NCCC-134
APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

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by

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Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting and Market Risk Management
St. Louis, Missouri, April 21, 22, 2014

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The Performance of U.S. Futures Markets on the World Stage: Ethanol

Practitioner's Abstract

This study examines the feasibility of Brazilian ethanol dealers using the U.S. ethanol futures contract as a price-risk management vehicle. This application is appropriate given that the U.S. and Brazil are the world's largest and second largest ethanol producers. This specific application is part of a larger consideration as to how U.S. futures markets perform for hedging international commodities. This study considers the reasons why U.S. ethanol contracts might and might not work as hedging vehicles for Brazilian ethanol inventories prior to conducting an empirical investigation. Our empirical hedge ratio model formulates three components of price risk for international users of U.S. futures markets. These are (1) the risk of commodity price change given the initial currency exchange rate, (2) the risk of exchange rate change, given the commodity's initial price, and (3) the risk of covariation between the commodity' price and the currency exchange rate. Based on these sources of price risk, the hedging portfolio consists of the U.S. ethanol futures contract and the Brazilian real futures contract. Our analysis reveals that the U.S. ethanol futures contract provides little price-risk protection for Brazilian ethanol holder while the Brazilian real futures contract offers some protection. In contract, we present results from crude oil futures markets where the U.S. crude oil futures contract gives the bulk of price risk protection and the currency futures contract provides much less. We conclude (1) that the ethanol findings are not universal and depend on the provisions of the U.S. ethanol futures contract and (2) the contracts traded on the Brazilian futures exchange do not compete directly with the U.S. contracts.

Keywords: Brazilian ethanol, hedging, price risk, exchange rate risk.

Introduction

Hedging U.S. produced commodities in U.S. commodity futures markets allows domestic producers and processors to reduce their price risk. This price risk reduction, measured by hedging effectiveness (Ederington), is widely seen as benefiting producers, processors, brokers, storers, or to any other agent who has a position in the cash (or spot) market for a commodity. These benefits accrue whether the hedging strategy derives from a simple "one-to-one" rule, a rule based on optimal hedge ratios estimated from an OLS regression, or a rule based on time-varying hedge ratios. In fact, the different methods for estimating hedge ratios represent a quest for the most effective hedge.

In a similar vein, hedging in foreign currency futures markets offers international bankers and corporate treasurers protection from exchange rate risk as they convert funds between currencies (Hill and Schneeweis, 1981; Kroner and Sultan, 1993). These currency hedges are likewise effective and the mobility of funds in the banking system eliminates localized basis risk.

This study combines these two hedging applications to examine hedges where U.S. futures contracts are used to hedge internationally produced and traded commodities. More specifically, this study examines the performance of U.S. ethanol futures markets as a hedging vehicle for the Brazilian ethanol trade. Similar studies include Jin and Koo (2006) who examined the problem from the standpoint of a Japanese wheat importer while Chang, McAleer and Tansuchat (2011), and Yun and Kim (2010) studied the problem from the standpoint of a crude oil trader. Dahlgran also reported a similar problem for U.S. cottonseed crushers who had effective hedging opportunities in the using the Canadian rapeseed futures contract as the hedge vehicle. .

Brazilian ethanol traders face price risk. An attempt to manage this price risk by hedging in U.S. ethanol futures markets introduces exchange rate risk as the spot position is priced in Brazilian reals while the futures position is priced in U.S. dollars and the hedging proceeds must converted to Brazilian reals upon the hedge's closure. This scenario is of interest because the U.S. and Brazil respectively are the largest and second largest ethanol producers in the world (table 1). Brazil's ethanol futures market is small and young while the U.S. has an ethanol futures market that is well established and together with the underlying ethanol swaps market provides an efficient market for the transfer of ethanol price risk (table 1). Given this situation, we ask the obvious question, "Can U.S. futures markets provide price risk management benefits to the Brazilian ethanol sector."

Table 1. Ethanol sectors: U.S. versus Brazil.

	U.S.	Brazil
Ethanol Production 2013[a]	13.3 bill gal	6.3 bill gal
World Rank 2013[a]	# 1	# 2
Refining		
Input(s)	Corn (1bu)	Sugar cane
	Natural gas	Electricity
Output(s)	Ethanol (2.6 gal)[b]	Sugar Crystals
	Distillers Dried Grains	Molasses → Ethanol
		Dry matter → Electricity
Consumption		
Road Fuel Blending Limits	10% Maximum	Flexible Fleet 50%
Futures Markets	CBT / CME	BM&F BOVESPA
Trading began	Mar 24, 2005	Jan 28, 2013
Volume (3-31-14)	998 contracts[c]	410 contracts[d]
	$72.2 mill[c]	$6.4 mill[d]

Sources:
a/ Renewable Fuels Association website [http://ethanolrfa.org/pages/World-Fuel-Ethanol-Production].
b/ CBOT *Ethanol Futures Corn Crush Reference Guide.*
c/ CME Group website. [http://www.cmegroup.com/trading/energy/ethanol/cbot-ethanol_quotes_volume_voi.html].
d/ BM&F BOVESPA website [http://www.bmfbovespa.com.br/en-us/markets/commodities-and-futures/commodities-and-futures.aspx?idioma=en-us].

Through their dominant influence on world supplies Brazil and the U.S. largely determine world ethanol prices. This joint influence should contribute to the integration of their ethanol markets. On the other hand, the different production technologies tend to diminish the integration of the two markets. Specifically, U.S. refiners use a bushel of corn to produce 2.6 gallons of ethanol in a fixed coefficients production technology.[1] In contrast, Brazilian ethanol refineries use sugar cane to produce either ethanol or sugar (Farina, et al.), depending on the relative price of the two products. A constant elasticity of transformation regression model for ethanol and sugar production is

$$(1) \qquad \ln\left(\frac{y_i^s}{y_i^e}\right) = \alpha + \psi \ \ln\left(\frac{p_i^s}{p_i^e}\right) + \varepsilon_i \,,$$

where y_i^s and p_i^s represent sugar production and price for observation i, respectively, and y_i^e and p_i^e represent the corresponding data for ethanol.

