Integration and hedging efficiency between the Brazilian and the U.S. ethanol markets

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INTRODUCTION

The growing importance of energy supply and the new environmental policies created to reduce GHG emissions have introduced relevant issues in the applied agricultural economics literature. Biofuels markets have stimulated important debates, in particular ethanol, where Brazil and the U.S. play important roles, since they are the largest world producers (EPA, 2016).

The development and the importance of the ethanol production in Brazil and in the U.S. have emerged in different periods and for different reasons. In Brazil, the sugarcane-based ethanol production started in the 1970's aiming to reduce the dependence from international oil prices. More recently, the ethanol production in the country has been driven by the dominant flex-fuel vehicle fleet, and by the market regulation that imposes a mandate to blend anhydrous ethanol with gasoline. In the U.S., the corn-based ethanol production was consolidated only after federal mandates determined a minimum production of anhydrous ethanol in the country. The development and availability of technologies that enable the flexible uses of theses crops, contribute partly to rises global-market volatility, creating new price drives for these markets (Borras et al., 2016).

Regardless the origin, and the use of different inputs (either sugarcane or corn), the production and the consumption expansion in both countries, which were also driven by local mandates and/or market (de)regulation, have caused significant impact on local markets prices dynamics, and consequently in the price discovery process. Many studies have found that local market prices have reduced their correlation with an international price reference, and point out that different aspects have contributed to reduce local market integration with international prices, such as the world production concentration mostly in two countries, and the trade protectionisms (Zhang et al., 2009; Tyner, 2010; Kristoufek et al., 2016). Other local and specific issues may also influence the price discovery, such as local preferences between the use of biofuels and fossil fuels in vehicles; and different standardization in the ethanol pattern (Balcombe and Rapsomanikis, 2008; Dabrik et al., 2016; Rodrigues and Bacchi, 2016).

Agents who face prices risk should consider all the aforementioned differences between local and international markets when creating their marketing strategies, since they contribute to increase market volatility, and can determine different price patterns in each market (Borras, et al., 2016). In order to create different market strategies, different players can use the derivative markets to promote hedging opportunities, price discovery and financial stability to their economies (Lien and Zhang, 2008; Saxena and Villar, 2008). Even though the derivatives markets can contribute to a more efficient hedging strategy, in markets with low trading volume and liquidity, individual bids and asks can influence prices and bring more risk to the market. Markets with those characteristics are referred as thin markets (Adjemian, Saitone, Sexton, 2016), such as the ethanol futures markets in Brazil and in the U.S. The investigation of how the spot and futures markets in both countries are integrated is particularly relevant for those who use derivatives as risk management tools. Intuitively, the less integrated the markets, the lower the hedging efficiency. Therefore, the research questions we try to answer with this study are: Is there a reference market for ethanol prices that can guide hedging strategies? Are hedging strategies efficient in the Brazilian and in the U.S. ethanol markets? We try to answer these questions using local prices from relevant spot markets in both countries, and futures prices from three futures exchanges.

Our main objectives are: (i) to investigate if the Brazilian and the U.S. prices are cointegrated, assessing their short and long run relationships, as well as the causality effects simulated by simulated shocks; and (ii) to identify which futures contract is the most efficient to hedge prices by different agents.

We use traditional time series methods to investigate prices short and long run relationships. The methodological approach includes Johansen cointegration analysis and the estimation of a Structural Vector Auto-Regressive Model with errors correction (SVEC). We also analyze impulse-response functions, as proposed by Sims (1986) and Bernanke (1986). In order to test for hedging efficiency in foreign markets we estimate the minimum variance hedge ratio using OLS regressions based in the model developed by Nayak and Turvey (2000), which accounts for simultaneously hedging using the ethanol and exchange rate futures contracts.

Our data set consists of daily cash ethanol prices in the main producing areas of both countries (i.e. Sao Paulo, Brazil; Mid-West, U.S.), as well as international reference prices for feedstock or substitute goods. Therefore, we estimate an autoregressive model that also includes sugar, corn and oil prices to assess the determinants of ethanol prices. Balcombe and Rapsomanikis (2008) and Kristoufek (2016) used similar procedures in their analysis, but using different econometric models. The dataset covers the period from January 2010 through December 2016. For the hedging efficiency analysis, we use daily ethanol cash prices in both countries, and ethanol futures prices from three different futures exchanges (CME, NYMEX and BMFBOVESPA), for the same period (2010-2016). We also use the exchange rate BRL/USD in the simultaneous hedge model.

