated with each KOV.

Table 1. Results of Deterministic and Monte Carlo Simulation Feasibility Analyses for a 50 MMGPY Ethanol Plant in Texas, 2007–2016

	Deterministic	Stochastic
Cost of Production for Ethanol		
Mean ($/gallon)	1.46	1.47
Standard Deviation ($/gallon)		0.16
Coefficient of Variation (%)		11.13
Minimum ($/gallon)		1.14
Maximum ($/gallon)		2.07
Average Annual Net Return		
Mean (mil $s)	3.67	1.97
Standard Deviation (mil $s)		4.37
Coefficient of Variation (%)		222.04
Minimum (mil $s)		−15.08
Maximum (mil $s)		12.95
Average Annual Ending Cash Reserves		
Mean (mil $s)	22.15	9.96
Standard Deviation (mil $s)		20.02
Coefficient of Variation (%)		200.94
Minimum (mil $s)		−68.69
Maximum (mil $s)		54.82
Net Present Value		
Mean (mil $s)	−26.80	−38.48
Standard Deviation (mil $s)		30.19
Coefficient of Variation (%)		−78.45
Minimum (mil $s)		−147.94
Maximum (mil $s)		35.74
Rate of Return on Investment		
Mean (%)	6.06	4.95
Standard Deviation (%)		3.64
Coefficient of Variation (%)		7,342.57
Minimum (%)		−8.48
Maximum (%)		15.45
Present Value of Ending Net Worth		
Mean (mil $s)	38.26	27.22
Standard Deviation (mil $s)		16.92
Coefficient of Variation (%)		0.00
Minimum (mil $s)		−48.09
Maximum (mil $s)		67.51
Prob Economic Success		9.40%
Prob (PVENW < 0.0)		6.46%
Prob (ROI < 0.0)		9.12%
Prob Insolvent (D/A > 0.75)		13.60%

The deterministic forecast of variable cost per gallon of ethanol with credits for DDGS was $1.46 in 2007 (table 1).[8] The stochastic forecast of variable cost per gallon has an average of $1.47, with a standard deviation of $0.16 and a coefficient of variation (CV) of 11.13%. The minimum and maximum variable costs per gallon are $1.14 and $2.07, respectively. Figure 1 presents the variable cost of production probability density function (PDF) chart for ethanol in 2007. The deterministic cost of production (the vertical line at $1.46/gal. in figure 1) is $0.61 less than the maximum and $0.32 greater than the minimum due to the skewed nature of the distribution for production costs.

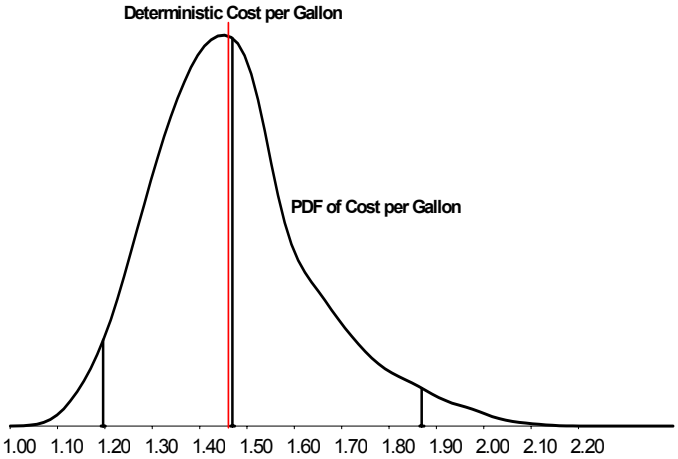

Figure 1. Probability density function forecast of the 2007 cost of production for ethanol vs. a deterministic forecast ($/gallon)

The deterministic economic analysis for the proposed ethanol plant forecasted an average annual net return of $3.67 million per year, whereas the stochastic analysis forecasted an average of $1.97 million with a minimum of −$15.08 million and a maximum of $12.95 million per year (table 1). Similarly, the deterministic forecast overstated the average annual ending cash reserves at $22.15 million relative to the stochastic forecast, which had an average ending cash reserve at $9.96 million with a range of −$68.69 million to $54.82 million. The deterministic forecast for the proposed investment not only ignored the risk of net returns and ending cash reserves but also produced biased estimates of these KOVs.

