THE PERFORMANCE OF U.S. ETHANOL FUTURES MARKETS ON THE WORLD STAGE

ABSTRACT

This study examines the feasibility of Brazilian ethanol dealers using the U.S. ethanol futures contracts 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's 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 in which 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.

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1 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, 1979), is widely seen as benefiting producers, processors, brokers, inventory holders, 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 way, hedging in foreign currency futures markets offers international bankers and corporate treasurers protection from exchange rate risk as they convert funds between currencies (HILL; SCHNEEWEIS, 1981; KRONER; 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 have been done by Jin and Koo (2006) who examined the problem from the standpoint of a Japanese wheat importer; Thompson and Bond (1987) who examined the problem from the standpoint of an Australian wheat exporter; Chang, McAleer and Tansuchat (2011) and Yun and Kim (2010) who studied the problem from the perspectives of U.S.and Korean crude oil traders, respectively, dealing in the international crude oil markets. Dahlgran (2000) reported a similar problem for U.S. cottonseed crushers who had effective hedging opportunities using the Canadian rapeseed futures contract.

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 Real while the futures position is priced in U.S. dollars. Hedging proceeds must convert to Brazilian Real upon the hedge's closure. This scenario is of interest because the U.S. and Brazil are the largest and second largest ethanol producers in the world, respectively (Table 1). Brazil's ethanol futures market is small and young while the U.S. has a well-established ethanol futures market and together with the underlying ethanol swaps market provides an efficient market for the transfer of ethanol price risk. Given this situation, we ask the obvious question, "Can U.S. futures markets provide price risk management benefits to the Brazilian ethanol sector?"

To address this question, we (1) examine price and exchange rate risk for the Brazilian ethanol;(2) analyze the effectiveness of hedging Brazilian ethanol with U.S. ethanol futures and US dollar/real futures contracts; and (3) compare the effectiveness of our Brazilian ethanol hedges with similar hedges in U.S. crude oil futures.

This paper proceeds as follows. The next section surveys the related literature. The third section outlines the methodology and data, followed by the results and discussion section. The last section expresses the summary and conclusions.

2 LITERATURE REVIEW

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 (Table 1). 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., 2011), depending on the relative price of the two products.

[1]The CBOT *Ethanol Futures Corn Crush Reference Guide* (CHICAGO BOARD OF TRADE, 2007) 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.

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/ Website (RENEWABLE FUELS ASSOCIATION, 2013).
b/ Website (CHICAGO BOARD OF TRADE, 2007).
c/ Website (CME GROUP, 2014b).
d/ Website (BM&F BOVESPA, 2014).

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, 2007). 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 by both exporting to Caribbean countries. Brazil removed its tariff in April of 2010 (INTERNATIONAL CENTRE FOR TRADE AND SUSTAINABLE DEVELOPMENT - ICTSD, 2010). The U.S. removed its 2.5 percent ad valorem tax plus and \$0.54/gallon tariff on January 1, 2012 (ICTSD, 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 (FACKLER; MCNEW, 1993). 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 (MARKETS.WIKI.COM, 2014). Volume and open interest in this contract dwindled until a revamping U.S. dollar-priced contract was launched on May 18, 2007 (FAN, 2007). This revamping contract also shifted the delivery point from Paulina to the main Port of Santos.

On May 8th, 2008, the BM&F merged with the São 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 28th, 2013, with the addition of the anhydrous fuel ethanol contract. This contract is for physical delivery in the 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 a 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, 2011; ORWEL, 2011), but current involvement of U.S. exchanges in Brazilian ethanol trading is limited to shared order routing through the CME Globex system (CME GROUP, 2014a). 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. It also identifies factors that suggest that these hedges may not be effective. The importance of each of these factors in the hedging outcome is the empirical question that this study addresses.

3 METHODOLOGY AND DATA

Brazilian ethanol production is unique in that sugar can be either a final product or an intermediate product that serves as an ethanol-production input. Furthermore, ethanol and sugar prices influence the balance of final-product sugar versus intermediate-product sugar going into ethanol. A constant elasticity of transformation regression model for ethanol and sugar production is used to represent this tradeoff.

