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Economics of Sugar-Based Ethanol Production and Related Policy Issues

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The feasibility of integrating ethanol production into an existing sugar mill was analyzed by a stochastic spreadsheet model. As the price of corn continues to rise, ethanol producers will eventually need to look at other feedstock alternatives. Sugarcane has been proven to work well in the production of ethanol in Brazil. The results indicated existing U.S. sugar mills could economically switch to ethanol production. As imports into the United States threaten to undermine the U.S. sugar program, sugarcane producers have a viable alternative. At the very least, the alternative exists to diversify their income streams with ethanol production.

Key Words: ethanol, feasibility analysis, simulation analysis, sugarcane

JEL Classifications: R51, R58, O22

Interest in renewable energy production in the United States has increased dramatically. Since 1995, ethanol and biodiesel production have each experienced a significant increase in the number of plants in operation and in production. For example, ethanol production has risen from 1.4 billion gallons in 1995 to nearly 6 billion gallons in 2006 (Renewable Fuels Association). *Ethanol Producer Magazine* reported that in early 2007, there were 118 ethanol plants operating in the United States with 60 additional plants under construction. In the United States, ethanol is produced from grains and almost exclusively from corn in a fermentation-distillation process. In other countries such as Brazil, Australia, and India, ethanol is produced from grinding sugarcane and fermenting the juice and/or molasses. In fact, Brazil was the world leader in ethanol production until 2006, when U.S. production surpassed that of Brazil.

Although corn-based ethanol production has been profitable over the past few years, the near doubling of corn prices in late 2006 and early 2007 has significantly reduced ethanol plant profitability. With almost 20% of the U.S. corn crop now being used in ethanol production, the food versus fuel versus feed debate is starting to gain national and worldwide attention. Although most believe that the future of ethanol production in the United States and the world lies with cellulosic production, during the transition period, ethanol could potentially be produced in the United States from sugarcane, thereby mitigating some of the problems in the food and feed sectors due to high corn prices.

The United States has a long history of supporting sugar producers with a price support and marketing quotas (Lord). These

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instruments generally lead to domestic sugar prices that have been five or six times higher than world sugar prices, although currently, they are only 50% higher than the world price. To maintain the higher domestic sugar price, the United States limits the amount of sugar imports to a few countries, each having the right to export specific quantities to the United States. Under the negotiated terms of the North American Free Trade Agreement, Mexico will soon (January 2008) be able to export unlimited duty-free quantities of sugar to the United States. Although there are some who do not believe that Mexico will export significant quantities of sugar to the United States in 2008, the potential is there to create significant pressure on the U.S. sugar program. Ethanol production could be an option in the event the sugar program has to change because of pressure from imports.

To date, no firm in the United States has begun producing ethanol from sugarcane juice. To determine whether ethanol production in the United States is feasible, a feasibility analysis with sugarcane as the feedstock is needed. One major consideration is that sugarcane is currently grown in only four states: Hawaii, Texas, Louisiana, and Florida. Given the significant investment required to initiate sugarcane production (roughly $700 per acre), initial ethanol production from sugarcane is very likely to come from existing sugarcane mills being retrofitted with fermentation and distillation tanks so that the mill can potentially produce some combination of sugar and ethanol.

Objective

The objective of this article was to analyze the feasibility of integrating ethanol production into an existing sugar mill that uses sugarcane juice as the feedstock for ethanol production.

Background

Sugarcane acreage in the United States increased from an average 704,000 acres in the early 1980s to 948,000 acres by the early 2000s (U.S. Department of Agriculture, Economic Research Service). At current fuel prices, it may be profitable for at least a few of the more than two dozen U.S. sugarcane mills to diversify their revenue stream by adding an ethanol plant.

One shortcoming of sugarcane-based ethanol production is that it cannot be produced year-round. Ethanol is produced only during sugarcane harvesting, and it cannot be stored because sugarcane will decompose and lose its juice. Brazil faces the same problem, as ethanol is produced only from April to November in the center/south region, where over 85% of the ethanol is produced. Ethanol is stored in large holding tanks so they have a supply for the off-season months. In the United States, this shortcoming might be mitigated by combining grain-based ethanol production with sugarcane-based ethanol production so that the fermentation and distillation infrastructure could be utilized year-round. However, this article focuses on the economics of adding ethanol production to an existing sugarcane mill. This assumes that either sugarcane acres would need to increase or the plant allocates existing sugarcane between sugar and ethanol production.