To test the notion of output mix adjustment, (1) was estimated using data from various sources. Semimonthly (24 observations per year) sugar and ethanol production data came from Brazilian Sugarcane Industry Association (UNICA) Sugarcane Harvest Reports for 2008/09 through 2012/13 (5 crop years plus a few trailing months). These reports contain production data for three regions: Sao Paulo state, the South Central Region (excluding Sao Paulo state), and other states. Sugar and ethanol prices came from the Center for Advanced Studies on Applied Economics (CEPEA). Sugar prices have a daily frequency while ethanol prices are weekly. We aggregated both series to correspond to the semimonthly intervals of the UNICA production reports.

Adding regions (i), crop years (j) and observations within years, (k) to (1) gives

$$(2) \qquad \ln\left(\frac{y_{ijk}^s}{y_{ijk}^e}\right) = \alpha_i + \delta_k + \psi_i \ln\left(\frac{p_{ijk}^s}{p_{ijk}^e}\right) + \varepsilon_{ijk} \,,$$

where region i = 1, 2, 3; crop year j = 1, 2, … 5; and season k = 1, 2, … 24.

Sugarcane crushing varies cyclically throughout the crop year. At the beginning and end of each crop year, sugarcane crushing is small relative to peak periods and the residual error's variability increases. In other words, the random error is heteroscedastic with a variance inversely related to the quantity of sugarcane processed. To correct for this, the regression was weighted by the quantity of sugarcane crushed in the region and period. Regional effects were insignificant as the probability of a larger F for H_0: $\alpha_1 = \alpha_2 = \alpha_3$ was 0.993 and the probability of a larger F for H_0: $\psi_1 = \psi_2 = \psi_3$ was 0.681 while the annual cycle was significant as the probability of a larger F for H_0: $\delta_1 = \delta_2 = \ldots = \delta_T$ was less than 0.0001. (2) was fit subject to these preliminary results giving

[1] The CBOT *Ethanol Futures Corn Crush Reference Guide* (2007, p. 2) uses 2.6 as the ethanol yield per bushel of corn. Shapouri, Duffield and Wang (2002) report values ranging from 2.50 to 2.69, and Eidman (2007) reports yields of 2.8 gal/bu.

$$\ln(y^s_{ijk} / y^e_{ijk}) = \hat{\alpha} + \hat{\delta}_k + \underset{(0.05973)}{0.2023} \ln(p^s_{ijk} / p^e_{ijk}) \qquad N = 350,\ dfe = 325,\ R^2 = 0.456,\ Prob(> F) < 0.0001$$

where the standard error is in parenthesis. This indicates that the output mix of Brazil's ethanol refineries responds to the sugar/ethanol price ratio.

We represent the technical sugar-ethanol production tradeoff as follows. Let y^*_s represent potential sugar production from processing a quantity of sugar cane (y_c) according to the relationship $y^*_s = f(y_c)$. Actual sugar production (y_s) is less than the potential amount because sugar (y^e_s) can be diverted to ethanol production (y_e) so $y^*_s = y_s + y^e_s$. Ethanol production depends on the amount of sugar equivalent diverted for that purpose so $y_e = g(y^e_s)$. Hence, $y_e = g(y^*_s - y_s) = g(f(y_c) - y_s)$. Normalizing this relationship to express output per unit of input gives $y_e / y_c = g(f(1) - y_s / y_c)$ which is linearly approximated as $y_e / y_c = \alpha - \beta (y_s / y_c)$. Adding regional and seasonal effects gives $(y^e_{ijk} / y^c_{ijk}) = \alpha_i + \delta_j - \beta_i (y^s_{ijk} / y^c_{ijk}) + \varepsilon_{ijk}$. After correcting for heteroscedasticity and retaining the group wise significant effects we get

$$(y^e_{ijk} / y^c_{ijk}) = \hat{\delta}_j - \underset{(0.0331)}{0.358} (y^s_{1jk} / y^c_{1jk}) - \underset{(0.0358)}{0.341} (y^s_{2jk} / y^c_{2jk}) - \underset{(0.0428)}{0.302} (y^s_{3jk} / y^c_{3jk})$$

$N=360$, $dfe=333$, $R^2=0.594$, $Pr (> F) < 0.0001$

The estimates of the ethanol-sugar production tradeoff are of the negative expected sign, are significant and display regional variability. The F statistic for H_0: $\beta_1 = \beta_2 = \beta_3$ is 8.13 and has a probability of a larger value of 0.0004 so the hypothesis of regional homogeneity is rejected. In summary, these results quantify the difference between U.S. and Brazilian ethanol refining and this difference will likely diminish Brazilian and the U.S. ethanol market integration. .

Demand forces may integrate the U.S. and Brazilian ethanol markets. Ethanol is used predominantly as motor fuel in both countries and worldwide integration of crude oil markets should extend through refining to domestic gasoline markets. Gasoline market integration should integrate the domestic ethanol markets. However, the nature of the respective auto fleets may diminish this effect. The U.S. auto fleet accommodates a maximum ethanol fuel blend of ten percent. In contrast, the Brazilian fleet is fuel-flexible in that it can use either ethanol or gasoline. (Phaneuf) In 2013, Brazilian road fuels were roughly fifty percent ethanol and fifty percent gasoline. (table 1)

Trade also contributes to the integration of the ethanol markets in the two countries but both Brazil and the U.S. had tariffs on ethanol imports. When these tariffs were in effect, ethanol trade between the U.S. and Brazil was limited though both exported to Caribbean countries. Brazil removed its tariff in April of 2010 (International Centre for Trade and Sustainable Development, 2010). The U.S. removed its 2.5 percent ad valorem tax plus and $0.54/gallon tariff on January 1, 2012 (International Centre for Trade and Sustainable Development, 2010; Wall Street Journal, 2012).