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

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

Data from various sources was used to test the notion of mixed adjusted outputs. Semimonthly (24 observations per year) sugar and ethanol production data came from the Brazilian Sugarcane Industry Association Sugarcane Harvest Reports from 2008/09 to 2012/13 (5 crop years plus a few trailing months) (UNIÃO DA INDÚSTRIA DA CANA-DE-AÇÚCAR - UNICA, 2014). These reports contain production data for three regions: São Paulo state, the South Central Region (excluding São 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.

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

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

Sugarcane crushing varies cyclically through the crop year. At the beginning and end of each crop year, sugarcane crushing is small compared 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. In order to correct this variability, the regression was weighted by the quantity of sugarcane crushed in the region and period. The regional effects were insignificant with a probability of a larger F for H_0: $\alpha_1 = \alpha_2 = \alpha_3$ of 0.993 and the probability of a larger F for H_0: $\psi_1 = \psi_2 = \psi_3$ of 0.681. On the other hand, 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. Subject to these preliminary results, (2) it was estimated as

$$ln\left(\frac{y_{ijk}^{s}}{y_{ijk}^{e}}\right) = \hat{\alpha} + \widehat{\delta_k} + 0.2023 ln\left(\frac{p_{ijk}^{s}}{p_{ijk}^{e}}\right)$$

N = 350, dfe = 325, R^2 = 0.456
(0.05973)
Prob(> F) < 0.0001

where the standard error is in parenthesis. This indicates a statistically significant response in the output mix of the Brazilian sugar sector where the production of end-product sugar relative to ethanol is positively influenced by the sugar price relative to the ethanol price.

We represent the final-product sugar/ethanol tradeoff as follows. Let y_s^* represent potential sugar production from a quantity of sugar cane (y_c) according to the production relationship $y_s^* = f(y_c)$. Intermediate-product sugar (y_s^e) is used to produce ethanol (y_e) so the sugar that remains in end-product form (y_s) is $y_s = y_s^*\ y_s^e$. Ethanol production derives from intermediate-product sugar so $y_e = g(y_s^e)$. Hence, $y_e = g(y_s^* - y_s) = g(f(y_c) - y_s)$. Normalizing this relationship to express ethanol output per unit of cane input gives $y_e / y_c = g(f(1) - y_s / y_c)$. A linear regression model of this relationship is $y_e / y_c = \alpha - \beta (y_s / y_c)$. Adding regional and seasonal effects give $(y_{ijk}^e / y_{ijk}^c) = \alpha_i + \delta_j - \beta_i (y_{ijk}^s / y_{ijk}^c) + \varepsilon_{ijk}$. After correcting for heteroscedasticity and retaining group-wise significant effects, the following result can be expressed

$$\left(\frac{y_{ijk}^{e}}{y_{ijk}^{c}}\right) = \widehat{\delta_j} - 0.358\left(\frac{y_{1jk}^{s}}{y_{1jk}^{c}}\right) - 0.341\left(\frac{y_{2jk}^{s}}{y_{2jk}^{c}}\right) - 0.302\left(\frac{y_{3jk}^{s}}{y_{3jk}^{c}}\right)$$

(0.0331) (0.0358) (0.0428)

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

The estimates of the ethanol-sugar production tradeoff are expected to have a negative sign and are significant. The tradeoff displays statistically significant regional variability as 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. In summary, these results indicate that the adjustment of Brazilian ethanol refining to sugar prices will likely diminish Brazilian and the U.S. ethanol market integration as this adjustment does not occur in U.S. ethanol refining.

3.1 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, 1960; STEIN, 1961). The profit outcome (π) of these combined positions is

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

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

$$\frac{x_f^*}{x_s} = \frac{-\sigma_{\Delta p,\Delta s}}{\sigma_{\Delta f}^2}$$

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

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

where Δ represents the difference of the hedging horizon, e_t represents the stochastic error at time t, and T represents the number of observations used for estimating 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) represent k length vectors and hedge ratios are estimated by fitting the multiple regression

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

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

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

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

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

This specification has been applied to soybean processing (DAHLGRAN, 2005; FACKLER; MCNEW, 1993; GARCIA; ROH; LEUTHOLD, 1995; TZANG; LEUTHOLD, 1990); cattle feeding (SHAFER; GRIFFIN; JOHNSON, 1978); hog feeding (KENYON; CLAY, 1987); cottonseed crushing (DAHLGRAN, 2000; RAHMAN; TURNER; COSTA, 2001); and U.S. ethanol refining (DAHLGRAN, 2009).