Deterministic forecasts of NPV, ROI, and PVENW were also biased with higher values than forecasted by the stochastic analysis. For example, the deterministic analysis forecasted ROI to be 6.06% while the stochastic forecast has a mean of

[8] Costs of production for ethanol are $0.20 to $0.25/gal. higher than recent estimates by Shapouri, Salassi, and Fairbanks (2006) due to the higher corn price used for the analysis.

4.95% with a range of −8.48% to 15.45%. The stochastic analysis also indicated that ROI has a 9.12% chance of being less than zero (table 1).

The Monte Carlo simulation feasibility analysis facilitated reporting the results for the KOVs as cumulative distribution functions (CDFs), as seen in figures 2 and 3. The CDF for NPV showed that NPV would range from a minimum of −$147.94 million to a maximum of $35.74 million. The CDF for NPV also indicated that there is less than a 10% chance that NPV will be positive and therefore less than a 10% chance of economic success. The deterministic NPV forecast bisected the CDF at about 65%, indicating that there is a 65% chance of NPV being less than the deterministic forecast.

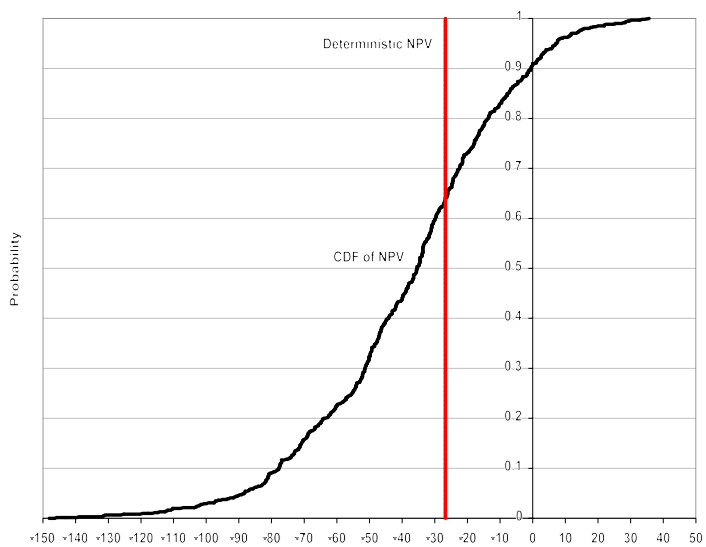

Figure 2. Cumulative distribution function of NPV vs. deterministic forecast (mil $s)

The CDF for ROI shows that there is considerable variability for this KOV, with a range of −0.08 to 0.15, about a 9% chance of a negative ROI, and about a 75% chance of ROI less than the 7.5% discount rate (figure 3). Investors concerned about the probability of the investment earning less than the discount rate could not obtain this information from a deterministic analysis.

The annual net return forecasts for the deterministic analysis are included in figure 4, along with a fan graph of the probability distributions for annual net returns. In each year, the deterministic forecast is slightly higher than the stochastic forecast's average. The 5th and 95th percentiles for the stochastic forecast show the lower and upper bounds of a 90% confidence interval for the forecast of the average annual net