Finally, U.S. futures contract specifications might limit their effectiveness in hedging Brazilian-produced ethanol. Ethanol futures trading is a recent innovation in both the U.S. and Brazil. U.S. ethanol futures contracts began trading in March of 2005 and futures trading volume and open interest have grown and currently provide sufficient liquidity (table 1). Dahlgran (2009) demonstrated that despite the smaller size of ethanol futures markets, direct hedging in ethanol markets is superior to cross hedging in gasoline futures markets (Franken and Parcell). In addition, the ethanol swaps market is several times larger than the futures market and ties directly to the ethanol futures market to provide additional liquidity (Dahlgran, 2010).

Brazilian ethanol futures contracts began trading on March 31, 2000 with launch of an ethanol futures contract on the Brazilian Mercantile and Futures Exchange (BM&F) (marketswiki.com). Volume and open interest in this contract dwindled until a revamped U.S. dollar-priced contract was launched on May 18, 2007 (Fan). This revamped contract also shifted the delivery point from Paulina to the main Port of Santos.

On May 8, 2008, the BM&F merged with the Sao Paulo Stock Exchange to become BM&F BOVESPA, the new home for Brazilian ethanol futures trading. A second Brazilian ethanol future contract was created with the addition of a cash-settled hydrous ethanol contract based on the Ethanol Hydrated Price Indicator of Paulina. This contract's price is quoted in Brazilian reals (BM&F BOVESPA, 2010). Another contract joined the mix on January 28, 2013, with the addition of the anhydrous fuel ethanol contract. This contract is for physical delivery (Paulina region, Sao Paulo state) of 30,000 liters of anhydrous fuel ethanol with prices quoted in reals (BM&F BOVESPA, 2013). BM&F BOVESPA describes its current ethanol products as this physical-delivery anhydrous fuel ethanol contract and the cash-settled hydrous ethanol contract (BM&F BOVESPA, 2013). Rumors circulate periodically that the CME is developing a Brazilian ethanol futures contract (Biofuels Digest, Orwel), but current involvement of U.S. exchanges in Brazilian ethanol trading is limited to shared order routing through the CME Globex system(CME Group). Differences in delivery points may limit the effectiveness of Brazilian use of U.S. ethanol futures markets.

This institutional background identifies factors that suggest that Brazilian ethanol refiners can effectively hedge price risk in U.S. ethanol futures markets, and it identifies factors that suggest that these hedges will not be effective. The importance of each of these factors in the hedging outcome is the empirical question that this study addresses.

Theoretical Model

Hedging behavior assumes that an agent seeks to minimize the price risk of holding a necessary spot (or cash) market position by taking an attendant futures market position (Johnson, Stein). The profit outcome (π) of these combined positions is

(3) $\pi = x_s (p_1 - p_0) + x_f (f_{M1} - f_{M0})$,

where x_s is the agent's necessary cash market position, p is the commodity's cash price, x_f is the agent's discretionary futures market position, f_M is the M-maturity futures contract's price, and subscripts 0 and 1 indicate initiating and terminating transaction times. The optimal futures position, x_f*, is the value of x_f that minimizes the variance of π. This minimum occurs when

$x_f^*/x_s = -\sigma_{\Delta p,\Delta s} / \sigma^2_{\Delta f}$.

The risk minimizing hedge ratio (x_f^*/x_s) is estimated by $\hat{\beta}_1$ in the regression

(4a) $\Delta p_t = \beta_0 + \beta_1 \Delta f_{Mt} + \varepsilon_t$, t = 1, 2, … T

where Δ represents differencing over the hedging horizon, ε_t represents stochastic error at time t, and T represents the number of observations used in estimating of β_0 and β_1. The risk minimizing futures position is $x_f^* = -\hat{\beta}_1 x_s$.

Anderson and Danthine (1980, 1981) generalized this approach to accommodate multiple futures positions. In this case, x_f and ($f_{M1} - f_{M0}$) in (3) are replaced by vectors of length k and hedge ratios are estimated by fitting the multiple regression

(4b) $\Delta p_t = \beta_0 + \sum_{j=1}^{k} \beta_j \Delta f_{jt} + \varepsilon_t$, t = 1, 2, 3, … T,

where Δf_{jt} is the change in the price of futures contract j over the hedge period, and $\hat{\beta}_j$ is the estimated hedge ratio indicating the number of units in futures contract j per unit of spot position.

For commodity processors the profit objective is

$$\pi = y\, p_{y,1} - x\, p_{x,0} + x_f\, (f_{M1} - f_{M0}).$$

In this case, input purchases (x) and output sales (y) are temporally separated by H but connected by product transformation with $y_t = \kappa\, x_{t-H}$. Hedge ratios are estimated by fitting

(4c) $p_{y,t} - \kappa\, p_{x,t-H} = \beta_0 + \sum_{j=1}^{k} \beta_j \Delta f_{jt} + \varepsilon_t$, t = 1, 2, 3, … T.

This specification has been applied to soybean processing (Dahlgran, 2005; Fackler and McNew; Garcia, Roh, and Leuthold; and Tzang and Leuthold), cattle feeding (Schafer, Griffin and Johnson), hog feeding (Kenyon and Clay), and cottonseed crushing (Dahlgran, 2005; Rahman, Turner, and Costa), and U.S. ethanol refining (Dahlgran 2009).

Ederington defines hedging effectiveness (e) as the proportionate price-risk reduction available through hedging, or

(5) $e = [\, V(\pi_u) - V(\pi_h)\,] / V(\pi_u)$

where V is the variance operator, π_u the agent's unhedged outcome ($x_f = 0$) and π_h is the agent's hedged outcome ($x_f = -\hat{\beta}_1 x_s$). When hedge ratios are estimated with regression models in (4a), (4b), or (4c), the regression R^2 provides an estimate of hedging effectiveness.