Our primary hypothesis is that several recently events in the U.S. and Brazil markets (such as crop seasonality, harvest shortfall and government intervention) have guided individually their domestic prices dynamics. The need to execute the Federal mandate and the establishment of a new industry in the U.S. have incurred into a fast ethanol production increasing. In addition, climate effects, as the drought in 2012, affected domestic corn production and stocks, influencing ethanol local prices and imports. In Brazil, the recent federal government intervention on gasoline prices limited the ethanol expansion, reducing the industry margins. In addition, climate effects in South Brazil had negatively influenced sugarcane yield and reduced ethanol supply. These joint issues can explain the low connection between both markets and may affect international price dynamics, as well as the hedge efficiency.

ETHANOL MARKET INTEGRATION

Brazil is a traditional producer and consumer of biofuels, mostly ethanol derived from the world's largest sugarcane producer. In addition, ethanol consumption have intensified after the introduction of flex-fuel vehicles in 2003, since the biofuel works as a close substitute for gasoline. On the supply side, the decisions regarding ethanol production are made considering the domestic sugarcane and international sugar prices and traded volumes. The gasoline and oil prices also influence the fluctuations of ethanol prices and production in the country.

The historical leadership of Brazil in the ethanol production was recently taken by the U.S., which became the largest biofuel producer in the world, sharing with Brazil a significant part of international ethanol production. In addition, the U.S. production is mostly designated for blending with gasoline in low volume, varying from 5% to 15%. The implication of the large anhydrous ethanol production is the close linkage with fuels markets. Consequently, variations in gasoline, oil and other fossil fuel prices can directly affect ethanol prices and production.

Few studies have recently explored price and volatility transmission of biofuels in the international market level. Regionally, a significant number of studies have been developing in the past years to study the dynamics of biofuels prices and their linkages to feedstock and fuel prices. Due to the importance of the U.S. and Brazil in the biofuel international market, most of the recent studies focused their analysis only on domestic price dynamics.

Balcombe and Rapsomanikis (2008) applied a study to the Brazilian biofuel market, investigating the long-term connection between ethanol, sugar and oil prices. Their findings pointed out to the importance of oil prices determining ethanol and sugar prices, as well as the causality from sugar prices to domestic ethanol prices. The authors suggest that biofuels do not seem to have any significant impact on commodities prices in this market.

Other studies also assessed the long run relationship between ethanol, sugar, sugarcane and gasoline prices in Brazil. Bentivolgio et al. (2016) explored the influences of Brazilian ethanol prices on sugar and gasoline prices using Granger causality tests in addition to a VECM model. Their study found evidences that ethanol prices have no effect on sugar nor gasoline prices. However, in the same study they found that gasoline prices drive ethanol prices in Brazil in the short and long-run.

Chen and Saghaian (2015) investigated the price linkage of the Brazilian ethanol and sugar prices with international oil prices, using data from 2003 to 2014. First, their study tested structural breaks points to determine the period when the three commodities prices established a common linkage. Thereafter, using a cointegration test and a VEC model estimation they could not find a long run relationship between prices. In addition, sugar prices drive more ethanol prices than the opposite, while oil prices were not relevant to explain sugar nor ethanol prices.

In another study, Zhang et al. (2009) investigated the high volatility of ethanol and food prices in 2008-2009, testing for the connection among fuels, biofuels and grain prices in the U.S. Their study used a VECM to assess the price relationships, and a MGARCH model to forecast prices volatilities. Their findings pointed out to a greater influence of gasoline on oil and ethanol prices, and the absence of a long run relationship among fuel (gasoline, oil and ethanol) prices and grain (soybeans and corn) prices.

