Project BDAPUC15-34

Corn Wet Mill Marketing Analysis and Valuation

Final Report

Executive Summary

The Corn Wet Mill Market Analysis and Valuation Study assessed the market for current and potential food ingredients, feed, and renewable chemicals that can be produced or that utilize products from a corn wet mill facility, and estimated the value of a corn wet mill based under various future market conditions.

Strengths of Northern Plains based corn wet mills include low corn costs, while new generation coops have the advantage of controlling feedstock. Opportunities for the industry include Mexican exports and policy based demand for corn starch and corn oil as feedstocks for biofuel production. Threats include changes in consumer attitudes towards high fructose corn syrup and the introduction of alternative sweeteners.

High fructose corn syrup prices are expected to rise in the near term based on time series analysis. Under an optimistic price forecast the value of a general corn wet mill is $291 million.

Project Narrative

Project Objectives

Conduct

(1) A market analysis including
    a. A SWOT analysis, and
    b. forecast the demand for sweetener and high fructose corn syrup, and assess consumer trends as they relate to foods that utilize wet mill products.
(2) A valuation analysis will use a real options approach to estimate the value of a corn wet under alternative future conditions.

Project Process and Organizations

The Department of Agribusiness and Applied Economics at North Dakota State University conducted the market and valuation analyses. David Ripplinger served as the project's Principal Investigator. Lake Agassiz served as the project's fiscal agent. The North Dakota Corn Utilization Council provided matching funds. David Ripplinger oversaw the entire project and led the SWOT analysis and consumer trend analysis. Raj Lakkakula, research assistant professor, assisted with the consumer trend analysis and conducted the forecasting analysis. Ryan Larsen, assistant professor (now at Utah State University), conducted the valuation analysis.

Preliminary findings were shared with Golden Growers board members in 2015. Findings were updated in 2016 using more recent data 2016.

Market data and intelligence from Data Monitor (a UK based marketing firm) were used in the first year (2015) to inform the analyses. However, the resource did not prove to adequate meet project needs and were not purchased in 2016 as originally planned. Funds initially budgeted for this line were reallocated to salary for effort to collect better data and conduct market analysis.

Results and Outcomes

Project objectives were achieved by the completion of the market and valuation analyses. Four documents are included in the final report as appendices. This information may be used by Golden Growers for planning/strategy development and decision-making.

Conclusions and Recommendations

1. Golden Growers faces a number of opportunities and threats and possesses a number of strengths and weaknesses. Decreased per-capita HFCS consumption, a shift to alternative sweeteners are threats to the HFCS industry. Opportunities include increased world consumption and the renewable fuel standard. Golden Growers business model, feedstock control, and feedstock carbon intensity provide strengths and weaknesses, while new products provide opportunities and threats.

2. We used quarterly and monthly data to forecast HFCS prices. Two years (2014-2015) of data was used as a holdout set for evaluating the performance of the models and the remaining data for estimation of the model. Based on the lowest out-of-sample root mean square error criterion, the quarterly model performed well compared to the monthly model. Quarterly model resulted in the SARIMA $(0,2,0)(3,0,2)_4$ model, while the monthly model resulted in the SARIMA $(3,2,1)(1,0,1)_{12}$. <u>The forecasts of HFCS prices of both quarterly and monthly models show an increasing trend for two years ahead.</u>

3. Real options provide a convenient manner to estimate the benefits of production flexibility. In this case, the flexibility of being able to produce ethanol and HFCS is analyzed. The results of the analysis highlight the sensitivity of the results to future price forecasts. When future price forecasts are favorable for HFCS, there is no value to switch to ethanol. On the other hand, if future price forecasts are not favorable for HFCS, the option value of being able to switch to ethanol is close to $16 million. Thus a firm would be willing to $16 million for the ability to produce both ethanol and HFCS out of the same facility. These results are also based on a generalized plant. Plant specific operating costs and scale could influence the results.

APPENDIX 1: Corn Wet Mill Valuation Research Update

NDSU NORTH DAKOTA STATE UNIVERSITY

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Corn Wet Mill Valuation Research Update

David Ripplinger
September 17th, 2015

Background

Changing Markets

<u>Consumer behavior</u>
- Opportunities (corn gluten, protein)
- Threats (sweeteners)

<u>New markets</u>
- Specialty foods
- Renewable chemicals

Impact on returns
- value of corn and plant ownership

Activities

Market Analysis

HFCS/Sweetener Demand Forecast

Valuation

Key Market Factors

1. Change in consumer preferences of HFCS to other sweeteners
2. Declining soft-drink sales
3. Change in relative prices of HFCS to other sweeteners
4. Emergence of Stevia and other high intensity sweeteners

Forecasting

- HFCS-42 prices and consumption
- Milling and Baking News/USDA

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1. Change in consumer preferences of HFCS to other sweeteners
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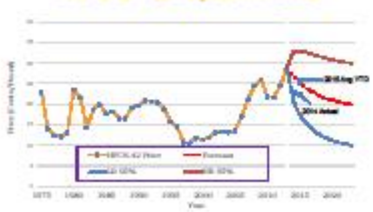
Forecasting

- HFCS-42 prices and consumption
- Milling and Baking News/USDA

HFCS-42 Spot Prices



Per Capita HFCS-42 Consumption

Comments

Forecasts are for HFCS-42, not 55. Will complete analysis for 55.

Forecast decline in price and consumption.

Forecasts have been quite accurate, but we are only 1-2 years in.

Valuation

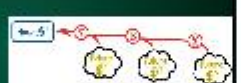
What is the value of your
- Corn
- Golden Growers shares

under potential future market conditions/strategies?

Methods: real options and net present value (NPV)

Net Present Value

Make a single best guess of future conditions: revenues, costs, profit.



Use those expectations to calculate a single value priced into today's dollars – the value of a share of GG stock.

HFCS-42 Spot Prices

What are corn prices going to be?

What are HFCS prices going to be?

How is the industry going to respond?

How is GG/ProGold going to respond?

All predictions are wrong, some are useful

Real Options

Incorporate uncertainty, the probability of high/low
- Corn prices
- HFCS prices

Estimate the impact of new product lines – technology, investment, markets

What products?
Food?
Alt. Sweeteners?
Fuel/chemicals

Market Analysis

Real Options Status

We have models for conducting real options analysis.

We have data for a representative corn dry mill.

We will conduct baseline analysis to estimate valuation this fall.

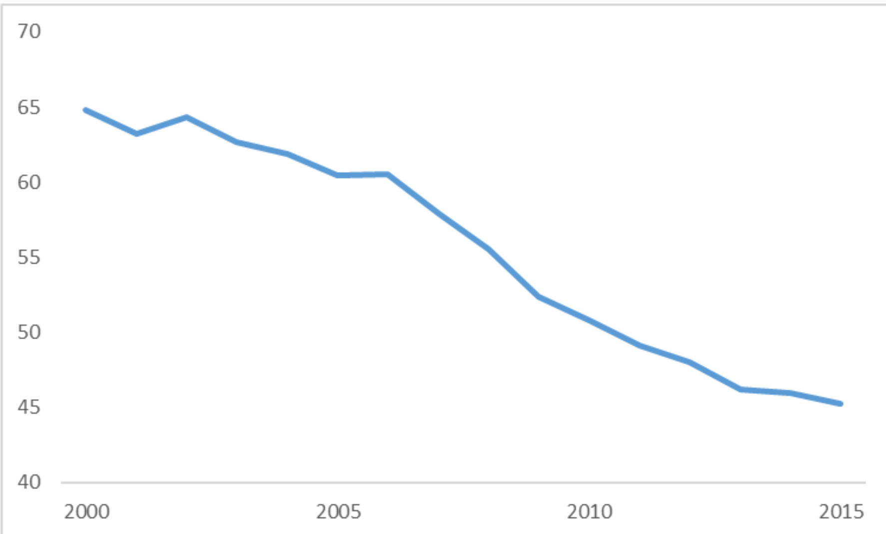
We are still considering new line options.

Questions

APPENDIX II. Corn Wet Mill Valuation SWOT Analysis

THREAT: Consumer Trends

HFCS consumption has been declining on a per capita basis for over a decade in large part because of real and perceived health effects[1].



US HFCS Disappearance per Capita, 2000-2015, USDA

While there are a number of factors that impact the perception and consumption of HFCS, three stand out:

1. Although similar to sucrose, some studies (), and more importantly the broad popular conception is that HFCS is unhealthy and leads to obesity.
2. HFCS is made from genetically modified (GM) corn. While food made using GM crops have not been proven to be unsafe, a large number of consumers believe differently and avoid products with GM ingredients.
3. HFCS remains the primary sweetener for soft drinks. Consumption of sweetened soft drinks has generally tracked the fall of HFCS consumption in the United States.

THREAT: Alternative Sweeteners

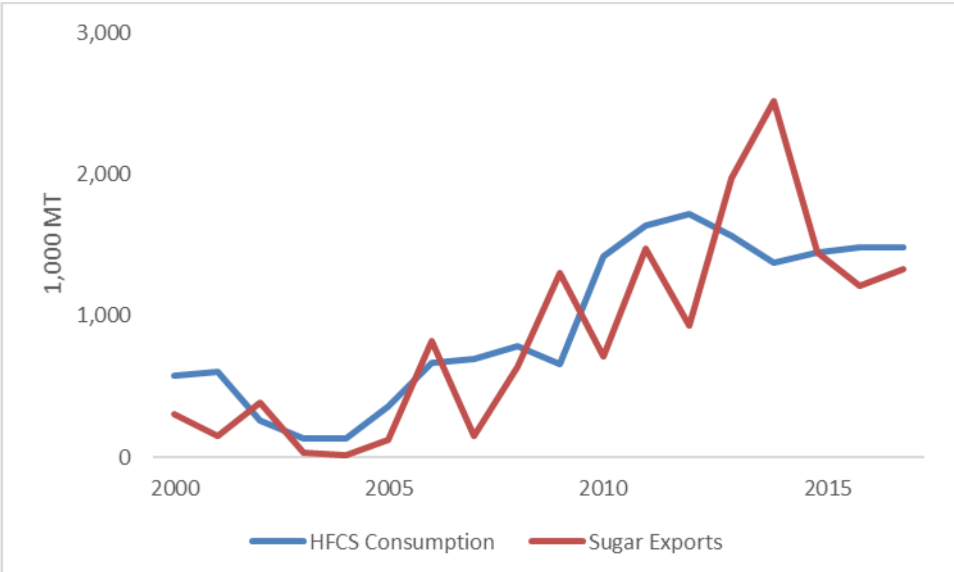
A variety of sweeteners have been introduced into the market in the last decade. They include natural, high intensity sweeteners like stevia and sugar alcohols including xylitol, sorbitol, and erythritol.

OPPORTUNITY: Mexico

NAFTA introduced free trade among the United States, Mexico, and Canada. Although trade liberalization under NAFTA began in 1994, it wasn't until 2008 that sugar provisions that allowed for unlimited, tariff free trade of sugar between Mexico and the United States were fully implemented.

[1] Borra, Susan T., and Ann Bouchoux. "Effects of science and the media on consumer perceptions about dietary sugars." *The Journal of nutrition* 139, no. 6 (2009): 1214S-1218S.

In 2009, Mexico exported a record amount of sugar to date and in 2010 consumption of HFCS more than doubled year over year to 1.4 million MT, a level that has stayed relatively constant since. Approximately 2/3's of this HFCS is imported, the remainder produced domestically by an industry that is running at capacity[2].



Mexican HFCS Consumption and Sugar Exports, 2000-2015, USDA

Global sugar and Mexican sugar exports and HFCS imports are key factors to US sweetener markets.