Outside Brazil, very little economic analysis has been done that evaluates sugarcane to ethanol production. Gallagher et al. recently compared the competitiveness of U.S. corn-based ethanol with sugar-ethanol processing in Brazil showing no specific trends, only cyclical periods of advantages for both industries. Moreover, a recent U.S. Department of Agriculture/Louisiana State University study showed the lack of economic feasibility to convert raw and refined sugar into ethanol (Shapouri, Salassi, and Fairbanks). The present study will quantify the economic viability of the Brazilian method of producing sugar and ethanol with juice and/or molasses in the United States.

Many feasibility studies have been made for ethanol production from corn and/or sorghum in the United States. These economic studies were either developed with deterministic prices for several key variables, such as ethanol prices and production, distillers' dry grain solubles prices and production, corn prices, and natural gas prices (Bryan and Bryan International 2001), or by Monte Carlo simulation models to incorporate risk for prices and production into their analysis (Lau; Outlaw et al; Richardson et al. 2007). Only two studies have looked at the economic feasibility or cost of production of sugarcane-based ethanol for the United States (Bryan and Bryan International 2003; Shapouri, Salassi, and Fairbanks). Both of these utilized average prices and production to determine break-even costs of production. One additional limitation of the Shapouri, Salassi, and Fairbanks article is that the cane juice used in ethanol production was valued in the process on the basis of the federal sugar program price support, which made it very uneconomical.

Methodology

Reutlinger proposed the use of Monte Carlo financial statement models to estimate the probability distribution for an investment's net present value (NPV). Because the NPV represents the present value of annual net returns and the change in net worth over the planning horizon, it is a good variable for summarizing the overall economic viability of a proposed business. A summary statistic called the probability of economic success was defined by Richardson and Mapp as the chance that NPV is greater than zero. Their logic was that if the NPV was greater than zero, the investment would generate a return exceeding the investor's discount rate or opportunity cost of capital, and so the investment was a success.

The sugarcane ethanol plant analyzed in this study will produce 40 million gallons of ethanol per year from existing sugarcane production. The ethanol plant will be able to grind 11,000 tons of cane per day for about 180 days, needing around 50,000 acres of sugarcane. The ethanol plant will own all the sugarcane harvesting and hauling equipment. Producers receive $17 per ton of sugarcane and have no harvesting cost.

The added investment cost for ethanol production equipment will be $70 million and will be financed with 50% equity and 50% debt at 9% interest over 10 years. Producers receive annual dividends on their equity equal to 15% of revenues. Once the juice is extracted from the cane, it will go to a fermentation tank and continue through the process until ethanol is produced. The $70 million investment cost includes fermentation, distillation, and storage tanks and vinasse handling.

The simulation model to analyze the ethanol plant is an annual Monte Carlo financial statement model. Similar simulation models have been used by Cochran, Richardson, and Nixon; Outlaw et al.; Richardson and Mapp; and Richardson et al. (2007) to analyze proposed businesses. The model consists of a production section that annually calculates the conversion of sugarcane into sugar and ethanol with stochastic values for cane yield and sugar content. The second section of the model calculates the variables for the income statement, i.e., annual receipts, production costs, fixed costs, and interest expenses. The third section calculates the cash flow financial statement variables, including annual interest earnings, principal payments, income taxes, investor dividends, and ending cash reserves. The final section of the model calculates the balance sheet with an annual updating of asset values, liabilities, and net worth. The model is recursive in that positive ending cash reserves for the current year are beginning cash reserves for the next year. If ending cash reserves are negative, the firm obtains a 1-year loan to cover the deficit and repays the principal plus interest the next year. The final segment of the financial model calculates the NPV as follows: $NPV = -\text{Beginning Net Worth} + \sum \text{Dividends}_t/(1 + i)^t + \text{Ending Net Worth}/(1 + i)^{10}$. This formula for the NPV quantifies the real change of net worth from retained earnings and changes in net worth, as well as the value of the earnings extracted from the firm, in current purchasing power.