Serra et al. (2011) used a VECM to evaluate the connections of corn, ethanol, gasoline and oil prices in the U.S., during the period of 2000-2008. Differently for other studies, they found that prices were cointegrated. Specifically, their results suggest that ethanol prices were guided by variations on gasoline and corn prices. Merkusheva and Rapsonamanikis (2014) analyzed the price linkage of ethanol, oil, and other grains in the U.S. market, indicating that oil prices guide all other prices. However, they suggest a different interpretation to the short-run analysis between fuel and grain markets, i.e., they did not find evidence that prices had a causality effect on each other.

Other previous developed studies have also estimated time series models to verify linkages among ethanol, fuels and commodities prices, especially focusing on the e impacts of biofuels on commodities prices. Serra et al. (2013) structured a critical literature review of several recent studies, exploring different methodology approaches. The authors concluded that both partial equilibrium and time series models have been used in the literature, and have obtained similar results. Similarly, Tyner (2010) explored the links between energy and agricultural markets since the boom of commodities prices in the U.S. The author highlighted the possible association of the corn ethanol industry increase to the establishment of federal mandates to the ethanol production.

Even though there are various studies in the area, there is a lack of studies that investigate prices in different markets simultaneously. Vacha et al. (2015) employed a wavelet coherent analysis to examine price relationships between biofuels and feedstock prices (especially grains) in the international level, pointing to a strong effect of corn in the formation of ethanol prices. Using a similar procedure, Kristoufek et al. (2016) identified price connections between ethanol and sugar, and ethanol and corn in Brazil and in the U.S. The authors found that both markets seem to have similar behavior in their ethanol markets, i.e., the feedstock or substitute prices were driving ethanol prices. In addition, Tokgoz and Elobeid (2006) also investigated price dynamics of sugar and ethanol in Brazil, and corn and ethanol in the U.S., including gasoline prices in their analysis. Their results suggest a strong causality of gasoline prices on ethanol prices. They also found a linkage between feedstock and ethanol prices, but in different ways, once ethanol production increases with an increase in sugar prices in Brazil. In the U.S., on the other hand, an increase in corn prices decreases the ethanol production.

Considering the relative small number of studies trying to understand price linkages in the ethanol international market, this research aims to bring new insights to the literature. First, with the analysis of the domestic causality effects of ethanol, feedstock and oil prices. Second, evaluating ethanol market integration between U.S. and Brazil. At last, including to the current literature, the analysis of the hedging effectiveness using futures contracts in both countries.

RESEARCH METHOD

We divide our empirical analysis into three different steps. First, we evaluate the regional dynamics of ethanol prices testing for prices cointegration, and causality effect in the U.S. and Brazilian domestic markets. Second, we investigate ethanol prices integration between the Brazilian and the U.S. markets. At last, we investigate the hedge effectiveness of ethanol futures contracts, in different futures exchanges.

Market integration methodological approach

We use traditional time series approaches to identify market integration between spot and future markets in Brazil and in the U.S. We use a cointegration test to identify the presence of a long-run relationship among prices (integration) and the vector error correction model (VECM) to verify how prices adjust from deviations to the equilibrium in the short run.

If all prices in the model are non-stationary, with the same integration order, we test the existence of long-run relationship among prices using the well-known Johansen multivariate test. If we find at least one cointegration relationship, we assume the different markets are integrated. The number of cointegration relationships can be determined after estimating the model in equation 1:

$$\Delta P_t = A_0 + \Pi P_{t-1} + \sum_{i=1}^{k-1} \Pi_i \Delta P_{t-i} + \varepsilon_t \quad (1)$$

Where $\mathbf{A_0}$ is a vector containing the intercept, and ΔP_t is a $(n \times 1)$ vector of the first difference of prices. The $(n \times n)$ matrix $\mathbf{\Pi}$, can be written as $\mathbf{\Pi} = \alpha\beta'$, where α and β are $(n \times r)$ matrices containing the speed of adjustment parameters and the cointegrating vectors, respectively. The matrix $\mathbf{\Pi_i}$ contains all the parameters estimated to represent the impact of lagged variables in the system, and $\boldsymbol{\varepsilon_t}$ is a vector of random error terms (Lutkepohl, 2006).