OPPORTUNITY: Renewable Fuel Standards

The Renewable Fuel Standard is a federal law that mandates the minimum use of biofuel by type. The law allows for levels set in the original law to be changed. The biodiesel mandate for 2018 levels announced in November include 2.1 billion gallons of biomass-based diesel. While soybean oil is the primary biodiesel feedstock, 1 billion pounds of corn oil, primarily from ethanol dry mills, has used to produce biodiesel up from 300 million pounds in 2011(EIA 2013, 2016).

STRENGTH: Low Cost Corn

Corn prices in North Dakota are typically lower than other corn growing regions due to limited feed and industrial use. Persistent low prices are a competitive advantage to regional corn users.

STRENGTH/WEAKNESS: Business Model

Golden Growers is a new generation cooperative that supplies corn to a wet corn mill in which it has an equity stake. It is not a wet corn mill operator, a technology company, a feed company, a food ingredient company, or a food manufacturer.

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[2] Zahniser, Steven, Lynn Kennedy, Getachew Nigatu, and Michael McConnell. "A New Outlook for the US-Mexico Sugar and Sweetener Market." (2016).

STRENGTH/WEAKNESS: Feedstock Control

While, as a new generation cooperative, Golden Growers can mitigate feedstock risk it also lacks complete flexibility to change feedstock specifications. Northern Plains cropping systems may allow for profitable production of non-GM corn.

STRENGTH/WEAKNESS: Carbon Intensity

There is interest in crops that have low carbon intensity, that is that have small carbon emissions associated with their production and transport. Corn has a low carbon footprint compared to other major US crops, less than that of sugar cane. North Dakota corn has a slightly higher relative footprint to corn grown in other states because of slightly lower yields.

THREAT/OPPORTUNITY: New Products

Wet corn mills have the ability produce a wide array of food ingredients, feedstuffs, fuels, and chemicals. The Wahpeton facility currently produces HFCS and corn gluten feed.

Corn Refiners Association Member Companies' Products

	Archer Daniels Midland Company	Cargill	Ingredion Incorporated	Tate & Lyle Americas
STARCH PRODUCTS				
Unmodified, food	■	■	■	■
Unmodified, industrial	■	■	■	■
Modified, food	■	■	■	■
Modified, industrial	■	■	■	■
Dextrins	■	■	■	■
SWEETENERS				
Glucose syrups	■	■	■	■
Maltodextrins	■	■	■	■
Dextrose monohydrate	■	■	■	■
Dextrose anhydrous		■	■	
High Fructose Corn Syrup-42	■	■	■	■
High Fructose Corn Syrup-55	■	■	■	■
Crystalline fructose	■			■
REDUCED-CALORIE SWEETENERS				
Allulose	■			■
Erythritol		■	■	
Glucose hydrolysates		■	■	
Hydrogenated starch hydrolysates			■	
Maltitol	■	■	■	
Mannitol	■	■	■	
Sorbitol	■	■	■	
Xylitol		■		
CO-PRODUCTS				
Crude oil	■	■	■	
Refined oil	■	■	■	
Corn gluten feed	■	■	■	■
Corn gluten meal	■	■	■	■
Corn germ or corn germ meal	■	■	■	■
Steepwater (CFCE)	■	■	■	■
Carbon dioxide	■			■
Corn fiber food/industrial ingredients	■	■	■	
FERMENTATION AND OTHER PRODUCTS				
Citric acid	■	■		■
Lactic acid	■	■		
Lysine	■			
Threonine	■			
Xanthan gum	■	■	■	
Ethanol, fuel/industrial	■	■	■	■
Ethanol, beverage	■	■		

Product lists are accurate as of publication date, but may change with time.

Adding new product lines would raise a number of business issues:

1. Golden Growers is not a technology business and would need to procure technology/equipment from another entity. In addition to innovation risk associated with adopting cutting-edge

technology, profits resulting from the use of licensed technology would likely be captured by the technology owner.
2. Golden Growers is not the operator and would need assurance that the operating partner is willing and able to operate the new line.
3. Golden Growers is not a product marketer and would need to rely on a third party to market products which would come at a cost.

Independent investigation of new opportunities may be prudent, however, involvement of third parties prior to execution of plans is necessary.

<u>New Product Possibilities</u>

Ethanol – although most commonly produced by dry mills built for ethanol production, a number of wet mills produce ethanol. Current US capacity matches mandated 2017 use of 15 billion gallons.

Corn oil – extraction of corn oil has become common in dry mills with crude oil used as a feedstock for biodiesel production. Lack of a blend wall, failed commercialization of other advanced biofuels, and support for the RFS under the Trump administration make continued expansion of the biodiesel mandate, which has supported all vegetable oil prices, likely.

Corn fiber – technology exists to produce fuel from corn fiber. This fuel would qualify as cellulosic biofuel and receive special consideration by federal biofuel policy. The economics of this pathway is not known by the authors at this time.

Other advanced biofuels – corn starch can be converted to another of fuels other than ethanol.

Enhanced animal feed – modification of corn gluten meal or other feed with improved feeding quality. Considerable emphasis is placed on feed for the rapidly expanding aquaculture industry.

Reduced calorie sweeteners/Sugar alcohols – there are a variety of high intensity sweeteners that can be manufactured from corn including those listed in Table X.

Xanthrophyll – a natural yellow pigment found in corn that can be removed and sold as a feed additive or cosmetics.

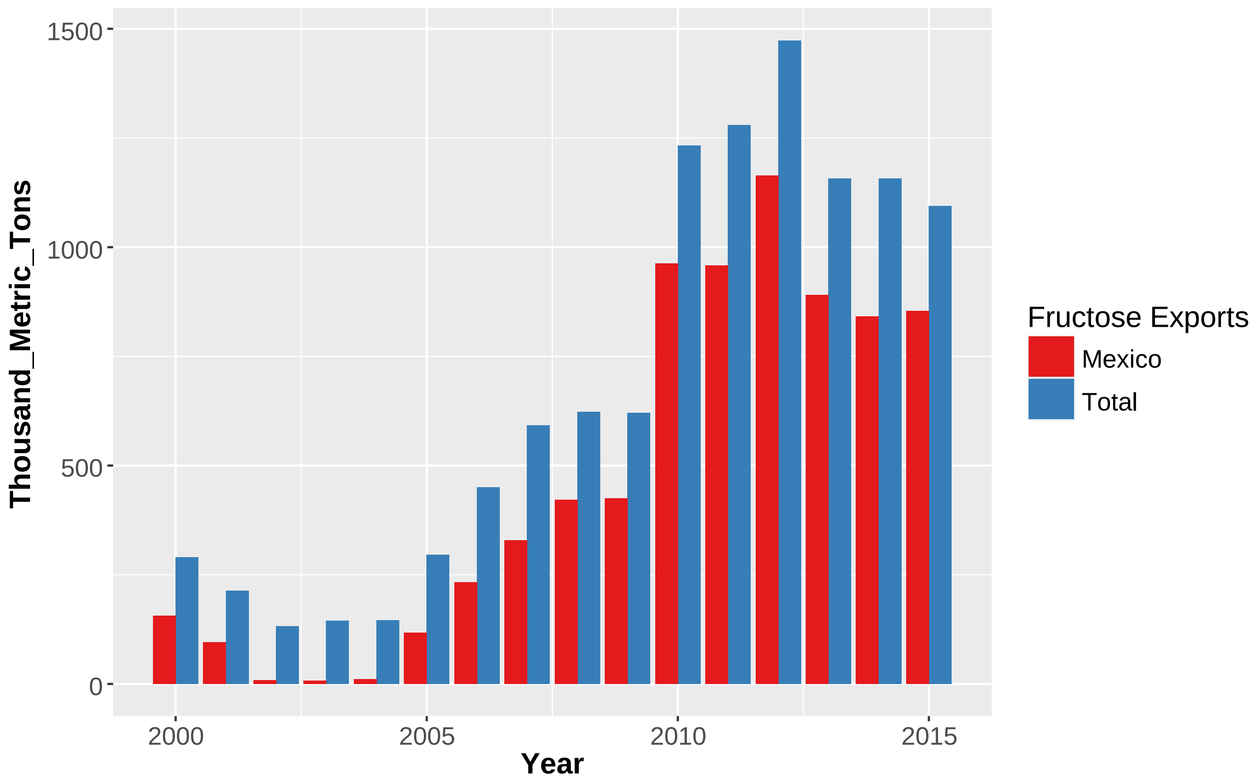
<u>Strategies</u>

Products with contradictory attributes, for example non-GM HFCS, should be avoided.

Natural hedges against continued decline of HFCS use, eg non GM sweeteners, should be identified and pursued.

APPENDIX III. Corn Wet Mill Valuation: Price Forecast

Sugar and HFCS have been major source of caloric sweetener use in the United States. However, since 2002, the total caloric sweetener consumption has consistently decreased, primarily due to a decrease in HFCS per-capita consumption. For example, the per-capita HFCS consumption declined from 37.7 pounds in 2002 to 26.8 pounds in 2014 (USDA, 2016a).[3] On the other hand, HFCS prices have increased from 13.05 cents per pound in 2002 to 22.89 cents per pound in 2014 (USDA, 2016b). In 2015, the HFCS price was at 26.58 cents per pound (USDA, 2016b). In contrast to domestic HFCS utilization, the total fructose exports from the United States have increased from 290 thousand metric tons in 2000 to 1094.5 thousand metric tons in 2015. Of these total exports, major share has been exported to Mexico, whose exports have increased from 156 thousand metric tons in 2000 to 854 thousand metric tons in 2015.



The United States Total Fructose Exports, 2000–2015

In light of the decrease in domestic HFCS utilization and increase in total fructose exports, it is important to determine HFCS prices. Moreover, due to a decrease in HFCS utilization, the corn-wet milling facilities are at risk of closure. For instance, on September 16, 2014, Cargill announced its

[3] It is important to note that HFCS consumption (at consumer level) is different from the HFCS deliveries (at market level). The United States Department of Agriculture (USDA) calculates the HFCS consumption at consumer level after accounting for losses at wholesale level, and retail level etc. The HFCS deliveries have decreased from 64.1 pounds per capita in 2002 to 45.6 pounds per capita in 2014.

decision to shut its corn-wet milling facility in Memphis (US) due to its under-utilization, and increased operational expenses (Sheffield, 2014).

The motivation for forecasting HFCS prices comes from the current HFCS market situation with the HFCS utilization (domestic versus exports) versus its price dynamics. The results of this study will help corn-wet mills make better strategic and operational decisions. For example, HFCS price forecasts can be used to value corn-wet mill assets, set production levels including shutdown or mothballing under extreme market conditions, and profits. Additionally, HFCS price forecasts in conjunction with HFCS export demand could be used to evaluate the amount of HFCS to be produced and the profitability of its operation in a corn-wet mill facility.

Most previous studies have estimated elasticities of various sweeteners (sugar, HFCS, and glucose etc) used as inputs as well as elasticities of various products (milk, sport drinks etc) used for consumption. For this study, we are interested in the elasticities of sweetener inputs such as sugar, and specifically HFCS. Lakkakula et al., (2016) found that the HFCS and sugar are not perfect substitutes as also stated by Moss and Schmitz (2002) in an earlier study.

Supply elasticities of HFCS are particularly important for understanding the sensitivities of change in supply when the price of HFCS increases. Literature suggests that the supply elasticities of HFCS vary from 0.07 (OECD/FAO, 2014) to 0.20 (Kennedy and Garcia-Fuentes, 2016), which indicate that the elasticities are relatively inelastic. The inelastic supply elasticity of HFCS implies that there would be a little change in quantity supplied when HFCS price increases by a cent. The previous claim is demonstrated as follows. Consider and compare the domestic utilization data and total fructose export data of 2002 and 2014.