Ederington (1979)defines hedging effectiveness (e) as the proportionate price-risk reduction available through hedging, or

$$e = \left[V(\pi u) - V(\pi h) \right] / V(\pi u) \quad (5)$$

where V is the variance operator, p_u the agent's unhedged outcome ($x_f = 0$) and p_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, P represents the spot price of Brazilian ethanol (in reals per liter), F represents the U.S. ethanol futures price (in dollars per gallon), R represents the spot exchange rate in dollars/real and R^{-1} represents the spot exchange rate in reals/dollar.

A single-currency portfolio return requires either converting the U.S. futures price to reals (*i.e.,* $\Delta f^{reals} = F_1(R^{-1})_1 - F_0(R^{-1})_0 = \Delta F\, \Delta R^{-1} + (R^{1})_0\, \Delta F + F_0 \Delta R^{-1}$) or converting the spot price from reals to U.S. dollars (*i.e.,* $\Delta p = P_1 R_1 - P_0 R_0 = \Delta P \Delta R + R_0 \Delta P + P_0\, \Delta R$). 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, $R_0 C(DP,\Delta F) / V(\Delta F)$, 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 changes 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.

The above considerations can be expressed together, in a hedge ratio estimation model, as

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

where all terms were previously defined except h which represents the hedge horizon, and F_t represents 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.

3.2 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 used the CEPEA anhydrous fuel ethanol price, quoted weekly in U.S. dollars per liter. These data are available from February 21, 2000 to March 1, 2014 (CENTRO DE ESTUDOS AVANÇADOS DE ECONOMIA APLICADA - CEPEA, 2014).

For the Brazilian real spot price, we used noon buying rates from the New York Federal Reserve Bank quoted daily in reals/dollar from February 22, 1995 to March 1, 2014 (FEDERAL RESERVE BANK OF NEW YORK, 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 (2014). 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 also came from Barchart. 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 (2014). Qaundl provides the corresponding data for the March, June, September and December maturities from December 1, 1995 to the present.

We used 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 used the next nearby maturity. This one-week maturity buffer avoids potential price volatility to increase at contract maturity.

We treated the weekly average spot price as the midweek value and match this price with the corresponding Wednesday futures prices since it 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 did 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 contract maturities provides a more accurate depiction of hedging opportunities during our sample period.

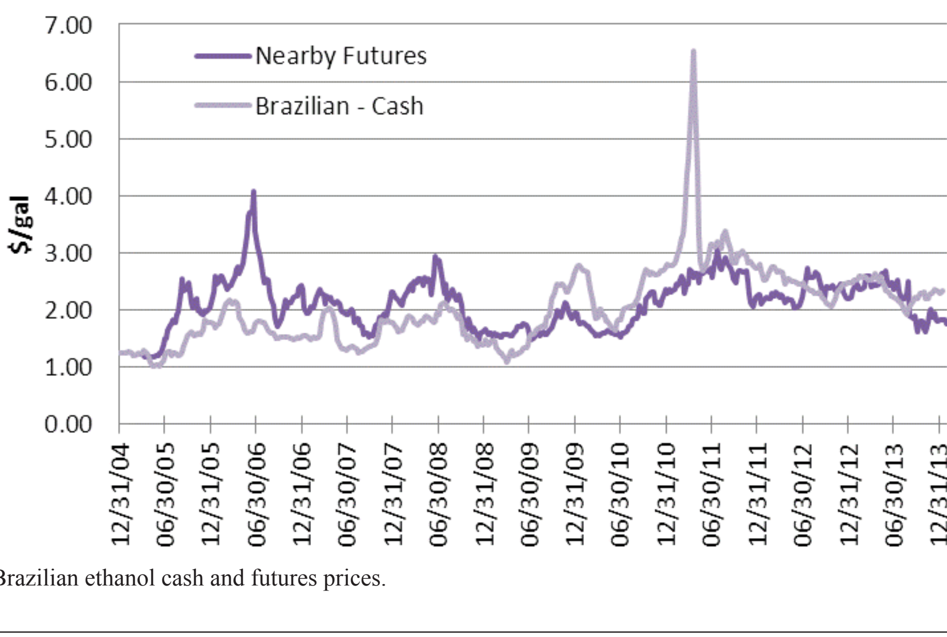

FIGURE 1 – Brazilian ethanol cash and futures prices.