According to Enders (2005), when the model presented in (1) is estimated using the maximum likelihood method, the rank of $\mathbf{\Pi}$ is determined. Two different test statistics (trace and eigenvalue) are used to test the null hypothesis of rank $\mathbf{\Pi} = 0$. If the null hypothesis cannot be rejected, the prices are not cointegrated and there is no integration among the markets. On the other hand, if the null hypothesis is rejected, a sequential test is conducted to determine the number of cointegrating relationships.

Once we find the markets to be integrated, we can use the matrix $\mathbf{\Pi}$ to investigate the long-run dynamics of prices, and how they adjust to deviations towards the equilibrium. The Vector Error Correction Model (VECM) can then be used, since it not only allows estimating the adjustment back to the equilibrium, but it also allows testing for causality, and to determine the impact of shocks to different prices using impulse response functions.

For this reason, we use the Structural VECM, an alternative decomposition of VECM, which consists in a system of simultaneous equations that enables us to obtain the dependency relationships between the variables. Furthermore, this method can provide well-fitted variance decomposition of forecast errors, as well as shocks estimations through the impulse response function from a structured contemporaneous relations matrix, as proposed by Sims (1986) and Bernanke (1986).

The impulse-response functions provide the forecast of impulse elasticities for *k* periods ahead. The elasticities obtained from this functions represent the prices behavior under individuals' shocks in one variable based on their past and current errors. The impulse-response functions also allow forecasting paths of simultaneous shocks using the system of variables. The variance decomposition of predictable errors helps to understand how much one price variance can be explained by the variance of other prices, showing the evolution of their dynamics behavior. It also allows to sort out the predictable errors that can be explained by the own variable as well by others (Enders, 2005). In addition, the Structural VECM estimation shows the contemporaneous relationship of the variables system, which indicates the number of matrix restrictions, regarding the economic theory and the restriction of maximum number of contemporaneous restrictions (Hamilton, 1994). The structural VECM consist on a structural VAR with errors correction. The SVAR is expressed by the following equation:

$$B_{0xt} = B_{1\,xt-1} + B_{2\,xt-2} + \cdots + B_{p\,xt-p} + e_t \qquad (2)$$

Where $\mathbf{x_t}$ is the vector of prices in the system; $\mathbf{B_j}$ are the matrices (*n x n*) for each j and $\mathbf{B_0}$ is the matrix of contemporaneous relationship; $\mathbf{e_t}$ is a vector *n x 1* of orthogonal shocks where the components are not serially correlated.

Additionally, we implement Granger causality tests using bivariate vector autoregressions to determine if lagged information in one specific price set provides any statistically significant information to another price set. If not, we conclude that the first price set does not Granger-cause the second. Once we have the results of all pairwise causality tests, we can have a better understand of how the different markets in Brazil and in the U.S. are related. Therefore, these results can help building a more appropriate sequence of shocks when implementing the impulse response functions.

This type of comparison can give us a better knowledge of how the ethanol markets are integrated in both countries, and how these markets are related in the long and short-run. In addition, the analysis in the regional levels can provide insights about the local spot prices interactions.

Hedge effectiveness

In this section we focus on the estimation of the optimal hedge ratio, based on the model proposed by Nayak and Turvey (2000). According to this model, a producer sells the commodity in the cash local market, while hedging the commodity price using a foreign futures contract and simultaneously hedging the currency. Using the mean-variance framework, the model can be written as follow:

$$\boldsymbol{HR = R + h(F_1 - f_2)e_r + gM(Q_1 - q_2)e_r + c(E_1 - e_2)}$$

(3)

Where, *HR* is the hedged revenue; *R* is the spot revenue at the end of the period; *h* and *c* are the positions of price futures market and the currency (exchange rate) futures market, respectively; F_1 e f_2 are the futures prices at the beginning and at the end of the period, respectively; E_1 e e_2 are the futures exchange rate at the beginning and at the end of the period, respectively; e_r represents the spot exchange rate at the end of the period; *G*, *M*, Q_1 e q_2 refer to the positions and prices for the crop yield futures contracts, not evaluated in the present study.