If the commodity and the futures contract are valued in different currencies as happens when the commodity is produced internationally and hedged domestically, then the currencies must be converted so that the portfolio return can be expressed in a single currency. In our particular case, let P represent the spot price of Brazilian ethanol (in reals per liter) and let F represent the

U.S. ethanol futures price (in dollars per gallon), and let R represent the spot exchange rate in dollars/real and let R^{-1} represent the spot exchange rate in reals/dollar. A single-currency portfolio return involves either converting the U.S. futures price to reals $\Delta f^{reals} = F_1 (R^{-1})_1 - F_0 (R^{-1})_0 = \Delta F\ \Delta R^{-1} + (R^{1})_0\ \Delta F + F_0\ \Delta R^{-1}$ or converting the spot price in reals to U.S. dollars, $\Delta p = P_1 R_1 - P_0 R_0 = \Delta P\ \Delta R + R_0\ \Delta P + P_0\ \Delta R$. The hedge ratio for the latter approach [$C(R_0\Delta P,\Delta F) + C(P_0\Delta R, \Delta F) + C(\Delta P\ \Delta R , \Delta F)$] / $V(\Delta F)$, reveals three components of hedging. The first term, $R_0\, C(\Delta P,\Delta F) / V(\Delta F)$, represents the traditional hedge ratio estimator with the spot price change converted to dollars at the initial exchange rate to make it comparable to the futures price change. The second term, $P_0\ C(\Delta R, \Delta F) / V(\Delta F)$, represents hedging the commodity's value change caused by and exchange rate change. And, the third term, $C(\Delta P\ \Delta R , \Delta F)$] / $V(\Delta F)$, represents the hedge ratio for the covariance between the spot price and the exchange rate.

Putting these considerations together in a hedge ratio estimation model gives

(6) $\Delta p_t = \Delta P\ \Delta R + R_{t-h}\ \Delta P + P_{t-h}\ \Delta R = \beta_0 + \beta_1\ \Delta F_t + \varepsilon_t,\ t = 1, 2, \ldots T$

where all terms are defined previously except h which represents the hedge horizon, and F_t may represent a vector of the prices of several futures contracts and maturities. In this application, ΔF includes the change in the price of the ethanol futures contract and the change in the price of the Brazilian real futures contract.

Data and Empirical Procedures

The data required to estimate (6) consist of Brazilian ethanol spot prices, Brazilian real spot prices, U.S. ethanol futures prices and Brazilian real futures prices. These data came from several sources.

For the Brazilian ethanol spot price, we use the CEPA anhydrous fuel ethanol price, quoted weekly in U.S. dollars per liter (CEPEA). These data are available from February 21 2000 to March 1, 2014.

For the Brazilian real spot price, we use noon buying rates from the New York Federal Reserve Bank quoted daily in reals/dollar from February 22, 1995 to March 1, 2014.

The U.S. ethanol futures contract trades on the Chicago Board of Trade. Daily prices (open, high, low, and settlement), volume, and open interest for all maturities came from barchart.com. These data are available from March 24, 2005, the contract's launch date, to December 31, 2013. The contracts mature in each calendar month.

The Brazilian real futures contract trades on the Chicago Mercantile Exchange and contracts mature in each calendar month. Daily prices (open, high, low, and settlement), volume, and open interest for all maturities from April 2, 2007 to December 31, 2013 came from barchart.com. The time span of these data was shorter than the time span of the ethanol futures prices so we supplemented these data with Brazilian real futures price data from quandl.com. Qaundl.com provides the corresponding data for the March, June, September and December maturities from December 1, 1995 to the present.

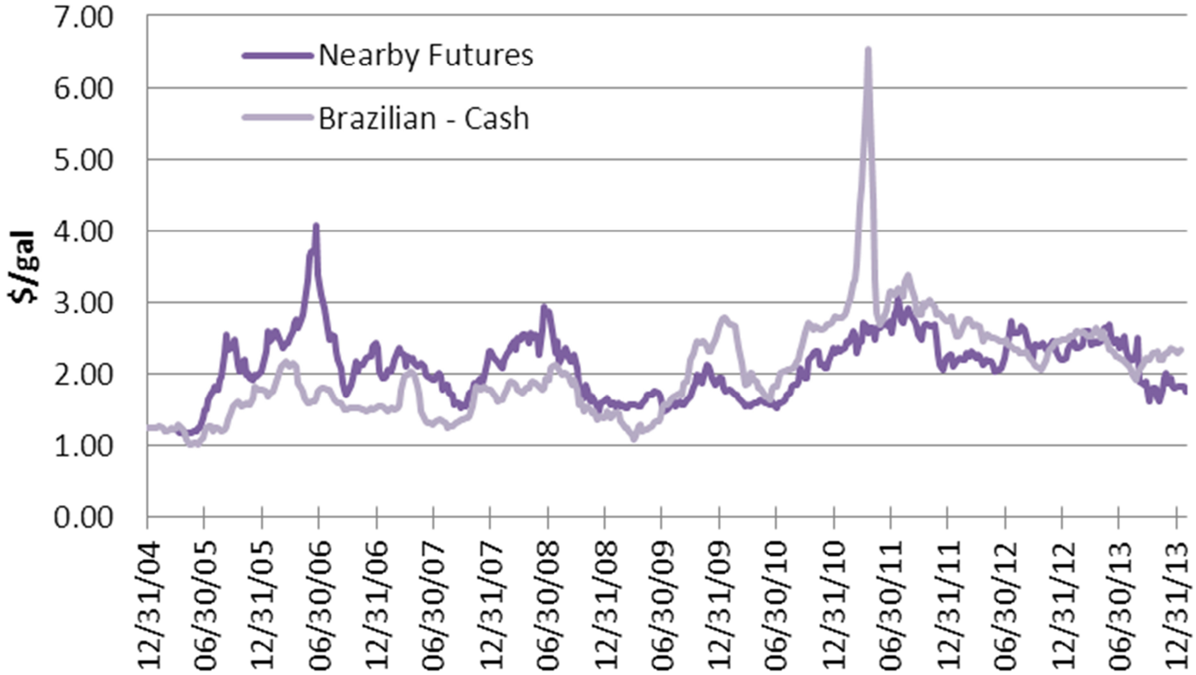

Figure 1. Brazilian ethanol cash and futures prices.