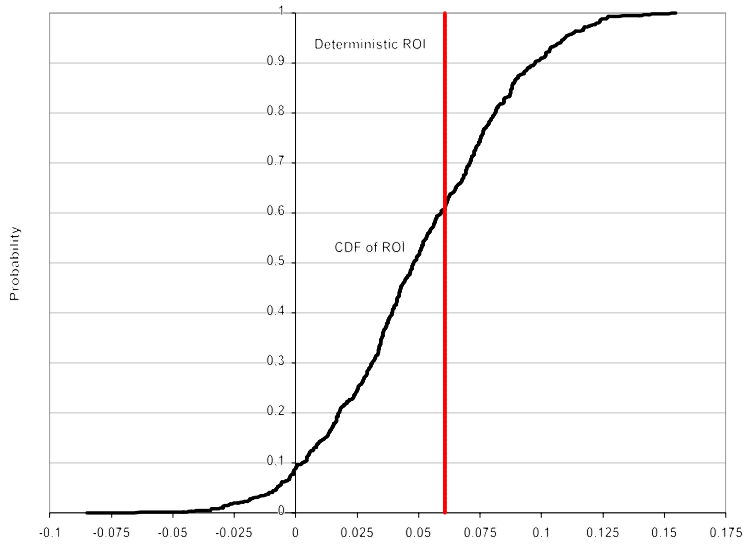

Figure 3. Cumulative distribution function for return on investment vs. deterministic forecast (fraction)

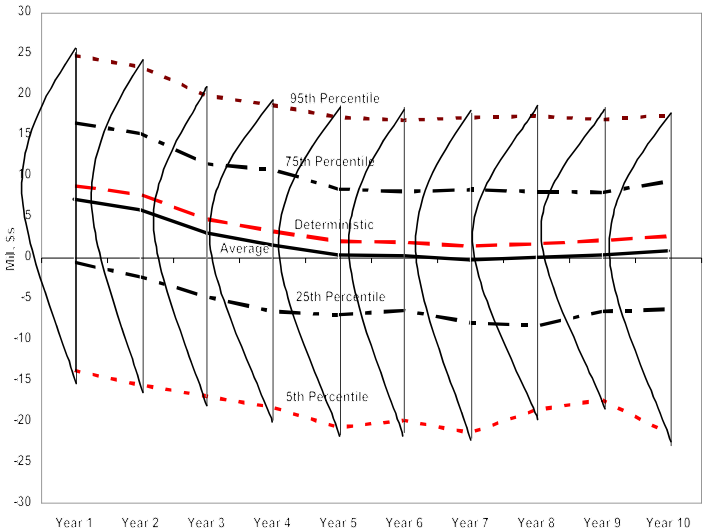

Figure 4. Fan graph of net cash return vs. deterministic forecast (mil $s)

return. The fan graph for annual net return shows there is a 25% chance that net returns will be less than −$5 million in year 3 and a 50% chance that net returns will be negative after year 4.

Annual ending cash flows are of considerable interest to investors. A graph of forecasted annual ending cash reserves for the proposed plant is included in Figure 5 for the deterministic and stochastic analyses. The deterministic analysis increasingly over-estimated average annual ending cash reserves each year of the planning horizon. The fan graph forecasts a significant chance of negative cash reserves in all years. The 90% confidence interval for annual ending cash reserves widens over the planning horizon due to the compounding effect of risk on cash reserves.

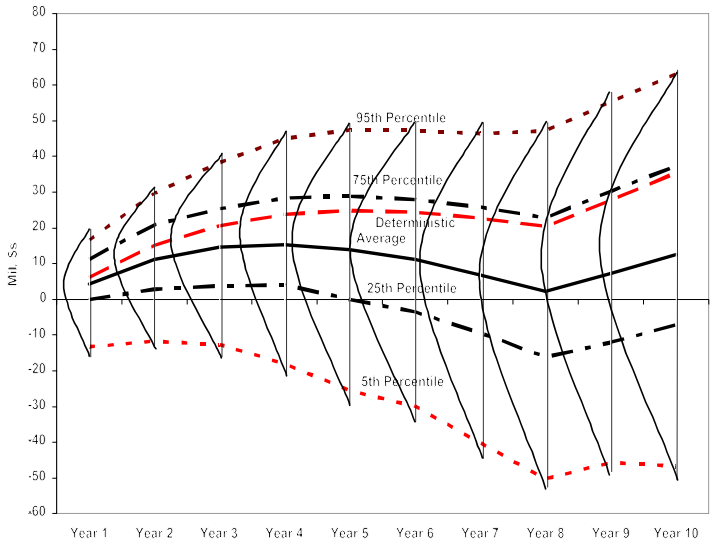

Figure 5. Fan graph of annual ending cash reserves vs. the deterministic forecast (mil $s)