Domestic HFCS utilization in 2002 equals 10,857.6 million pounds (37.7 pounds multiplied with an approximate population of the U.S. in 2002, which is equivalent to 288 million) and total fructose exports during the same year is equivalent to 291 million pounds (131851 metric tons and there are 2204.62 pounds in a metric ton). Therefore, the total HFCS supply in 2002 equal 11148.6 million pounds. Similarly consider the data for the year 2014 in which the domestic HFCS utilization is about 8,549.2 million pounds (26.8 pounds multiplied with the U.S. population in 2014 i.e., 319 million) whereas total fructose exports equal 2551 million pounds (1157310 metric tons and there are 2204.62 pounds in a metric ton). Therefore, the total HFCS supply in 2014 equal 11100.2 million pounds.

Autoregressive integrated moving average (ARIMA) model has been widely used in time series analysis for forecasting univariate time series. Box and Jenkins (1970) proposed ARIMA model and hence these models were popularly known to be Box-Jenkins models. The ARIMA model was later transformed to include seasonal autoregressive and moving average terms to become the seasonal ARIMA model.

This study uses seasonal autoregressive integrated moving average (SARIMA) method to forecast HFCS prices. Specifically, we use quarterly and monthly HFCS prices to design both quarterly and monthly models and evaluate the accuracy of the forecasts. Three forecast accuracy measures insample mean absolute error (MAE), insample root mean squared error (IRMSE), and outofsample root mean squared error (ORMSE)are used to compare the performance of various SARIMA models. Many argue that the reliability of any estimated model would be analyzed based on the outofsample prediction accuracy (Stock and Watson, 2003). Therefore, in our study, the SARIMA model that has the lowest ORMSE was preferred to forecast HFCS prices.

Model

This section specifies both non-seasonal and seasonal autoregressive integrated moving average models in addition to several test procedures before forecasting HFCS prices. The test procedures include Ljung-Box test for autocorrelation in the residuals and Jarque-Bera test for normality of the residuals of the fitted model.

We follow the backshift notation used in Box and Jenkins (1970) to describe the ARIMA model. Nonseasonal autoregressive integrated moving average (ARIMA) model, ARIMA(p,d,q) is represented as follows

$$(1 - \varphi_1 B - \dots - \varphi_p B^p)(1 - B)^d y_t = c + (1 + \vartheta_1 B + \dots + \vartheta_q B^q) e_t \qquad (1)$$

where p, d, q are number of non-seasonal autoregressive lags, number of non-seasonal differences required to attain stationary, number of non-seasonal moving average lags, respectively.

For seasonal ARIMA model we have SARIMA(p,d,q)(P,D,Q)$_m$, where P,D,Q are number of seasonal autoregressive lags, number of seasonal differences required for the time series to attain stationarity, number of seasonal moving average lags, respectively.

For example, a quarterly SARIMA(1,1,1)(1,1,1)$_4$ model is represented as follows (Hyndman and Athanasopoulos, 2014)

$$\underbrace{(1-\phi_1 B)}_{\text{Non-seasonal AR(1)}} \overbrace{(1-\Phi_1 B^4)}^{\text{Seasonal AR(1)}} \underbrace{(1-B)}_{\text{Non-seasonal difference}} \overbrace{(1-B)^4}^{\text{Seasonal difference}} y_t = \underbrace{(1+\theta_1 B)}_{\text{Non-seasonal MA(1)}} \overbrace{(1+\Theta_1 B^4)}^{\text{Seasonal MA(1)}} e_t \qquad (2)$$

where B is backshift operator representing the lag, and φ, Φ, ϑ, Θ are the parameters of the model to be estimated.

Similarly, the monthly model is represented as follows

$$\underbrace{(1-\varphi_1 B)}_{\text{Non-seasonal AR(1)}} \overbrace{(1-\Phi_1 B^{12})}^{\text{Seasonal AR(1)}} \underbrace{(1-B)}_{\text{Non-seasonal difference}} \overbrace{(1-B)^{12}}^{\text{Seasonal difference}} y_t = \underbrace{(1+\vartheta_1 B)}_{\text{Non-seasonal MA(1)}} \overbrace{(1+\Theta_1 B^{12})}^{\text{Seasonal MA(1)}} e_t \qquad (3)$$

Forecast Accuracy Measures

We use three forecast accuracy measures for selecting the best SARIMA model to forecast the HFCS prices. They are

1. Mean Absolute Error: $MAE = \frac{1}{n}\sum_{i=1}^{n}|\widehat{y_i} - y_i| = \frac{1}{n}\sum_{i=1}^{n}|e_i|$
2. In-sample Root Mean Square Error: $IRMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\widehat{y_i} - y_i)^2}$
3. Out-of-sample Root Mean Square Error: $ORMSE = \sqrt{\frac{1}{k}\sum_{j=1}^{n}(\widehat{y_j} - y_j)^2}$

where n, k, $\widehat{y}_i$, y_i, $\widehat{y}_j$, y_j represent number of observations in the training set, number of observations in the test set, forecasts (predicted values) of HFCS prices in the training set used for estimation, actual HFCS prices of training set, forecasts of HFCS prices in test set, and actual HFCS prices in the test set, respectively.[4]

Diagnostic Tests

Unit root test

In time series analysis, a stationarity (constant mean, and constant auto-covariance) data series is a precondition in order to maintain the stability of the model. There are many tests to perform unit root tests in the time series including Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (1992), and Augmented Dickey-Fuller (ADF) test etc (Kwiatkowski et al., 1992; Dickey and Fuller, 1979). We used ADF test for testing unit root in the HFCS prices for both quarterly and monthly models (Dickey and Fuller, 1979). The ADF test for a differenced time series is shown below:[5]

$$\Delta y_t = \alpha + \rho y_{t-1} + \gamma_1 \Delta y_{t-1} + \ldots + \gamma_L \Delta y_{t-L} + e_t \tag{4}$$

where Δy_t is the first non-seasonal difference, y_{t-1} is one period lag of prices, and Δy_{t-L} is the L period lag of differenced prices. If the test statistic of the ρ value is less than -2.9, then we reject the null of non-stationarity. It is important to note that, when a trend variable (for a trend non-differenced data) is included in the ADF test, the critical value of the test statistic would be -3.5.

Choice of Lag in Model Selection

We used autocorrelation functions (ACF) and partial autocorrelation functions (PACF) of the stationary HFCS prices for a first guess model. However, various models are selected randomly and evaluated by comparing the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The model that gives the lowest AIC and/or BIC value is selected for the estimation.

[4] Training set is the set of observerations used in the model estimation; while the test set (holdout set) is the set of out of sample observations used for testing the performance of the estimated model.

[5] In quarterly model, HFCS prices are stationary only at the difference of differenced series: $\Delta^2 y_t = \alpha + \rho y_{t-1} + \gamma_1 \Delta^2 y_{t-1} + \ldots + \gamma_L \Delta^2 y_{t-L} + e_t$

Autocorrelation test

To detect any autocorrelation in the residuals of the fitted model, we carry out Ljung-Box test. The LjungBox test for autocorrelation in the residuals is defined as follows (Ljung and Box, 1978)

$$X = n(n+2)\sum_{l=1}^{h}\frac{\widehat{\rho_l^2}}{n-l} \tag{5}$$

where n is the sample size, $\hat{\rho}_l$ is the sample autocorrelation at lag l, and h is the number of lags being tested. The null hypothesis is that the residuals are independently distributed or there is no autocorrelation in the residuals, while the alternate hypothesis is that there is autocorrelation in the residuals. The test statistic is a χ^2 distribution with h degrees of freedom. The degrees of freedom (h) is computed based on autoregressive and moving average lags. For example, if we are fitting an SARIMA(p,d,q)(P,D,Q) model, then the degrees of freedom equals [$h - (p + q + P + Q$].

Normality Test

We perform the Jarque-Bera test for normality of the residuals as shown below (Jarque and Bera, 1980)

$$JB = \left(\sqrt{\frac{n}{6}}S\right)^2 + \left(\sqrt{\frac{n}{24}}(K-3)\right)^2 \tag{6}$$

where n is the sample size, S is the sample skewness coefficient, K is the sample kurtosis coefficient, and JB is the Jarque-Bera statistic. The JB statistic has a chi-square (χ^2) distribution with two degrees of freedom. The null hypothesis of the normality of the residuals is rejected if the JB test statistic is larger than the critical value of the (χ_2^2) distribution. At the 5% level of significance, the critical value of the (χ^2) distribution is 5.99 (Newbold, Carlson, and Thorne, 2013). Therefore, at $p < 0.05$, if the JB statistic is less than 5.99, we fail to reject the null hypothesis of normality and hence conclude that the residuals of the fitted model exhibit normal distribution (Newbold et al., 2013).

Data

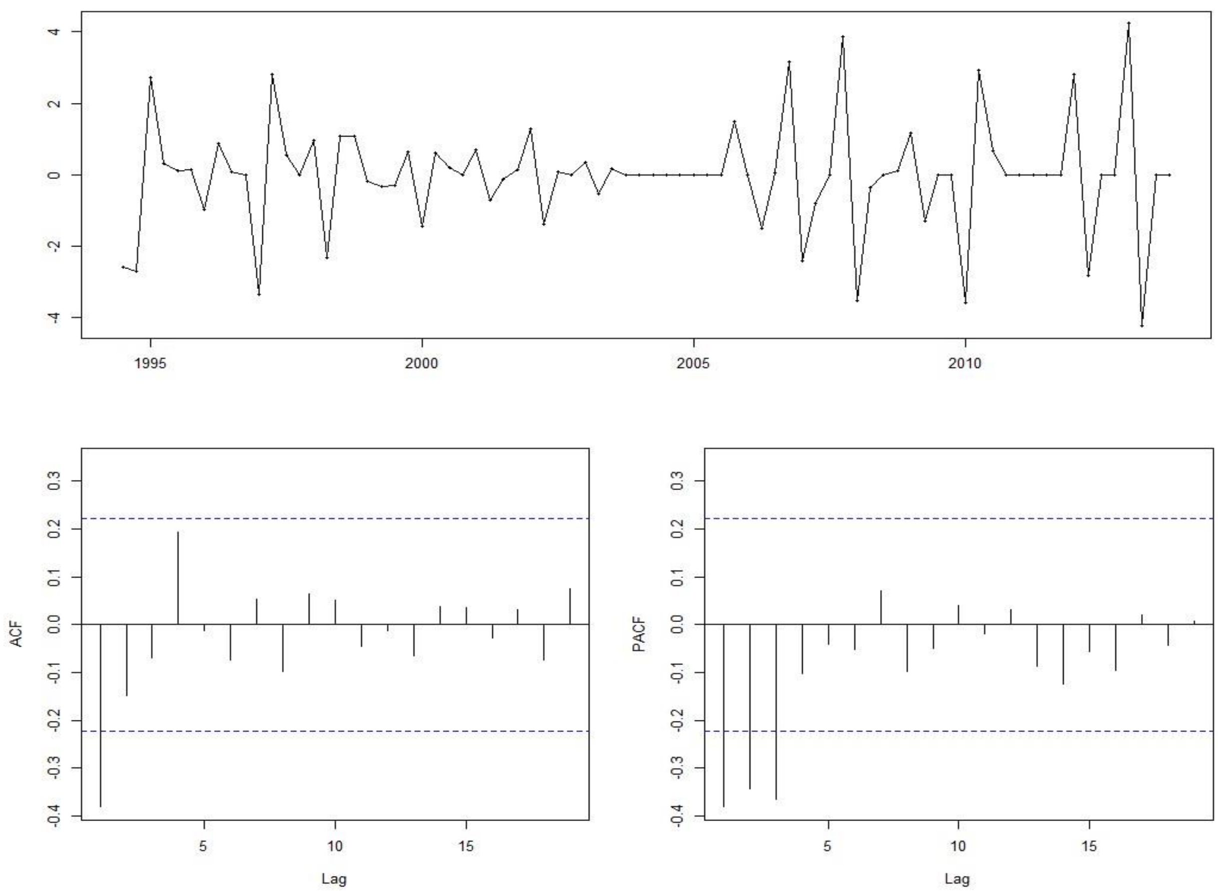
We collected the US HFCS42 spot price data for the 1994-2015 period from the United States Department of Agriculture's Sugar and Sweetener Yearbook Tables (USDA, 2016b). The HFCS42 spot price data were measured in cents per pound. For both quarterly and monthly models, we used data from 1994-2013 period for the model estimation and the last two-year data were used as holdout sample for evaluating out-of-sample performance of the fitted model. Therefore, in quarterly model, we have 88 observations in total, out of which 80 observations were used in model estimation and remaining 8 observations were used as a holdout sample. Similarly, in monthly model, we have 264 observations in total, out of which 240 observations were used in model estimation, and the holdout set consists of remaining 24 observations.