The stochastic variables in the model are variables that management cannot control:

- yield of sugarcane (tons/acre)
- sugar content of sugarcane (lbs. of sugar/ton)
- price of sugarcane ($/ton)

Table 1. Sugarcane Ethanol Plant Assumptions

Variable	Units	Ethanol Plant
Sugarcane crushed for ethanol	%	100
Acres of sugarcane harvested	acres	50,000
Tons of cane mill grinds per day	tons/day	11,000
Average sugarcane yield	tons/acre	35,000
Sugarcane lost during handling	fraction	8.0%
Average price paid for sugarcane	$/ton	17.00
Gallons of ethanol per ton of sugarcane	gallons/ton	19.62
Ethanol production	gallons/year	32,285,066
Plant costs		
Fraction of the new plant financed	fraction	0.50
Length of loan	years	10
Interest rate	%	9.0
Year to start the ethanol plant loan	Year	2007
Dividend rate on equity borrowed	%	15

- price of unleaded gasoline ($/gallon)
- price of electricity ($/KWH)
- price of ethanol ($/gallon)

Parameter estimation for the multivariate probability distributions to simulate these random variables was done in two parts. The sugarcane yield and quality of cane data were least plentiful, with only 5 years of data. These two variables were simulated as a multivariate empirical (MVE) with a Parzen Kernel density to expand the distribution, as suggested by Richardson, Lien, and Hardaker. Sixteen years of historical price data for the remaining stochastic variables were used to estimate the multivariate empirical distribution following the procedure outlined by Richardson, Klose, and Gray. The stochastic variables were detrended to remove systematic error, and the residuals were used to parameterize the MVE probability function. The parameters for both multivariate distributions were estimated by Simetar, a Microsoft Excel add-in (Richardson, Schumann, and Feldman).

The deterministic component of the MVE price distribution came from linear trend forecasts and existing forecast models. Projected annual mean prices for gasoline came from Bryant et al. The mean ethanol price was assumed to be $2.00 per gallon over the planning horizon. The projected prices and yields were treated as the assumed means for the 10-year planning horizon in the MVE distributions.

The model was programmed in Microsoft Excel because it offers easy-to-use programming capabilities, and add-ins are available to simulate random variables. The risk analysis add-in selected for developing the model was Simetar, because it provides tools for parameter estimation, simulation of multivariate distributions, and the ranking of risky alternatives (Richardson, Schumann, and Feldman).

The completed Monte Carlo model was simulated for 10 years. The random variables were simulated by the Latin Hypercube method and the Mersenne Twister Random Number Procedure. The Mersenne Twister has been shown not to degenerate for large problems. The model's 10-year planning horizon starts in 2007 and was replicated for 500 iterations.

The information used to describe and analyze the economic viability of the proposed ethanol plant is summarized in Table 1. Cost of the plant and ethanol production coefficients for the sugarcane-based ethanol plant were provided by the export manager of Alcohol for Dedini, the world's largest manufacturers of sugar mill and ethanol plants (Campos), and the CEO of Chaves Consultoria, a sugar and ethanol consultant firm (Chaves), both located in Piracicaba, Brazil. Ethanol conversion factors were obtained from Fernandes.

Table 2. Assumed Mean Levels for Stochastic Variables Used in the Feasibility Analysis

	Cane Yield (tons/acre)	Sugar Yield (lbs./ton)	Sugarcane Price ($/ton)	Ethanol Price ($/gal.)
2007	35.0	240.0	17.00	2.00
2008	35.0	240.0	17.00	2.00
2009	35.0	240.0	17.00	2.00
2010	35.0	240.0	17.00	2.00
2011	35.0	240.0	17.00	2.00
2012	35.0	240.0	17.00	2.00
2013	35.0	240.0	17.00	2.00
2014	35.0	240.0	17.00	2.00
2015	35.0	240.0	17.00	2.00
2016	35.0	240.0	17.00	2.00

Note: Historical yield and sugar content data exhibited no statistically significant trend; hence, the average of the past 5 years was assumed.