Additional information available from a Monte Carlo simulation feasibility analysis could include probability distributions for financial ratios and other values of interest to the decision maker. For example, if the financing institution required the debt-to-asset ratio to remain below 75%, the proposed ethanol plant would have a 13.6% chance of being declared insolvent over the 10-year planning horizon (table 1). The probability that the investment will lose real net worth (i.e., a negative PVENW) is 6.46%, based on the probabilistic forecast for PVENW.

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 and recent forecasts of average annual prices, 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: annual net return, 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, could also be reported using a Monte Carlo simulation model.

The greatest benefit of a Monte Carlo simulation feasibility analysis is that the methodology explicitly incorporates risk faced by investors. By incorporating probability factors for variables that investors cannot forecast with certainty, the analyst can develop realistic probabilistic forecasts of KOVs. Additional benefits of the methodology include the decision maker's ability to see the range of KOVs as well as the probabilities of unfavorable outcomes. Charts and probabilities, which can more accurately portray the probable outcomes for an investment than a single point estimate, can be used to convey risky outcomes to the decision maker. These charts and probabilities are particularly useful when the inherent risk in the proposed project causes the KOV distributions to be skewed to the left or right or change shape over time.

This paper demonstrated the advantages of simulation risk analysis to assess 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.

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Appendix:
Stochastic Variables and Equations for the Ethanol Feasibility Model

Stochastic Variables

(A.1) $Ethanol\ Price_t = Mean\ Price_t \times [1 + MVE\ (S_i\ F(S_i), C_8)]$
(A.2) $DDGS\ Price_t = Mean\ Price_t \times [1 + MVE\ (S_i\ F(S_i), C_7)]$
(A.3) $Corn\ Price_t = Mean\ Price_t \times [1 + MVE\ (S_i\ F(S_i), C_6)]$
(A.4) $Gasoline\ Price_t = Mean\ Price_t \times [1 + MVE\ (S_i\ F(S_i), C_5)]$
(A.5) $Natural\ Gas\ Price_t = Mean\ Price_t \times [1 + MVE\ (S_i\ F(S_i), C_4)]$
(A.6) $Electricity\ Price_t = Mean\ Price_t \times [1 + MVE\ (S_i\ F(S_i), C_3)]$
(A.7) $Inflation\ Rate_t = Mean\ Rate_t \times [1 + MVE\ (S_i\ F(S_i), C_2)]$
(A.8) $Prime\ Interest\ Rate_t = Mean\ Rate_t \times [1 + MVE\ (S_i\ F(S_i), C_1)]$
(A.9) $CD\ Interest\ Rate_t = Prime\ Interest\ Rate_t - CD\ Wedge$
(A.10) $OP\ Interest\ Rate_t = Prime\ Interest\ Rate_t - OP\ Wedge$
(A.11) $Down\ Time_t = GRKS$ (minimum, middle, maximum)

Receipts

(A.12) $Ethanol\ Production_t = Maximum\ Production\ per\ Day_t \times (365 - Down\ Time_t)$
(A.13) $Gasoline\ Required_t = Ethanol\ Production_t \times 0.05$
(A.14) $Gross\ Ethanol\ Production_t = Ethanol\ Production_t + Gasoline\ Required_t$
(A.15) $Ethanol\ Receipts_t = Gross\ Ethanol\ Production_t \times Ethanol\ Price_t$
(A.16) $Corn\ Used_t = Ethanol\ Production_t / Conversion\ Rate$
(A.17) $DDGS\ Receipts_t = Corn\ Used_t \times DDGS\ per\ bu\ Corn \times DDGS\ Price_t$
(A.18) $Interest\ Earned_t = Positive\ Cash\ Reserves_{t-1} \times CD\ Interest\ Rate_t$
(A.19) $Total\ Receipts_t = Ethanol\ Receipts_t + DDGS\ Receipts_t + Interest\ Earned_t$