Estimation Results

In this section, we present and discuss the results comparing both quarterly and monthly models. We also discuss the results of different diagnostic tests before forecasting HFCS prices. As mentioned earlier, the foremost step for forecasting HFCS prices is to test the data for stationarity using ADF test.

For quarterly model, we found that the non-seasonal first differenced HFCS prices are not stationary in addition to the raw data. Therefore, we transformed the data by taking the difference of differenced HFCS prices to ensure it is stationary. We performed ADF test to verify that the second differenced HFCS prices are stationary. The Augmented Dickey-Fuller test statistic (ρ) was found to be 5.56, which is less than the critical value (2.9) at 5% level of significance.

Based on the ACF and PACF, our first guess model was SARIMA (3,2,1)(0,0,0)$_4$.



Quarterly model: ACF and PACF of double-differenced HFCS prices

We estimated the first guess model along with the five other models created randomly by changing both the seasonal and non-seasonal autoregressive and moving average lags. The AIC and BIC results of the models are shown in Table 1. Based on the results in Table 3, we chose the model SARIMA (0,2,1)(1,0,1)$_4$ as it has the lowest AIC and BIC values.

Identification of ARIMA models

S.No.	ARIMA(*p,d,q*)(*P,D,Q*)$_m$	AIC	BIC
Quarterly Models			
1	*(3,2,1)(0,0,0)*$_4$	*198.12*	*186.33*
2	(3,2,1)(1,0,1)$_4$	198.62	182.12
3	(2,2,2)(1,0,1)$_4$	199.63	183.14
4	(1,2,0)(1,0,1)$_4$	172.25	162.82
5	**(0,2,1)(1,0,1)**$_4$	**202.50**	**193.07**
6	(3,0,0)(2,1,0)$_4$	181.29	167.31
Monthly Models			
1	*(1,1,1)(1,0,1)*$_{12}$	*986.68*	*969.29*
2	(3,1,1)(1,0,1)$_{12}$	983.36	959.02
3	(2,1,2)(2,0,1)$_{12}$	984.98	957.17
4	(1,1,0)(2,0,1)$_{12}$	986.72	969.34
5	**(0,1,1)(2,0,1)**$_{12}$	**990.21**	**972.83**
6	(3,0,0)(2,1,0)$_{12}$	891.32	870.74

Notes: ARIMA models shown in *italics* ar eour first guess models based on ACFs and PACFs. ARIMA models shown in **bold** are the models chosen based on the lowest AIC and BIC values

After estimation of the model SARIMA (0,2,1)(1,0,1)$_4$, we performed residual analysis. Based on the residual analysis, we conclude that there is no significant autocorrelation in the residuals as we fail to reject the null hypothesis of the Ljung-Box test statistic (because *p*-values are high).

In order to compare our chosen model with other competing models, we selected a total of 11 models (including the models shown in Table 5) to assess the performance of the out-of-sample prediction accuracy. Although our chosen model performed well compared to most other models, we found SARIMA(0,2,0)(3,0,2)$_4$ with the least out-of-sample RMSE as shown in Table X.

Evaluation of out-of-sample performance comparing different models

S.No.	ARIMA(*p,d,q*)(*P,D,Q*)$_m$	Out-of-sample RMSE
Quarterly Models		
1	(3,2,1)(1,0,1)$_4$	5.06
2	(2,2,2)(1,0,1)$_4$	3.93
3	**(0,2,0)(3,0,2)**$_4$	**1.29**
4	*(0,2,1)(1,0,1)*$_4$	*4.03*

5	$(3,0,0)(2,1,0)_4$	5.81
6	$(3,0,1)(2,1,0)_4$	5.69
7	$(3,0,2)(2,1,0)_4$	5.69
8	$(3,0,1)(0,1,1)_4$	5.84
9	$(3,0,3)(0,1,1)_4$	5.85
10	$(3,0,2)(0,1,1)_4$	5.49
11	$(2,1,5)(0,1,1)_4$	4.66
Monthly Models		
1	**$(3,2,1)(1,0,1)_{12}$**	**3.98**
2	$(2,1,2)(2,0,1)_{12}$	4.80
3	$(0,1,0)(1,0,1)_{12}$	4.68
4	*$(0,1,1)(2,0,1)_{12}$*	*4.81*
5	$(3,0,0)(2,1,0)_{12}$	6.04
6	$(3,0,1)(0,1,2)_{12}$	5.95
7	$(3,0,1)(2,1,0)_{12}$	6.02
8	$(3,0,2)(2,1,0)_{12}$	6.11
9	$(3,0,1)(1,1,0)_{12}$	6.48
10	$(4,0,3)(0,1,1)_{12}$	7.55
11	$(3,0,2)(0,1,1)_{12}$	6.02

Notes: ARIMA model shown in *italics* represents the chosen model from table 1 while the model shown in **bold** represents the model with the lowest out-of-sample RMSE.

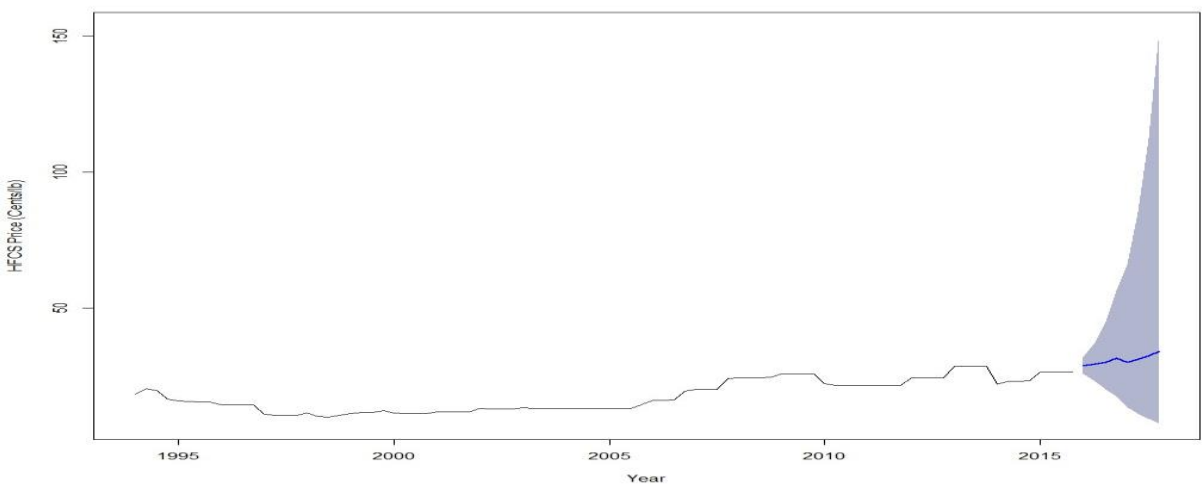
In-sample and out-of-sample accuracy measures of selected models

S.No.	ARIMA$(p,d,q)(P,D,Q)_m$	MAE	IRMSE	ORMSE
Quarterly Models				
1	$(0,2,0)(3,0,2)_4$	0.85	1.23	1.29
2	$(0,2,1)(1,0,1)_4$	0.63	1.07	4.03
Monthly Models				

1	$(3,2,1)(1,0,1)_{12}$	0.26	0.54	3.98
2	$(0,1,1)(2,0,1)_{12}$	0.24	0.52	4.81

Notes: MAE is mean absolute error, IRMSE is in–sample root mean square error, and ORMSE is out–of–sample root mean square error.

We performed the diagnostic tests such as the Jarque-Bera test for testing the normality of the residuals in case of the SARIMA$(0,2,0)(3,0,2)_4$. We found that the Jarque-Bera test statistic is 4.07, which is less than the critical value of chisquare distribution at 5% level of significance (5.99). Hence, we fail to reject the null hypothesis and conclude that the residuals of the SARIMA$(0,2,0)(3,0,2)_4$ exhibit a normal distribution. Finally, we performed Ljung-Box test for autocorrelation in the residuals of the SARIMA$(0,2,0)(3,0,2)_4$. We found that the Ljung-Box test statistic is 33.06. Hence, we conclude that there was no evidence of any autocorrelation in the residuals of the fitted model. After performing residual analysis and the diagnostic tests, we believe that the SARIMA$(0,2,0)(3,0,2)_4$ was correctly specified. Subsequently, it was used for forecasting HFCS prices.