The model assumes the current ethanol tax credit of $0.51/gallon continues throughout the analysis period. In addition, the small producers' credit of $0.10/gallon on ethanol production up to 15 million gallons is included.

Results

Projected mean values for the stochastic variables affecting the business are summarized in Table 2. The annual projected means for other variables were projected by linear trend or the historical means.

The estimated total cost of production per gallon of ethanol from sugarcane is $1.87 (Table 3). For sugarcane-based ethanol, the cost includes $0.91/gallon for the cost of sugarcane and $0.18/gallon for cane processing, $0.28/gallon for ethanol processing, and other expenses totaling $0.50/gallon.

The results of simulating the proposed ethanol plant are summarized in Table 4. The proposed ethanol plant has a mean NPV of $45.8 million with a minimum of $4.7 million and a maximum of $90.4 million. The plant has a 100.0% chance of the NPV being positive or the plant being an economic success.

Table 3. Estimated Ethanol Production Costs from Sugarcane ($ per gallon)

Feedstock	0.91
Cane processing	0.18
Administrative costs	0.10
Ethanol processing	0.28
Denaturant	0.08
Capital costs	0.11
Depreciation	0.21
Total cost	1.87

Annual net cash income (NCI) is also summarized in Table 4. Average NCI remains in the $33 million/year range over the planning horizon as the mean ethanol price is kept flat at $2.00/gallon. The risk associated with NCI is measured by the coefficient of variation (CV). A 23.5 CV in 2007 means that the relative variability about the average NCI for the plant is 23.5% in the first year. The CV increases slightly over time because of occasionally having to finance cash flow deficits.

These results are conditioned upon the $0.51/gallon ethanol tax credit continuing. Subsequent sensitivity analyses were conducted that indicated the plant would not be profitable without the tax credit.

Summary and Conclusions

The objective of this article was to determine whether it is feasible to integrate ethanol production into an existing sugar mill that uses sugarcane juice as the feedstock for ethanol production. As the price of corn, which is the traditional feedstock for ethanol plants, continues to rise, ethanol producers will eventually need to look at other alternatives for their feedstock. An alternative

Table 4. Summary Statistics for Simulation Analysis

Summary of Net Present Value	
Mean	$45,802,904
Standard deviation	$15,113,493
Minimum	$4,672,856
Maximum	$90,409,530
Probability of success	
P(NPV > 0)	100.00%

Projected Annual Net Cash Income (million dollars)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mean	33.8	33.9	33.7	33.9	33.8	33.9	33.8	33.7	33.7	32.0
Standard deviation	7.9	9.0	8.8	8.8	8.5	8.5	8.7	8.6	8.5	8.7
Coefficient of variation (%)	23.5	26.4	26.1	26.1	25.2	25.1	25.7	25.5	25.2	27.2
Minimum	13.6	14.4	14.1	14.8	14.5	14.4	14.8	14.9	15.3	13.5
Maximum	55.3	56.6	59.9	55.2	59.0	54.3	53.9	54.6	54.8	56.4

feedstock that has been proven to work very efficiently in Brazil is sugarcane.

By a stochastic spreadsheet model, it was determined that existing U.S. sugar mills could add the necessary equipment to produce ethanol and have a very good chance of a successful economic outcome. The results indicate virtually no chance that the plant could not generate positive annual returns and an overall positive NPV.

The implications of these results are far-reaching, as imports into the United States threaten to undermine the U.S. sugar program. Although there is little information to determine whether ethanol can be produced economically with sugar beets, at least sugarcane producers appear to have a viable alternative to sugar production. Or, at the very least, the alternative exists to diversify their income streams with ethanol production.

References

Bryan and Bryan International. *Dumas Texas Area Ethanol Feasibility Study*. Cotopaxi, CO: Bryan and Bryan International, August 2001.

———. *Economic Impact Assessment for Ethanol Production and Use in Hawaii*. Golden, CO: Bryan and Bryan International, November 14 2003.

Bryant, H., J. Outlaw, J. Richardson, L. Higgins, and J. Campiche. "Effects of Recent Fossil Energy Market Developments on US Ethanol." College Station, TX: Texas A&M University, Agricultural and Food Policy Center, Briefing Paper 06-5, September 2006.