We use the nearby futures contract as the hedge vehicle if its last trading day is at least one week beyond the hedge termination date. Otherwise, we use the next nearby maturity. This one-week maturity buffer avoids potential price volatility increases at contract maturity.

We treat the weekly average spot price as the midweek value and match this price with the corresponding Wednesday futures prices. This avoids weekend-related volatility effects.

The weekly Brazilian ethanol spot price (converted to dollars per gallon) series and the Wednesday nearby U.S. ethanol futures price (also in dollars per gallon) are plotted in figure 1. The most prominent feature of these data is the spike in the first half of 2011 caused by a brief inter-harvest shortage of sugarcane (Jelmayer, 2011). Because of the serial correlation in the data, we used dummy variables to account for the price spike period.

We do not use matched ethanol and Brazilian real futures maturity months. This pairing is attractive as both contracts have maturities for each calendar month and nearly matching last trading days (third business day of the month for ethanol and last business day of the previous month for the Brazilian real). However, this correspondence is not universal as the Brazilian real has only four maturities per year through April 2007 and ethanol's last trading day was the business day prior to the 15th of the month through the August 2006 maturity. The less strict use of the nearby ethanol and the nearby Brazilian real contact maturities provides a more accurate depiction of opportunities during our sample period.

After consideration of data sources and data characteristics, the empirical model becomes

(7) $\Delta(p_t\, r_t) = \beta_0 + \sum_{i=1}^{n} \delta_i \Delta D_{it} + \beta_1\, \Delta r_{Tt} + \beta_2\, \Delta f_{Tt} + \varepsilon_t$ where $\varepsilon_t = \rho\, \varepsilon_{t-1} + \nu_t$

where D_{it} represents dummy variables, one for each observation in the March 23, 2011 through May 4, 2011 time period.

Empirical Results

Table 2 summarizes the results of estimating (7). The columns correspond to one, two, four, eight and thirteen week inventory hedging horizons. The regression intercept is insignificant for all hedge horizons. The dummy variables shown below the intercept correspond to weeks of March 23, 2011 through May 4, 2011 when sugar cane stocks were depleted (Jelmayer, 2011). The data frequency depends on the hedge horizon and, depending on the hedge horizon, the observation corresponding to a particular dummy variable may not be included in the data set. Table 2 indicates that none of the dummied observations is included under a thirteen week hedge horizon while all of the observations are included under a one week hedge horizon. Regardless of the hedge horizon, the coefficients on the dummy variables indicate the rarity of the observations as the corresponding t-values ranges from 11.03 to 27.62.

The hedge ratio for the real is positive and significantly different from zero regardless of the hedge horizon while the hedge ration for the U.S. ethanol futures contract attains a significant positive value only for the eight and thirteen week hedge horizons. For the shorter hedge horizons the U.S. ethanol futures contract offers Brazilian ethanol inventory-holders little price risk protection. Serial correlation decreases in significance as the hedge horizon increases. Table 2 shows the t-value for serial correlation falling from -11.66 to -0.01 for a four week horizon then becoming positive and somewhat significant slightly for the eight and thirteen week horizons.

Hedging effectiveness compares the variation of the unanticipated hedged outcomes with unanticipated unhedged outcomes. The effects represented by dummy variables and serial correlation would be present whether hedging occurred or not so hedging effectiveness with regard to (7) depends on $\beta_1 = \beta_2 = 0$ (the null hypothesis) versus $\beta_1 \neq 0$ and $\beta_2 \neq 0$ (the alternative htpothesis). The F statistic for testing the null against the alternative is

(8a) $$F = \frac{(SSE_0 - SSE_a)/(dfe_0 - dfe_a)}{SSE_a / dfe_a}$$

where SSE_0 and dfe_0 are the error sum of squares and error degrees of freedom under H_0 while SSE_a and dfe_a are the error sum of squares and error degrees of freedom under H_a. Hedging effectiveness is the proportionate reduction in the unanticipated variation due to hedging so

(8b) $$e = \frac{SSE_0 - SSE_a}{SSE_0}$$

Rearrangement of (8a) gives

(8c) $$e = \frac{F \times (dfe_0 - dfe_a)}{dfe_a + F \times (dfe_0 - dfe_a)}.$$

This relationship is used to compute the effectiveness statistic reported in table 2. Hedging effectiveness is significantly different form zero for all hedge horizons and except for the transition from a one week to the two week hedge horizon, hedging effectiveness increases with the hedge horizon (table 2).

For comparison, table 2 also reports the effectiveness of hedging U.S. ethanol inventories with U.S. ethanol futures contracts. These results indicate that hedging U.S. ethanol inventories with U.S. ethanol futures contracts is substantially more effective than hedging Brazilian ethanol inventories with these contracts. One major finding provided by table 2 is that the significant risk protection afforded to Brazilian ethanol inventory-holders is provided by hedging with the Brazilian real contract.