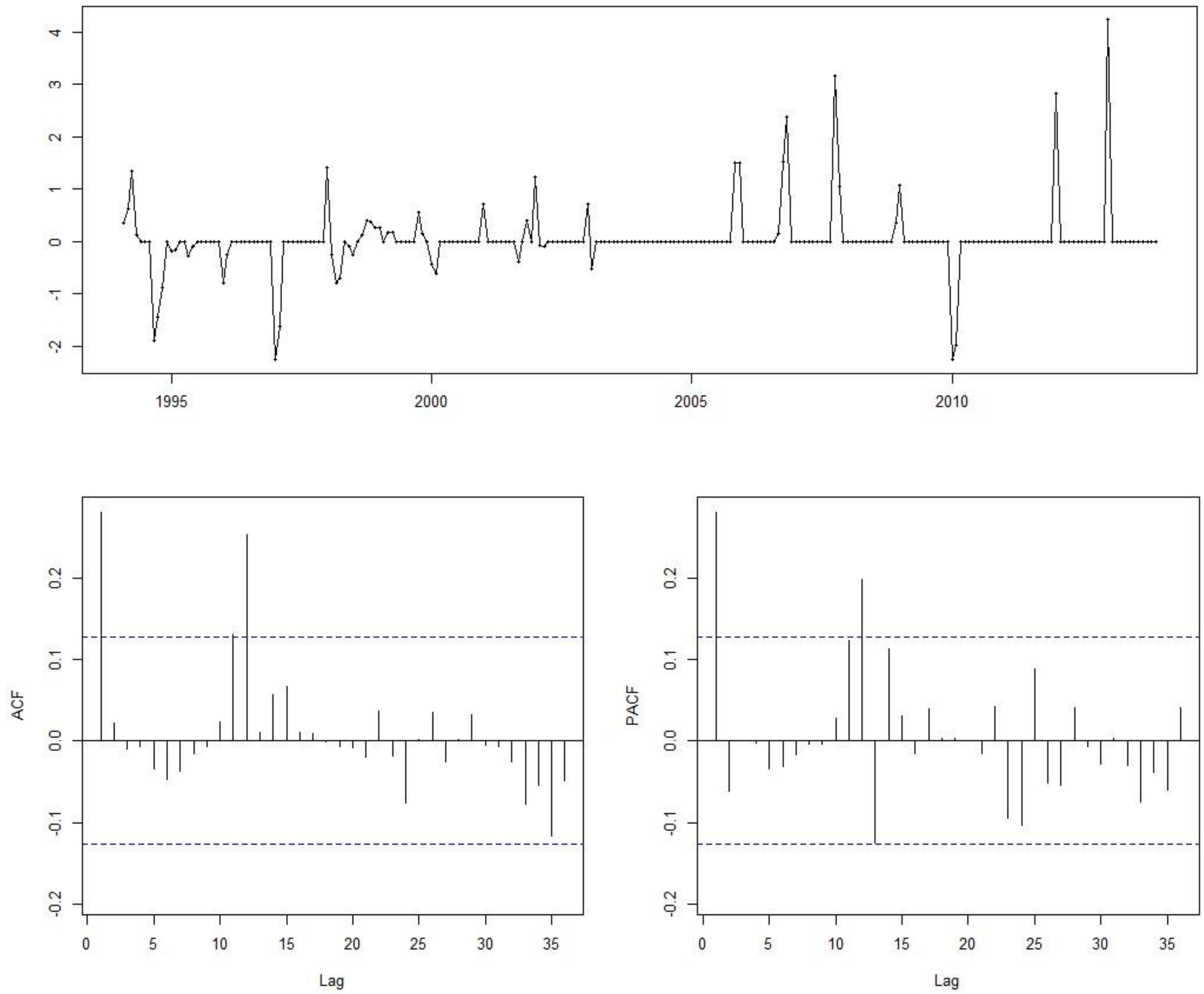


Quarterly forecasts from ARIMA$(0,2,0)(3,0,2)_4$

Monthly Model

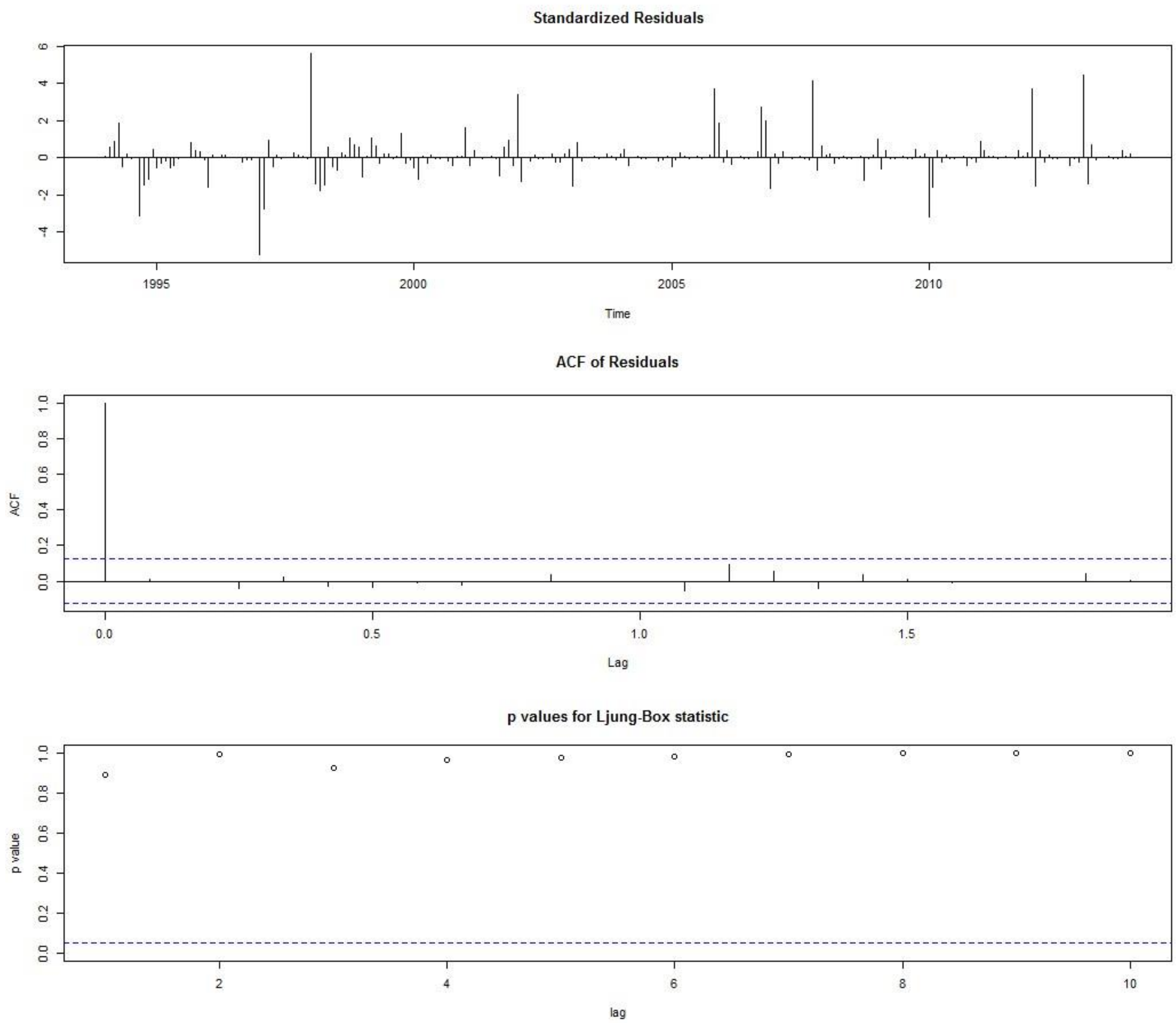
Alternatively, the monthly HFCS prices are found to be stationary after taking a nonseasonal first difference. The ADF test statistic (ρ) was found to be 5.79 (less than the critical value, 2.9, at $p < 0.05$).

The figures below show the differenced HFCS prices along with its ACF and PACF. Our first guess model was SARIMA$(1,1,1)(1,0,1)_{12}$ based on ACF and PACF. Similar to the quarterly model, we estimated the first guess model along with the other five models. Based on the lowest values of AIC and BIC, we chose the model SARIMA $(0,1,1)(2,0,1)_{12}$ for further estimation.



Monthly model: ACF and PACF of single-differenced HFCS prices

After estimation of the model SARIMA(0,1,1)(2,0,1)$_{12}$, we performed residual analysis. The residual analysis do not show significant autocorrelation in the model residuals as we fail to reject the null hypothesis of the LjungBox test statistic.

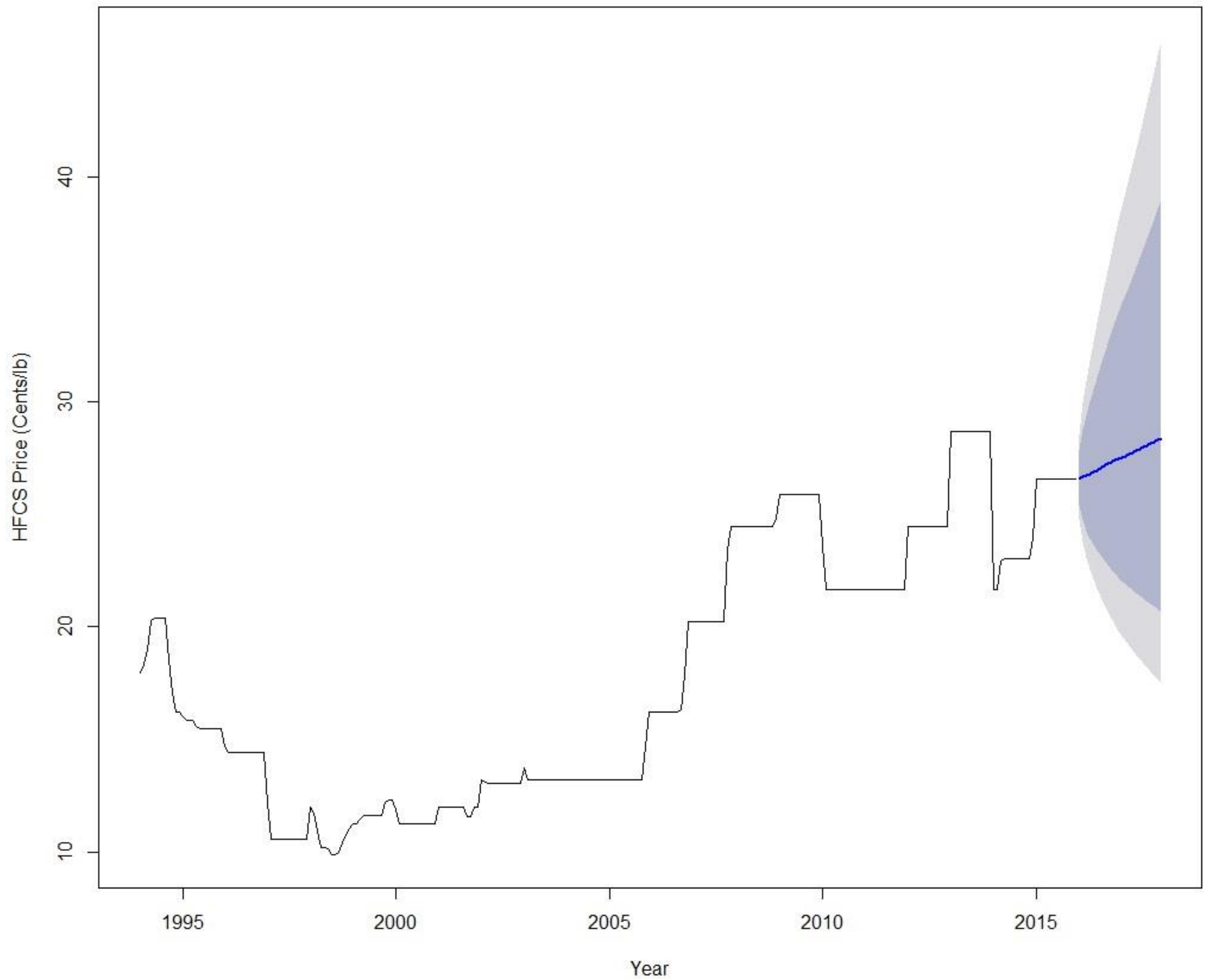


Monthly Model: Residual Analysis

Similar to the quarterly model, we selected a total of 11 models to evaluate the performance of the out-of-sample prediction accuracy. We found SARIMA(3,2,1)(1,0,1)$_{12}$ with the least out-of-sample RMSE as shown in Table 2.

The Jarque-Bera test used to test for normality of the residuals of the SARIMA(3,2,1)(1,0,1)$_{12}$. We found that the Jarque-Bera test statistic to be 1211 (larger than the critical value of chi-square distribution at 5% level of significance [5.99]). Hence, we reject the null hypothesis and hence conclude that the residuals of the SARIMA(3,2,1)(1,0,1)$_{12}$ model do not exhibit a normal distribution. Therefore, a further investigation was required.

Finally, we also performed Ljung-Box test for autocorrelation in the residuals of the SARIMA(3,2,1)(1,0,1)$_{12}$. The Ljung-Box test statistic was found to be 5.73 and hence we conclude that there was no evidence of any autocorrelation in the residuals of the fitted model.