Campos, R. Personal Communication. Export Manager—Alcohol, Dedini, Piracicaba, Sao Paulo, Brazil, March 2006.

Chaves, I. Personal Communication. CEO—Chaves Consultoria, Riberao Preto, Sao Paulo, Brazil, August 2006.

Cochran, M.J., J.W. Richardson, and C. Nixon. "Economic and Financial Simulation for Small Business: A Discussion of the Small Business Economic, Risk, and Tax Simulator." *Simulation* 54,4(1990):177–88.

Ethanol Producer Magazine. *Plant List*. Internet site: www.ethanolproducer.com/plant-list.jsp (Accessed March 9, 2007).

FAPRI (Food and Agricultural Policy Research Institute). *February 2007 Baseline*. Columbia, MO: University of Missouri, FAPRI, 2007.

Fernandes, A. *Cálculos na Agroindústria da Cana-de-açúcar*, 2nd ed. Piracicaba, Brazil: Sociedade dos Técnicos Açucareiros e Alcooleiros do Brazil, 2003.

Gallagher, P., G. Schamel, H. Shapouri, and H. Brubaker. "The International Competitiveness of the U.S. Corn-Ethanol Industry: A Comparison with Sugar-Ethanol Processing in Brazil." *Agribusiness* 22,1(2006):109–34.

Lau, M. "Location of an Agribusiness Enterprise with Respect to Economic Viability: A Risk Analysis." Ph.D. dissertation. Texas A&M University, December 2004.

Lord, R. *Sugar: Background for 1995 Farm Legislation.* Washington, DC: U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report 711, April 1995.

Outlaw, J.L., D.P. Anderson, S.L. Klose, J.W. Richardson, B.K. Herbst, M.L. Waller, J.M. Raulston, S.L. Sneary, and R.C. Gill. *An Economic Examination of Potential Ethanol Production in Texas.* College Station, TX: Texas A&M University, Agricultural and Food Policy Center, Research Report 03-1, February 2003.

Renewable Fuels Association. *Industry Statistics.* Internet site: www.ethanolrfa.org/industry/statistics/ (Accessed March 9, 2007).

Reutlinger, S. "Techniques for Project Appraisal Under Uncertainty." *World Bank Staff Occasional Papers Number Ten.* Baltimore, MD: John Hopkins University Press, 1970.

Richardson, J.W., B.K. Herbst, J.L. Outlaw, and R.C. Gill III. *Including Risk in Economic Feasibility Analyses: The Case of Ethanol Production in Texas.* College Station, TX: Texas A&M University, Agricultural and Food Policy Center, 2007.

Richardson, J.W., S.L. Klose, and A.W. Gray. "An Applied Procedure for Estimating and Simulating Multivariate Empirical (MVE) Probability Distributions in Farm-Level Risk Assessment and Policy Analysis." *Journal of Agricultural and Applied Economics* 32,2(August 2000):299–315.

Richardson, J.W., G. Lien, and B. Hardaker. "Simulating Multivariate Distributions with Sparse Data: A Kernel Density Smoothing Procedure." Poster paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12–18, 2006.

Richardson, J.W., and H.P. Mapp, Jr. "Use of Probabilistic Cash Flows in Analyzing Investments Under Conditions of Risk and Uncertainty." *Southern Journal of Agricultural Economics* 8(December 1976):19–24.

Richardson, J.W., K.D. Schumann, and P.A. Feldman. *Simetar: Simulation & Simulation to Analyze Risk.* College Station, TX: Department of Agricultural Economics, Texas A&M University, 2006.

Shapouri, H., M. Salassi, and J.N. Fairbanks. *The Economic Feasibility of Ethanol Production from Sugar in the United States.* U.S. Department of Agriculture, Economic Research Service and Louisiana State University Agricultural Center, July 2006. Internet site: www.usda.gov/oce/reports/energy/EthanolSugarFeasibilityReport3.pdf (Accessed August 6, 2006).

U.S. Department of Agriculture, Economic Research Service. *Briefing Rooms, Sugar and Sweeteners: Background.* Internet site: www.ers.usda.gov/Briefing/Sugar/Background.htm (Accessed March 9, 2007).