Expenses

(A.20) $Corn\ Cost_t = Corn\ Used_t \times (Corn\ Price_t + Texas\ Price\ Wedge_t)$
(A.21) $Gasoline\ Cost_t = Gasoline\ Required_t \times Gasoline\ Price_t$
(A.22) $Natural\ Gas\ Cost_t = Ethanol\ Production_t \times 0.038 \times Natural\ Gas\ Price_t$
(A.23) $Electricity\ Cost_t = Ethanol\ Production_t \times 0.8 \times Electricity\ Price_t$
(A.24) $Other\ Costs_t = VC / gallon_{t-1} \times (1 + Inflation\ Rate_t) \times Ethanol\ Production_t$
(A.25) $Total\ Variable\ Cost_t = Corn\ Cost_t + Gasoline\ Cost_t + Natural\ Gas\ Cost_t + Electricity\ Cost_t + Other\ Costs_t$
(A.26) $Plant\ Debt\ Interest_t = Principal\ Owed_t \times Fixed\ Interest\ Rate_t$
(A.27) $Operating\ Interest_t = Total\ Variable\ Cost_t \times OP\ Interest\ Rate_t \times Fraction\ of\ year$
(A.28) $Carryover\ Loan\ Interest_t = Cashflow\ Deficits_{t-1} \times OP\ Interest\ Rate_t$
(A.29) $Total\ Interest\ Cost_t = Plant\ Debt\ Interest_t + Operating\ Interest_t + Carryover\ Loan\ Interest_t$
(A.30) $Depreciation_t = Plant\ Cost \times MACRS_t + Capital\ Replacement_t \times MACRS_t$
(A.31) $Total\ Expenses_t = Total\ Variable\ Cost_t + Total\ Interest\ Cost_t + Depreciation_t$

(A.32) $Net\ Returns_t = Total\ Receipts_t - Total\ Expenses_t$

(A.33) $Net\ Cash\ Income_t = Total\ Receipts_t - Total\ Variable\ Costs_t - Total\ Interest\ Cost_t$

Cashflow

(A.34) $Cash\ Inflows_t = Net\ Cash\ Income_t + Positive\ Cash\ Reserves_{t-1}$

(A.35) $Dividends_t = Maximum\ [\ 0.0, Net\ Returns_t \times 0.35]$

(A.36) $Principal\ Payment_t = Fixed\ Annual\ Payment - Plant\ Debt\ Interest_t$

(A.37) $Federal\ Income\ Taxes_t = Positive\ Net\ Returns_t \times Income\ Tax\ Rate$

(A.38) $Cash\ Outflows_t = Principal\ Payment_t + Repay\ Cashflow\ Deficit_{t-1} + Capital\ Replacement_t + Dividends_t + Federal\ Income\ Taxes_t$

(A.39) $Ending\ Cash_t = Cash\ Inflows_t - Cash\ Outflows_t$

Balance Sheet

(A.40) $Assets_t = Land\ Value + Book\ Value\ Plant_t + Positive\ Ending\ Cash_t$

(A.41) $Liabilities_t = Plant\ Debt_{t-1} - Principal\ Payments_t + Negative\ Ending\ Cash_t$

(A.42) $Net\ Worth_t = Assets_t - Liabilities_t$

Financial Ratios and KOVs

(A.43) $NPV = -\ Beginning\ Net\ Worth + \sum (Dividends_i + \Delta Net\ Worth_i) / (1 + 0.075)^i$

(A.44) $PVENW = Net\ Worth_{10} / (1 + 0.075)^{10}$

(A.45) $D/A_t = Liabilities_t / Net\ Worth_t$

(A.46) $ROI_t = (Net\ Returns_t + Total\ Interest\ Cost_t) / Initial\ Plant\ Cost$