Monthly forecasts from ARIMA(3,2,1)(1,0,1)$_{12}$

As a whole, the quarterly model performed well compared to monthly model based on the out-of-sample root mean square error. Additionally, the quarterly model also satisfied the normality assumption in the residuals of the fitted model. However, the forecast results of HFCS prices from both the quarterly and monthly models show an increasing trend.

The robustness of the forecast results of both the quarterly and monthly models could be verified with the diagnostic tests including the normality and the autocorrelation tests on the residuals of the best fit models. However, the validation of the forecast results could also be verified with the actual HFCS prices after 2015. On looking at the actual prices of the U.S. HFCS prices after 2015 also point to the increase in HFCS price to 31.25 cents per pound which are in line with the direction of the forecast results found in this study.

Discussion

Interesting times in the sweetener market particularly in the HFCS market. High HFCS export demand primarily from Mexico could be partly due to the NAFTA (North American Free Trade Area) integration in 2008. In the recent decades, there were two important trade disputes between the United States and Mexico related to bilateral sugar and nonsugar sweeteners. For example, Mexico levied anti-dumping duties on nonsugar (HFCS) sweetener imports during the 1997–2001 period (Kornis, 2006). Another example of the disputes between the countries include the 20% tax on sale of products emanating from the U.S. that contain HFCS as a major sweetener discriminating them from the Mexican domestic sweetener products during the 2002–2006 period (Kornis, 2006). The impact of these disputes are clearly seen from the decrease in U.S. exports to Mexico during the respective periods. Eventually, the World Trade Organization (WTO) ruled in the favor of the United States. However, after 2006 there has been a substantial increase in the U.S. HFCS exports to Mexico.

The increase in HFCS prices between 2002 and 2014 may be partly due to an increase in export demand of HFCS especially from Mexico. For instance, U.S. HFCS exports to Mexico have increased from 9,773 MT in 2002 to 1,147,289 MT in 2013 (USDA, 2016c). However, the U.S. HFCS exports have been stabilized after 2013 primarily due to the introduction of a Mexican soda excise tax policy in 2014. It will be interesting to see the long term effects of a Mexican excise tax policy on sweetener beverages introduced in 2014 on U.S. HFCS exports to Mexico. A recent study by Colchero et al. (2016) have indicated that on an average the

Mexican excise tax policy on beverages has decreased its purchases by 6%. Whether the increase or decrease of the HFCS price would partly depend on the impact of the Mexican excise tax policy on its beverage sales in the near future and thereby affecting the amount of US HFCS exports to Mexico.

The HFCS industry operates in an oligopolistic framework where the member companies belonging to the Corn Refiners Association (CRA) including the *Archer Daniels Midland Company*, *Cargill Incorporated*, *Ingredion Incorporated*, and *Tate and Lyle Americas* operate about 27 domestic plants across eleven states in the United States (CRA, 2016). The member companies or other affiliates of the CRA also operate 38 international plants (CRA, 2016). Based on the HFCS industry structure, it is more likely that the HFCS supply would not change much. At present, even though the domestic HFCS utilization and the market share has decreased, the export market has compensated for much of the share loss domestically.

Conclusions

We used quarterly and monthly data to forecast HFCS prices for the 1994-2015 period. We used two years (2014-2015) of data as a holdout set for evaluating the performance of the models and the remaining data for estimation of the model. Based on the lowest out-of-sample root mean square error criterion, the quarterly model performed well compared to the monthly model. Quarterly model resulted in the SARIMA $(0,2,0)(3,0,2)_4$ model, while the monthly model resulted in the SARIMA $(3,2,1)(1,0,1)_{12}$. The forecasts of HFCS prices of both quarterly and monthly models show an increasing trend for two years ahead.

APPENDIX IV. Corn Wet Mill Valuation: Real Options

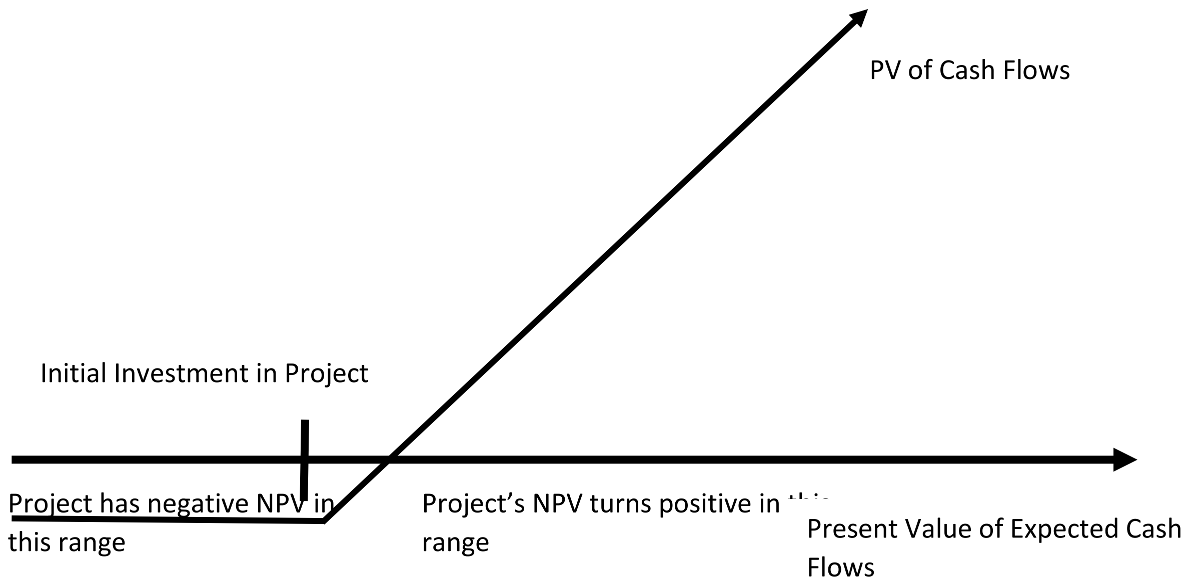
The agricultural economy is facing many challenges. Low commodity prices, political uncertainty, and changing consumer preferences are impacting the financial performance and management decisions. Production from a corn wet mill provides a perfect example. A corn wet mill has the ability to produce a variety of end products. The most common is ethanol and high fructose corn syrup. The surge in ethanol production motivated the investment in excess ethanol production. On the other hand, current world economic conditions have provided an opportunity for the United States to begin exporting ethanol. High Fructose Corn Syrup (HFCS) has become a standard ingredient in many sweetened beverages and food products. This has provided solid demand for HCFS. Conversely, HFCS has become public enemy #1 when discussing the obesity epidemic. As a result, demand for HCFS has begun to soften. How far it will soften is yet to be seen. Current HCFS prices are strong so consequently we have not seen the results of shifts in consumer demand. That does not mean that it is not relevant to look at production flexibility in a corn wet mill facility. The ability to be flexible and adapt to changes in demand may be worth a premium. The objective of this project is look at a generic corn wet mill facility to analyze that question. Is there a premium for being flexible? Or in other words, is a facility worth more if it can produce both HFCS and Ethanol. It is worth noting that Ethanol is the alternative product here. This is based on the fact that there exist current facilities that are equipped to switch between HFCS and Ethanol. Ethanol data is also readily available and easy to work with. This should not prevent an individual from thinking about producing something else besides ethanol. For example, there are current sweetener products that have potential to have high demand. One issue is that there exists very little data on those products and the ability or cost to switch from HFCS to those products has not been heavily studied. For those reasons, this study uses the HFCS/Ethanol example.

1.1 Real Option Methodology

The traditional method used to analyze the profitability of a project is net present value (NPV). NPV provides a framework to compare the cost of the project to the present value of future cash flows. Mathematically we can formulate NPV as:

$$NPV = \sum_{t=1}^{T} \frac{(C_t)}{(1+r)^t} \quad - C_0,$$

where T is the number of periods for the project, r is the required rate of return or discount rate, C_t is the net cash flow in time t, and C_0 is the initial cash outlay for the project. NPV is straightforward and easy to implement but it also has its drawbacks. One of the biggest drawbacks of NPV is that managerial/production flexibility cannot be included. For that reason, Real Options (RO) has become very useful to analyze projects that include production flexibility. RO builds upon NPV and still incorporates future cash flows, initial cash outlay, and discount rates. But it also includes the option to defer an investment, abandon an investment, or in this case switch production. Real Options have been used heavily to analyze seed trait development, pharmaceutical products, natural resource projects, R&D projects, and supply chain management issues. The figure below illustrates the RO methodology in an option framework. This example is concerned with the option to delay an investment. For example, in pharmaceutical research, companies often find that it is beneficial to delay the development of a certain product.



The Option to Delay an Investment

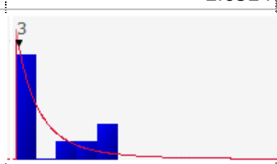
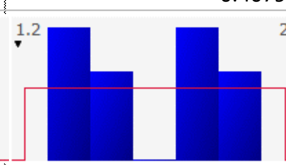
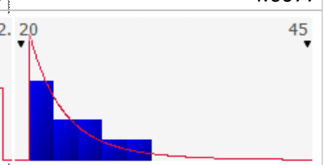
The diagram is analogous to a call option. The underlying asset is the investment (production facility), the strike price of the option is the initial outlay, and the life of the option is the period of the investment project. The present value of the cash flows for this project and the variance of the cash flows represent the value and variance of the underlying asset.

A switching option builds on the traditional options framework by incorporating the ability to switch outputs or inputs. Research has been done of the value of being able to switch from traditional gasoline to ethanol. This was done using flex fuel vehicles. The researchers found that consumers should be willing to pay a premium for flex fuel cars. This type of research has also been done on fertilizer production facilities where the manufacturing plant has the ability to switch from two different types of fertilizer. The research found that there was a significant premium associated with production flexibility.

Research surrounding the ethanol/HFCS question is limited. One project was completed in Brazil. The researchers looked at facility that could produce either ethanol or sugar. Although they used a little different framework (a bivariate lattice), they found that the ability to switch between ethanol and sugar has significant value. One other important finding of this research is that the authors found that using the bivariate lattice approach and stochastic simulation provided similar results. For that reason, this analysis will use stochastic simulation.