One possible explanation for the limited effectiveness of Brazilian inventory hedging in U.S. ethanol futures markets is that import tariffs on ethanol in both the U.S. and Brazil may have reduced the integration of the ethanol markets in the two countries. Table 3 contains the hedge-ratio estimation results using data from only the post-tariffs period (beginning January 1, 2012). The results are similar to those obtained from the full sample period. Serial correlation is significant only for the one-week hedge horizon, the hedge ratio for the Brazilian real is positive and the hedge ratio for ethanol tends to be insignificant. The overall hedge effectiveness is roughly the same as for the entire sample and substantially less than for a similar hedge of U.S. ethanol, and effectiveness is due largely to the inclusion of the Brazilian real in the hedging portfolio. The smaller number of observations in the post tariff period tends to restrict the degrees of freedom and hence the significance levels of the resulting statistics and prevents estimating hedge ratios for a thirteen-week hedge horizon.

Tables 2 and 3 consistently indicate that the effectiveness of hedging Brazilian ethanol inventories in U.S. futures markets derives primarily from hedging currency conversions and little is gained by hedging the ethanol price risk, hedging effectiveness increases as the hedge horizon increases, and serial correlation dissipates as the hedging horizon increases. We question whether these results are universal, applying to many commodities or are they unique to hedging Brazilian ethanol in U.S. ethanol futures markets. To address this question, a similar analysis examined the use of U.S. crude oil futures markets to hedge international crude oil inventories (Liu). Table 4 summarizes these results.

Liu's study assumed oil producers/importers in Canada, Mexico and Australia have spot crude oil positions denominated in the respective local currencies. Hedge horizons of one, two and four weeks are analyzed using weekly data. The Australian, Canadian, and Mexican data series respectively begin November 1, 1995, Mat 29, 2006, and July 17, 2000 and all series end December 31, 2012. Two sets of results are shown for each country -- one shows the effectiveness of hedging the change in the crude oil's domestic value, given the initial exchange rate, with only the crude oil futures contract (i.e., $R_0\ \Delta P$), and the other set of results shows the effectiveness of hedging crude oil value changes with both the nearby crude oil futures contract and the country's nearby currency futures contract,.

Table 2. Hedge ratios and hedge effectiveness for hedging Brazilian ethanol inventories in the U.S. ethanol futures market, March 24, 2005 through Dec 31, 2013..

	1 week[a]		2 weeks		4 weeks		8 weeks		13 weeks	
Intercept	0.000	(0.09)	0.000	(0.07)	-0.002	(-0.42)	-0.005	(-0.67)	-0.008	(-0.70)
$D_{3/23/11}$	0.202	(14.96)***								
$D_{3/30/11}$	0.246	(11.33)***	0.264	(12.06)***	0.402	(11.03)***				
$D_{4/06/11}$	0.350	(13.10)***								
$D_{4/13/11}$	0.572	(20.22)***	0.597	(21.27)***						
$D_{4/20/11}$	0.736	(27.62)***								
$D_{4/27/11}$	0.536	(24.63)***	0.564	(25.43)***	0.730	(19.87)***	0.664	(12.25)***		
$D_{5/04/11}$	0.236	(17.49)***								
ΔF_{real}	0.648	(11.68)***	0.716	(5.78)***	0.891	(4.26)***	1.073	(3.76)***	0.892	(2.70)**
$\Delta F_{ethanol}$	-0.002	(-0.32)	-0.009	(-0.74)	0.026	(1.24)	0.056	(1.79)*	0.083	(1.76)*
AR(1)	-0.476	(-11.44)***	-0.373	(-5.99)***	-0.099	-(1.04)	0.240	(1.76)*	0.238	(1.34)
Effectiveness	0.236***		0.124***		0.146***		0.235***		0.289**	
Degrees of freedom	448		224		108		51		30	
U.S. Effectiveness	0.005		0.319***		0.658***		0.795***			

Notes: t-values in parentheses. * indicates significance at less than 5%, ** indicates significance at less than 10%, *** indicates significance at less than 0.001%.

Table 3. Hedge ratios and hedge effectiveness for hedging Brazilian ethanol inventories in the U.S. ethanol futures market, January 1, 2012 through Dec 31, 2013..

	1 week		2 weeks		4 weeks		8 weeks		13 weeks
Intercept	-0.001	(0.57)	-0.002	(-0.60)	-0.004	(-0.56)	-0.005	(-0.41)	
ΔF_{real}	0.500	(3.52)***	0.771	(2.76)**	0.443	(1.14)	0.682	(1.69)	
$\Delta F_{ethanol}$	0.023	(1.62)*	0.026	(0.88)	0.018	(0.40)	-0.005	(-0.08)	
AR(1)	-0.307	(-3.27)***							
Effectiveness	0.124	***	0.139	***	0.056		0.226		
Degrees of freedom	103		50		23		10		

Notes: t-values in parentheses. * indicates significance at less than 5%, ** indicates significance at less than 10%, *** indicates significance at less than 0.001%.

Table 4. The effectiveness of Canadian, Mexican and Australian crude oil inventories in U.S. crude oil futures markets.

		1 week	2 weeks	4 weeks
Canada	$R_0\ \Delta P = \alpha + \Delta F_{oil}\ \beta_{oil}$	0.68***	0.75***	0.88***
	$\Delta S = \alpha + \Delta F_{oil}\ \beta_{oil} + \Delta F_R\ \beta_R$	0.80***	0.82***	0.91***
	N	346	85	26
Mexico	$R_0\ \Delta P = \alpha + \Delta F_{oil}\ \beta_{oil}$	0.80***	0.82***	0.77***
	$\Delta S = \alpha + \Delta F_{oil}\ \beta_{oil} + \Delta F_R\ \beta_R$	0.87***	0.90***	0.86***
	N	644	160	53
Australia	$R_0\ \Delta P = \alpha + \Delta F_{oil}\ \beta_{oil}$	0.43***	0.85***	0.82***
	$\Delta S = \alpha + \Delta F_{oil}\ \beta_{oil} + \Delta F_R\ \beta_R$	0.58***	0.71***	0.85***
	N	898	221	74

Notes: t-values in parentheses. * indicates significance at less than 5%, ** indicates significance at less than 10%, *** indicates significance at less than 0.001%.