By considering data sources and data characteristics, the empirical model becomes

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

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

4 RESULTS AND DISCUSSION

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 dummied observations are included under a one-week hedge horizon. Regardless of the hedge horizons, 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 ratio 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. The significance of serial correlation decreases as the hedge horizon increases. Table 2 shows the t-value for serial correlation decreasing from -11.66 to -0.01 for a four week horizon then becoming positive and slightly significant 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 hypothesis). The F statistic for testing the null against the alternative is

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

TABLE 2 – Hedge ratios and hedge effectiveness for hedging Brazilian ethanol inventories in the U.S. ethanol futures market, from March 24, 2005 to December 31, 2013.

Intercept	0.000	(0.09)	0.000	(0.07)	-0.002	(-0.42)	-0.005	(-0.67)	-0.008	(-0.70)
D3/23/11	0.202	(14.96)***								
D3/30/11	0.246	(11.33)***	0.264	(12.06)***	0.402	(11.03)***				
D4/06/11	0.350	(13.10)***								
D4/13/11	0.572	(20.22)***	0.597	(21.27)***						
D4/20/11	0.736	(27.62)***								
D4/27/11	0.536	(24.63)***	0.564	(25.43)***	0.730	(19.87)***	0.664	(12.25)***		
D5/04/11	0.236	(17.49)***								
ΔFreal	0.648	(11.68)***	0.716	(5.78)***	0.891	(4.26)***	1.073	(3.76)***	0.892	(2.70)**
ΔFethanol	-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%.

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

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

Rearrangement of (8a) gives

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

This relationship is used to compute the effectiveness statistic reported in Table 2. Hedging effectiveness is significantly different from 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 increase of 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. A major finding (Table 2) is that a significant risk protection was afforded by the Brazilian ethanol inventory-holders 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 on 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. Effectiveness is largely due 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 wonder whether these results are universal and applied to many commodities or they are unique to hedging Brazilian ethanol in U.S. ethanol futures markets. To address this matter, a similar analysisby Liu examined the use of U.S. crude oil futures markets to hedge international crude oil inventories (LIU, 2014). Table 4 summarizes these results.

Liu assumed that 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 on November 1, 1995, Mar 29, 2006, and July 17, 2000 and all series end on 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

TABLE 3 – Hedge ratios and hedge effectiveness for hedging Brazilian ethanol inventories in the U.S. ethanol futures market, from January 1, 2012 to December 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)	
ΔFreal	0.500	(3.52)***	0.771	(2.76)**	0.443	(1.14)	0.682	(1.69)	
ΔFethanol	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	$R_0DP = \alpha + \Delta F_{oil}b_{oil}$	0.68***	0.75***	0.88***
	$DS = \alpha + \Delta F_{oil}b_{oil} + \Delta F_R b_R$	0.80***	0.82***	0.91***
	N	346	85	26
Mexico	$R_0DP = \alpha + \Delta F_{oil}b_{oil}$	0.80***	0.82***	0.77***
	$DS = \alpha + \Delta F_{oil}b_{oil} + \Delta F_R b_R$	0.87***	0.90***	0.86***
	N	644	160	53
Australia	$R_0DP = \alpha + \Delta F_{oil}b_{oil}$	0.43***	0.85***	0.82***
	$DS = \alpha + \Delta F_{oil}b_{oil} + \Delta F_R b_R$	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%.

rate, with only the crude oil futures contract (i.e., R_0DP), 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 4 indicates that hedge effectiveness generally increases as the hedge horizon increases. This is consistent with the ethanol hedging results. One striking result in Table 4 is that the commodity hedge generates most of the hedging effectiveness (comparing 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 results which most of the hedging effectiveness derives from the currency hedge.

5 SUMMARY AND CONCLUSIONS

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 can work as well as reasons why it might 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 effectiveness increments. 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, we conclude that 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 offered by the U.S. This BM&F BOLESPA Brazilian contract will likely provide better hedging opportunities for Brazilian producers and will likely succeed for this reason. The hedging performance of the Brazilian contract merits further study.

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