Stochastic simulation is a method to analyze a project using thousands of different scenarios, or in this case 5,000 different scenarios. These scenarios are not arbitrary. Each scenario consists of a “draw” from the defined statistical distribution for the key variables. In this case, the key variables are corn prices, HFCS price, ethanol price, feedstuff prices, and operating expense prices[6]. A statistical distribution is fit for each variable. For each scenario, a random draw from that distribution is taken and combined with the random draws from the other key variables to result in finding 5,000 different solutions. This provides a comprehensive look at the potential outcomes of the project. The table below shows the distributions for the three key variables in this research. It also highlights the correlation between the variables. A Pareto distribution was used for Corn and HFCS prices while a Uniform distribution was used for Ethanol prices. The correlation also highlights a key result, corn and ethanol prices are negatively correlated with HFCS prices. This could indicate the value of a switching option

Distribution of Key Variables

Name	Corn	Ethanol	HFCS
Range	Sheet3!K1:K11	Sheet3!L1:L11	Sheet3!M1:M11
Best Fit (Ranked by AIC)	RiskPareto(3.3628,3.0870)	RiskUniform(1.2665,2.6796)	RiskPareto(6.5288,21.218)
Function	3.531520435	1.605770084	24.20117354
AIC	29.9507	12.63	52.3497
Minimum	3.087	1.2665	21.2175
Maximum	+Infinity	2.6796	+Infinity
Mean	4.3936	1.973	25.0551
Mode	3.087	1.2665	21.2175
Median	3.7937	1.973	23.594
Std. Deviation	2.0524	0.4079	4.6077
Graph			
Correlation	Corn	Ethanol	HFCS
Corn	1.000		
Ethanol	0.939	1.000	
HFCS	-0.370	-0.358	1.000

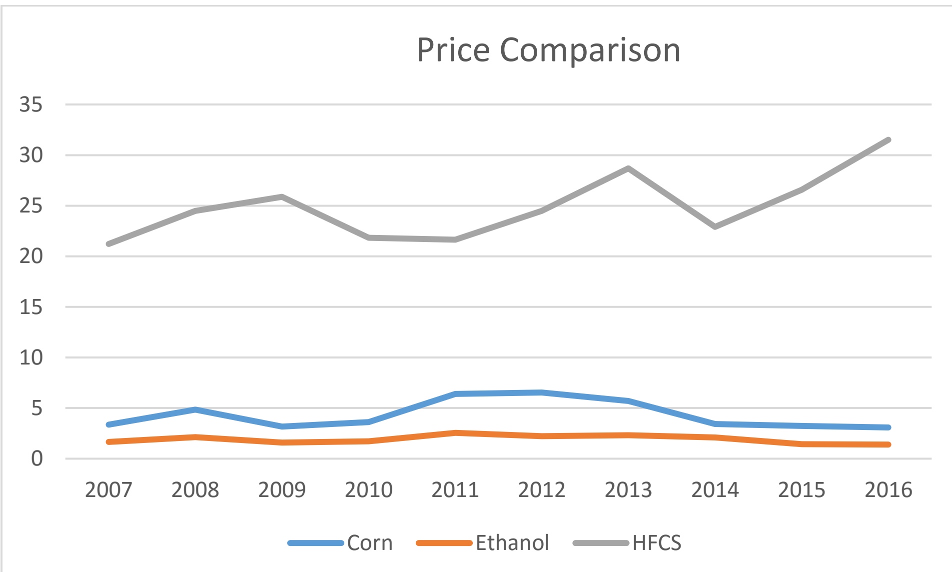
Data Sources

Data for this project was gathered from several different sources. Bloomberg was used to find data on corn prices, ethanol, and HFCS prices. USDA was used to find data on feedstuff prices. Operating expenses were based on research done by universities and USDA. It is important to note that these

[6] Please contact authors for detailed description of operating costs and model specifications.

expenses are generalized for the purpose of this research. An individual facility may have different expenses based on location and scale.

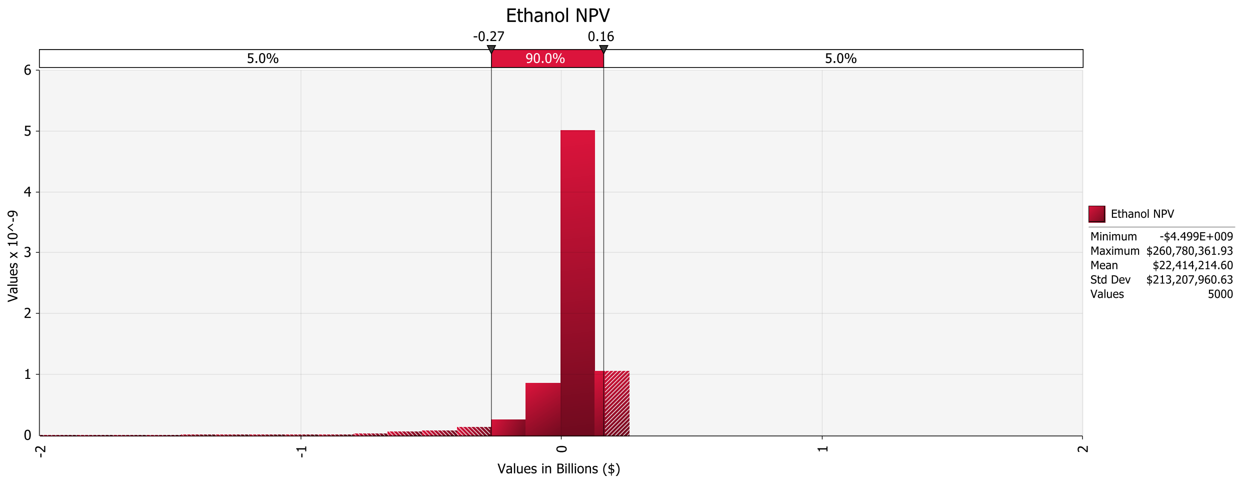
Two important price situations are impacting HFCS production currently. The first is that corn prices have dropped since the high period of 2007-2012. The second is that HFCS prices have increased over the past year. The analysis in this research will take both issues into consideration. This will be done by providing two different scenarios. The first scenario is based on how things currently sit, or an optimistic HFCS scenario. The second scenario is based on a pessimistic HFCS outlook and optimistic ethanol outlook. This is done by adjusting the distribution of HFCS prices downward and adjusting the ethanol prices upward. It is important to note that the adjustment is not dramatic so as to skew the results dramatically.



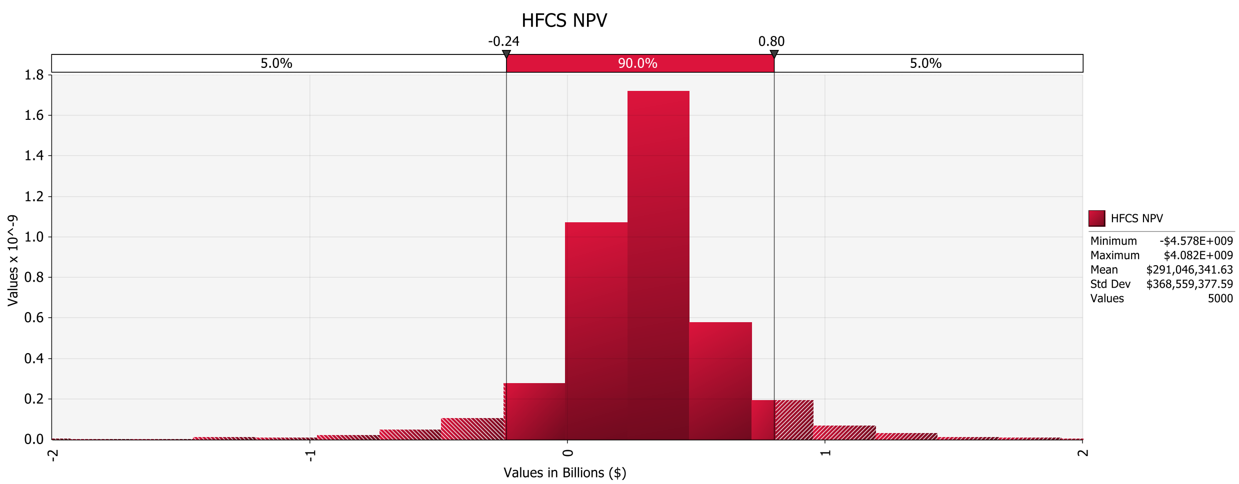
Historical Prices

Results

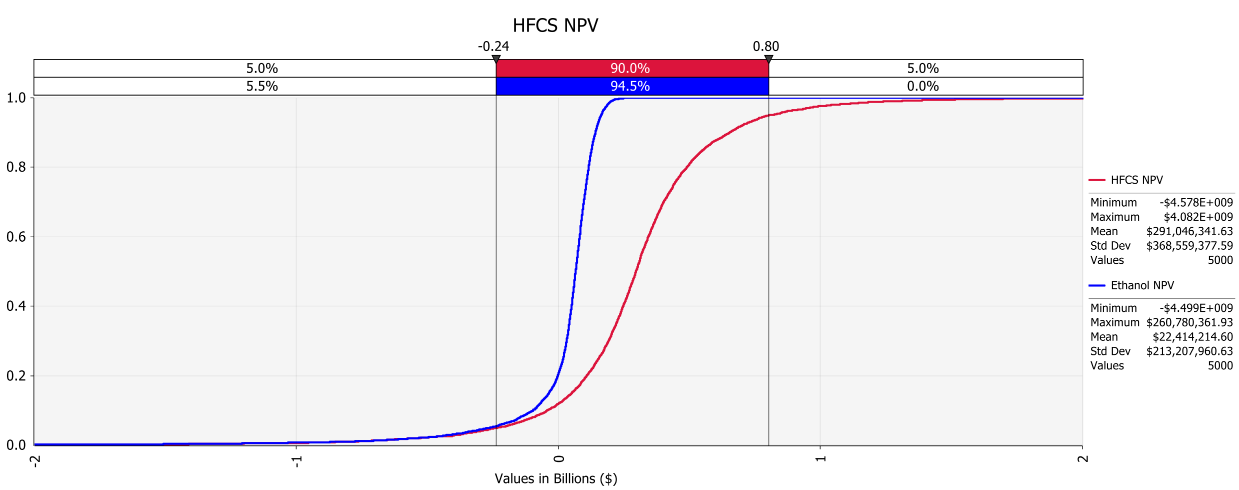
The simulation model was run for 5,000 iterations. The figures below present the results of the analysis based on current prices. This is scenario 1, or based on continued favorable prices for HFCS over the next 10 years and moderate prices for ethanolThe average NPV for producing only ethanol is just over $22 million and a standard deviation of $213 million. On the other hand, the average NPV for HFCS production is just over $291 million. This NPV estimation is based on no reduction in demand and consequently favorable prices over the next 10 years. Those results were based on the fact that the facility would produce only ethanol or HFCS. Just by looking at the estimated NPV, it would be easy to identify the lack of benefit to shift from producing HFCS to ethanol. By switching to Ethanol when it is more profitable than HFCS would actually reduce NPV and result in a negative option value. In other words, no rational decision maker would choose that option. On the other hand, if ethanol was the main product, it would definitely be profitable to have the option to switch to HFCS.