Table 4 indicates that hedge effectiveness generally increases as the hedge horizon increases. This is consistent with the ethanol hedging results. One striking results in table 4 is that the degree that the commodity hedge generates most of the hedging effectiveness (compare the first model for each country to the second). This general result applies across the three countries and hedge horizons. This result is inconsistent with the ethanol hedging where most of the hedging effectiveness derives from the currency hedge.

Conclusions and Implications

This study has examined the feasibility of using the U.S. ethanol futures contract as a vehicle for hedging Brazilian ethanol inventories. We cited reasons why this should work as well as reasons why it should not work. Our analysis indicates that significant price risk reduction can be obtained but the contract that creates most of this reduction is the Brazilian real futures contract. The U.S. ethanol futures contract is not an effective vehicle for managing the price risk associated with Brazilian ethanol spot-market positions.

We compared our results to the results from a similar hedging problem involving world oil markets. This comparison reveals that our results do not apply across the energy commodities as U.S. crude oil futures contracts provide effective hedges for international holders of crude oil positions, and currency hedges contribute only small amounts of additional effectiveness. Hence, the lack of effective international price risk-management capabilities is likely due to the design of the U.S. ethanol futures contract as the domestic delivery points are inappropriate points of price discovery for international ethanol producers.

From this observation, a conclusion follows. While Brazil's futures exchange, the BM&F BOLESPA, has frequently revamped its ethanol futures contract the price risk management capabilities of this contract do not compete with the ethanol futures contract offering from the U.S. This BM&F BOLESPA Brazilian contract will likely provide better hedging opportunities for Brazilian producers and will likely succeed for that reason. The hedging performance of the Brazilian contract merits further study.

References

Anderson, R.W., and J. Danthine. 1980. "Hedging and Joint Production: Theory and Illustrations." *Journal of Finance* 35:487-501.

Anderson, R.W., and J. Danthine. 1981. "Cross Hedging." *Journal of Political Economy* 89:1182-1196.

Barchart.com. 2014. U.S. Ethanol Futures Prices. Online at http://acs.barchart.com/. [Accessed March 1, 2014.]

Biofuels Digest. 2011. "CME is Developing Futures Contract for Brazilian Ethanol." Biofuels Digest September 27, 2011. Online at http://www.biofuelsdigest.com/bdigest/2011/09/27/cme-is-developing-futures-contract-for-brazilian-ethanol/. [Accessed May 30, 2014.]

BM&FBOVESPA. 2010. "BM&FBOVESPA Launches Cash-Settled Hydrous Ethanol Futures Contracts -- Trading begins on May 17" Press release May 10, 2010. Online at http://www.bmfbovespa.com.br/en-us/News/2010/BMFBOVESPA-launches-cash-settled-hydrous-ethanol-futures-contracts-2010-05-10.aspx?idioma=en-us. [Accessed May 30, 2014.]

BM&FBOVESPA. 2013. "BM&FBOVESPA Launches New Commodity Derivatives for the Sugar/Ethanol Sector" Press release January 28, 2013. Online at http://www.bmfbovespa.com.br/en-us/News/2013/BMFBOVESPA-launches-new-commodity-derivatives-for-the-sugarethanol-sector-2013-01-28.aspx?tipoNoticia=1&idioma=en-us. [Accessed May 30, 2014.]

Brazilian Sugarcane Industry Association (UNICA) 2014. "Sugarcane Harvest Reports" various years. Online at http://www.unicadata.com.br/index.php?idioma=2. [Accessed February through May, 2014.]

Chicago Board of Trade. "CBOT Ethanol Futures – Corn Crush Reference Guide." Online. Online at http://www.cbot.com/cbot/docs/73511.pdf. [Accessed March 2007.]

CME Group. "Unparalleled Opportunities." Online at http://www.cmegroup.com/international/files/CME103_UpdatedBro_BMF.pdf. [Accessed May 2014.]

CEPEA. 2014. (Center for Advanced Studies on Applied Economics). Ethanol Prices. Online at http://cepea.esalq.usp.br/english/ethanol/. [Accessed March 1, 2014.]

Chang, C., M. McAleer, and R. Tansuchat. 2011. "Crude oil hedging strategies using dynamic multivariate GARCH." *Energy Economics,* 33(5): 912–923

Dahlgran, R. A. 2010. "Ethanol Futures: Thin but Effective? —Why?" Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. Online at http://www.farmdoc.illinois.edu/nccc134. [Accessed March 2014.]

Dahlgran, R.A. 2000. "Cross-Hedging the Cottonseed Crush: A Case Study." *Agribusiness* 16:141-158.

Dahlgran, R.A. 2005. "Transaction Frequency and Hedging in Commodity Processing." *Journal of Agricultural and Resource Economics* 30:411-430.

Dahlgran, R. A. 2009. "Inventory and Transformation Hedging Effectiveness in Corn Crushing." *Journal of Agricultural and Resource Economics,* 34(1): 154-171.

Ederington, L.H. 1979. "The Hedging Performance of the New Futures Markets." *Journal of Finance* 34:157-170.

Eidman, V. R. 2007. “Economic Parameters for Corn Ethanol and Biodiesel Production.” *Journal of Agricultural and Applied Economics* 39:345-356.

Fackler, P.L., and K.P. McNew. 1993. “Multiproduct Hedging: Theory, Estimation, and an Application.” *Review of Agricultural Economics* 15:521-535.

Fan, G. 2007. “Brazil New Ethanol Futures Sees Lukewarm Start”. MarketWatch, The Wall Street Journal. May 18, 2007. Online at http://www.marketwatch.com/story/brazil-new-ethanol-futures-contract-sees-lukewarm-start. Accessed May 30, 2014.