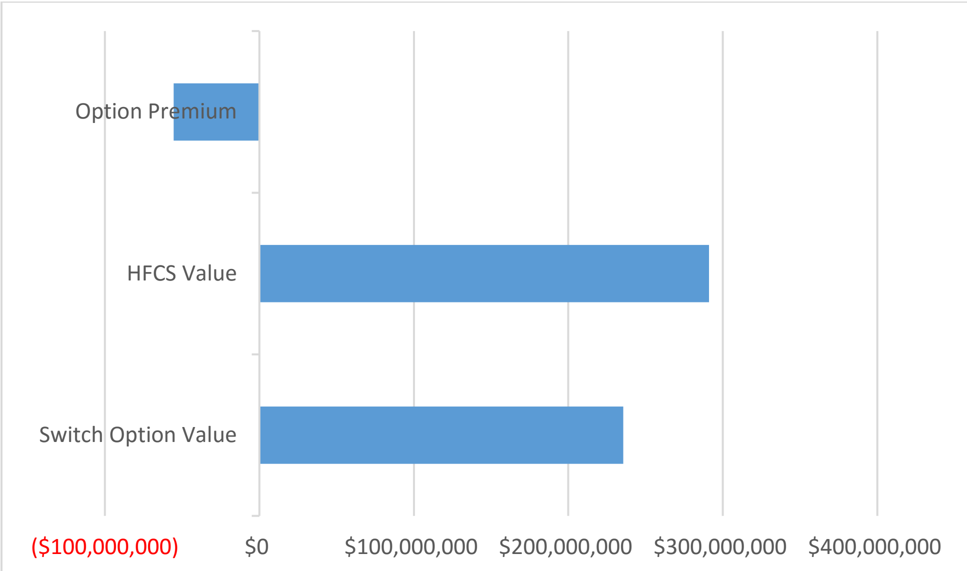
Ethanol NPV Simulation Results



HFCS NPV Simulation Results

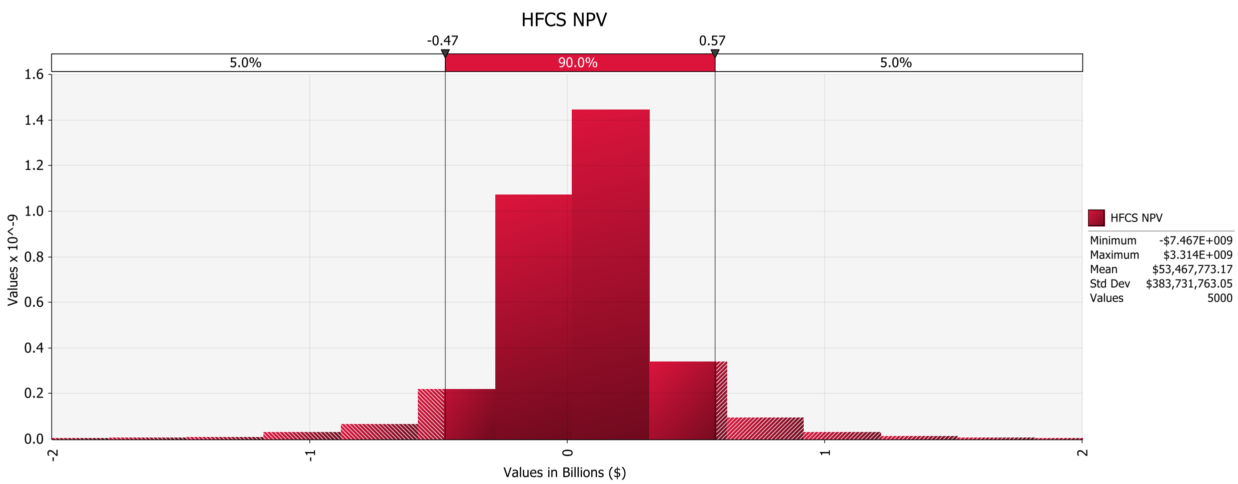


Ethanol vs HFCS

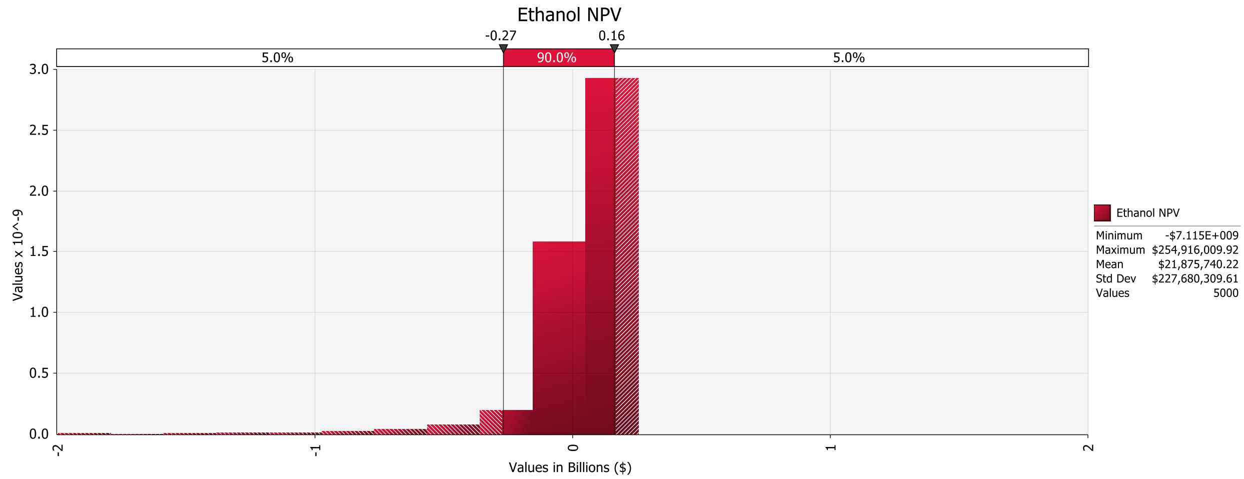


Ethanol/HFCS Option Value

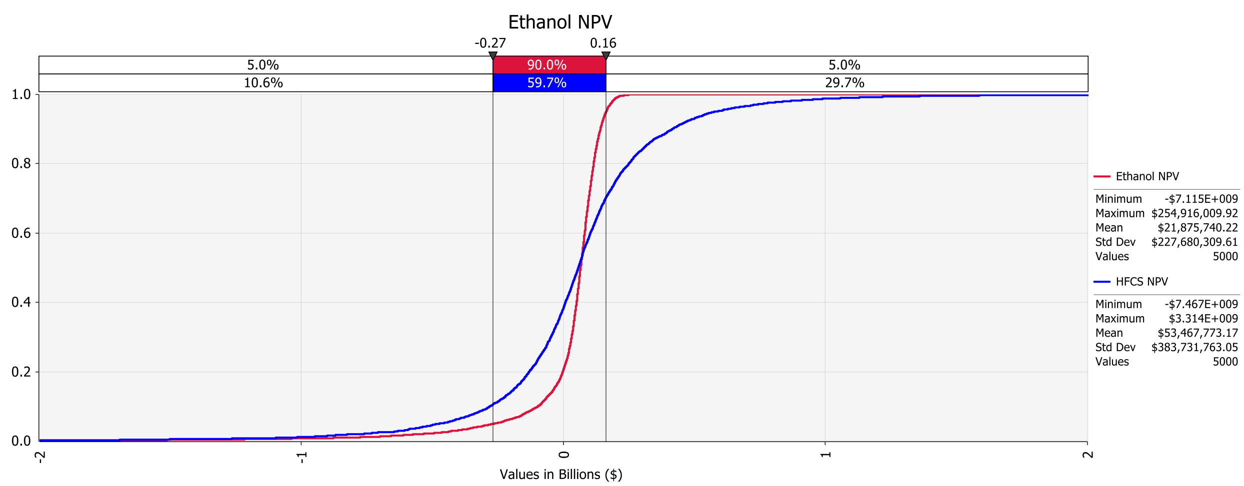
The second scenario consists of adjusting HFCS prices downward to reflect a shifting consumer demand. One could look at this scenario as a pessimistic HFCS view and a positive ethanol view. Ethanol prices are adjusted slightly upward to account for increased optimism. The HFCS NPV is reduced to just over $53 million. This highlights the impact of reduced HFCS prices. But even with reduced prices, the NPV is positive and profitable. The ethanol NPV is close to $22 million and still relatively close to the first scenario NPV. In the first scenario, it was clear the HFCS was the better investment. But now, with the two lines crossing, HFCS does not dominate ethanol. Now the value to switch between ethanol and HFCS is positive and close to $17 million. This can be interpreted as the value a company would be willing to pay to have the capacity to switch between the two outputs.

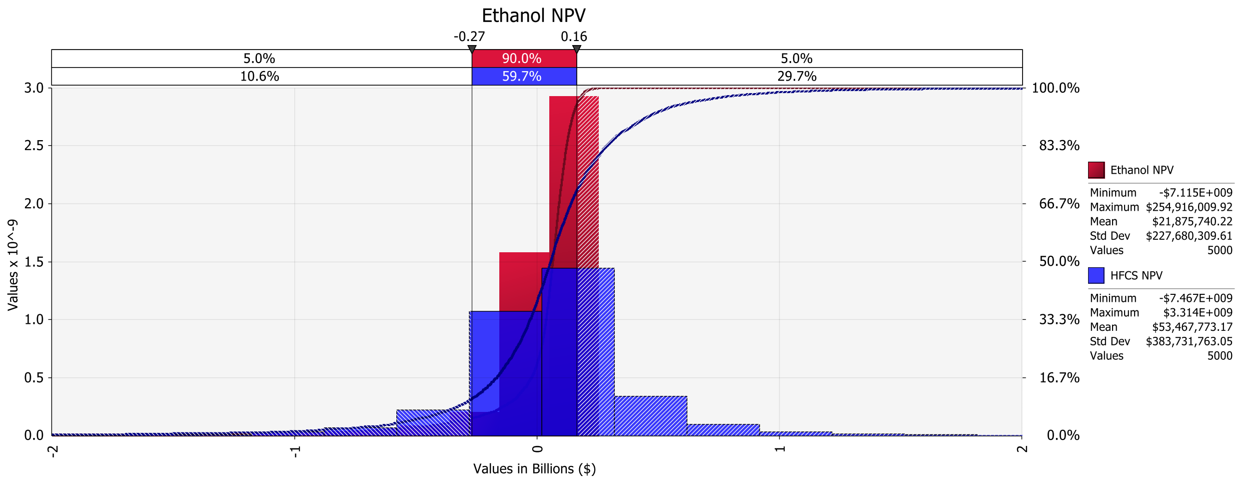


HFCS NPV

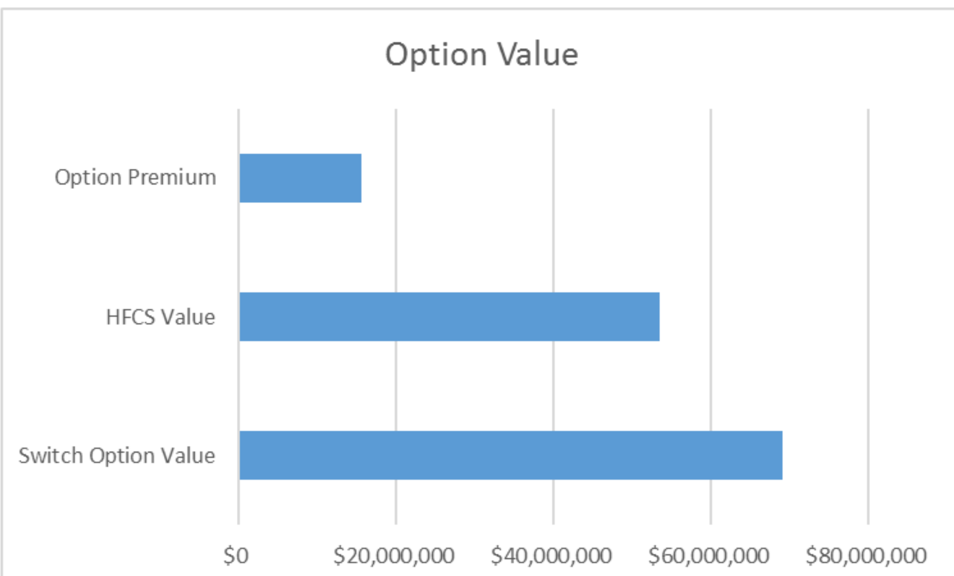


Ethanol NPV





HFCS vs Ethanol



Option Value

Summary

Real options provide a convenient manner to estimate the benefits of production flexibility. In this case, the flexibility of being able to produce ethanol and HFCS is analyzed. The results of the analysis highlight the sensitivity of the results to future price forecasts. When future price forecasts are favorable for HFCS, there is no value to switch to ethanol. On the other hand, if future price forecasts are not favorable for HFCS, the option value of being able to switch to ethanol is close to $16 million. Thus a firm would be willing to $16 million for the ability to produce both ethanol and HFCS out of the same facility. These results are also based on a generalized plant. Plant specific operating costs and scale could influence the results.

Valuation Summary

Value of Wet Mill Based on Optimistic HFCS Forecast		
HFCS Only	Ethanol Only	HFCS/Ethanol Combination
$291 Million	$22 Million	$235 Million

Value of Wet Mill Based on Pessimistic HFCS Forecast		
HFCS Only	Ethanol Only	HFCS/Ethanol Combination
$53 Million	$22 Million	$69 Million