Farina, E., C. Viegas, P. Pereda, and C. Garcia. 2011. “Ethanol Market and Competition.” Pp 229-258 in *Ethanol and Bioelectricity: Sugarcane in the Future of the Energy Matrix* / [coordination and supervision Eduardo L. Leão de Sousa e Isaias de Carvalho Macedo ; English translation Brian Nicholson], São Paulo, UNICA, 2011. Online at http://www.unica.com.br/files/publications/, and http://sugarcane.org/resource-library/books/Ethanol%20Market%20and%20Competition.pdf. [Accessed May 2014]

Garcia, P., J.S. Roh, and R.M. Leuthold. 1995. “Simultaneously Determined, Time-Varying Hedge Ratios in the Soybean Complex.” *Applied Economics* 27:1127-1134.

Hill, J., and T. Schneeweis. 1981. "A Note on the Hedging Effectiveness of Foreign Currency Futures." *Journal of Futures Markets* 1(no. 4): 659-664.

International Centre for Trade and Sustainable Development. 2010. “Brazil Scraps Ethanol Tariff as US Considers Extending its Own.” April 30, 2010. Online at http://www.ictsd.org/bridges-news/biores/news/brazil-scraps-ethanol-tariff-as-us-considers-extending-its-own. [Accessed May 30, 2014.]

Jelmayer, R. 2011. “Brazil Wants Petrobras to Weigh in on Ethanol.” Wall Street Journal, April 8, 2011. Online at http://online.wsj.com/news/articles/SB10001424052748704415104576250742298954426?KEYWORDS=ROGERIO+JELMAYER&mg=reno64-wsj. [Accessed March 2014.]

Jin, H.J., and W.W. Koo. 2006. “Offshore hedging strategy of Japan-based wheat traders under multiple sources of risk and hedging costs.” Journal of International Money and Finance, 25(2):220–236.

Johnson, L.L. 1960. “The Theory of Hedging and Speculation in Commodity Futures.” *Review of Economic Studies* 27:131-159.

Kenyon, D., and J. Clay. 1987. "Analysis of Profit Margin Hedging Strategies for Hog Producers." *Journal of Futures Markets* 7:183-202.

Kroner, K.F., and J. Sultan. 1993. "Time-varying Distributions and Dynamic Hedging with Foreign Currency Futures." *Journal of Financial and Quantitative Analysis* 28(4): 535-551.

Liu, J. 2014. The Performance of U.S. Futures markets in Hedging Internaitonal Crude Oil. Unpublished Master's Thesis. University of Arizona.

Markets.wiki.com. "Ethanol Derivatives". Online at http://www.marketswiki.com/mwiki/Ethanol_Derivatives#cite_note-0. [Accessed May 30, 2014].

Federal Reserve Bank of New York. 2014. Brazilian Real Noon Buying Rates. Available at http://www.ny.frb.org/markets/fxrates/historical/home.cfm. [Accessed March 1, 2014].

Orwel, G. 2011. "CME Group Mulls Launch of Brazil Ethanol Contract." DTN, The Progressinve Farmer, September20, 2011. Online at http://www.dtnprogressivefarmer.com/dtnag/common/link.do?symbolicName=/ag/blogs/template1&blogHandle=ethanol&blogEntryId=8a82c0bc31d5e6e30132885f60f40752. [Accessed May 30.]

Phaneuf, E. 2007. "US, Brazil Ethanol Industry Comparison-The Economics, History, & Politics Behind it All." *University of Arkansas, Fayetteville, Arkansas*. Online at http://www.emilephaneuf.com/US-Brazil_Ethanol_Industry_Comparison---Emile_%20Phaneuf.pdf. [Accessed March 15, 2014.]

Quandl.com. 2014. Brazilian Real Futures Prices, March, June, September and December Maturities. Online at http://www.quandl.com/futures/brazilian-real-futures. [Accessed March 1, 2014.]

Rahman, S.M., S.C. Turner, and E.F. Costa. 2001. "Cross-Hedging Cottonseed Meal." *Journal of Agribusiness* 19:163-171.

Barchart.com. 2014. U.S. Ethanol Futures Prices. Online at http://acs.barchart.com/. [Accessed March 1, 2014.]

Shafer, C.E., W.L Griffin, and L.D. Johnson 1978. "Integrated Cattle Feeding Hedging Strategies, 1972-1976." *Southern Journal of Agricultural Economics* 10(1978):35-42.

Shapouri, H., J. A. Duffield, and M. Wang. 2002. "The Energy Balance of Corn Ethanol: An Update." U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses. Agricultural Economic Report No. 814. Washington, DC, 2002. Online. Available at http://www.usda.gov/oce/reports/energy/aer-814.pdf. [Accessed March 2007.]

Thompson, S.R., and .G.E. Bond. 1987. Offshore Commodity Hedging under Floating Exchange Rates Am. J. Agr. Econ. 69 (1): 46-55.

Tzang, D., and R.M. Leuthold. 1990. "Hedge Ratios under Inherent Risk Reduction in a Commodity Complex." *Journal of Futures Markets* 10:497-504.

Stein, J.J. 1961. “The Simultaneous Determination of Spot and Futures Prices.” *American Economic Review* 51:1012-1025.

Franken, J. R. V., and J. L. Parcell. 2003. “Cash Ethanol Cross Hedging Opportunities.” Journal of Agricultural and Applied Economics, 35:509-516.

Wall Street Journal. “Review and Outlook -- Ethanol in Winter.” January 3, 2012. Online at http://online.wsj.com/news/articles/SB10001424052970204720204577126920356709682?KEYWORDS=brazil+ethanol+tariff&mg=reno64-wsj. [Accessed May 2014.]

Won-Cheol Yun, Hyun Jae Kim. 2010. “Hedging strategy for crude oil trading and the factors influencing hedging effectiveness.” *Energy Policy,* 38(5): 2404–2408.