The primary approach of the income hedging of Nayak and Turvey (2000) implemented the perspective of simultaneous price and exchange rate hedging (HS):

$$\boldsymbol{HS = R + hfe_R + ce}$$

(4)

Where, for simplification, $f = F_1 - f_2$ and $e = E_1 - e_2$.

We can therefore represent the variance of equation (4) as:

$$\boldsymbol{\sigma_{HS}^2 = \sigma_R^2 + h^2\sigma_{fe_r}^2 + c^2\sigma_e^2 + 2h\sigma_{R,fe_r} + 2c\sigma_{R,e} + 2hc\sigma_{fe_r,e}} \quad (5)$$

Where the variances are given by $\sigma_R^2 = Var(R)$; $\sigma_{fe_r}^2 = Var(fe_r)$; $\sigma_e^2 = Var(e)$;

And the covariances are $\boldsymbol{\sigma_{R,fe_r} = Cov(R, fe_r)}$; $\boldsymbol{\sigma_{R,e} = Cov(R, e)}$ e $\boldsymbol{\sigma_{fe_r,e} = Cov(fe_r, e)}$.

Then, hedging decision is based on the minimum variance of the simultaneous hedge in relation to the futures price (*h*) and exchange rate (*c*) position, resulting in the first order conditions:

$$\frac{\partial \sigma_{HS}^2}{\partial h} = 2h\sigma_{fe_r}^2 + 2\sigma_{R,fe_r} + 2c\sigma_{fe_r,e} = 0$$
$$\frac{\partial \sigma_{HS}^2}{\partial c} = 2c\sigma_e^2 + 2\sigma_{R,e} + 2h\sigma_{fe_r,e} = 0 \quad (6)$$

Reordering the system of equations, we obtain:

$$h^* = \frac{1}{1-\rho_{fe_r,e}^2}\left(-\frac{\sigma_{R,fe_r}}{\sigma_{fe_r}^2} + \frac{\sigma_{R,e}\sigma_{fe_r,e}}{\sigma_{fe_r}^2\sigma_e^2}\right) \quad (7.1)$$

$$c^* = \frac{1}{1-\rho_{fe_r,e}^2}\left(-\frac{\sigma_{R,e}}{\sigma_e^2} + \frac{\sigma_{R,fe_r}\sigma_{fe_r,e}}{\sigma_{fe_r}^2\sigma_e^2}\right) \quad (7.2)$$

Where, h^* e c^* are respectively the positions of minimum risk in both the price and the currency futures markets; $\rho_{fe_r,e}^2 = \left(\frac{\sigma_{fe_r,e}}{\sigma_{fe_r}\sigma_e}\right)^2$ represents the squared correlation coefficient between the futures prices (expressed in local currency) and the futures exchange rate prices.

We can use the results of the minimization problem given in equations 7.1 and 7.2 to replace the optimal values in equation 3:

$$\left(\sigma_{HS}^{RM}\right)^2 = \sigma_R^2 + (h^*)^2\sigma_{fe_r}^2 + (c^*)^2\sigma_e^2 + 2h^*\sigma_{R,fe_r} + 2c^*\sigma_{R,e} + 2h^*c\sigma_{fe_r,e} \quad (8)$$

Therefore, the absolute risk reduction is given by the difference between the non-hedged revenue and the simultaneous hedged revenue.

$$RR_{HS} = \sigma_R^2 - \left(\sigma_{HS}^{RM}\right)^2 = \frac{1}{\theta\sigma_e^2}\left(\frac{\sigma_{R,fe_r}\sigma_{fe_r,e}}{\sigma_{fe_r}^2} - \sigma_{R,e}\right)^2 + \frac{\sigma_{R,fe_r}}{\sigma_{fe_r}^2} \quad (9.1)$$

Where, $\theta = 1 - \rho_{fe_r,e}^2$, and the other variables have already been specified.

We can evaluate the risk reduction obtained with the use of the futures price contract (only) in the hedged revenue if we assume that $\sigma_{R,e} = 0$ and $\sigma_{fe_r,e} = 0$.

$$RR_h = -\frac{\sigma_{R,fe_r}}{\sigma_{fe_r}^2} \quad (9.2)$$

Similarly, we can evaluate the risk reduction obtained with the use of exchange rate futures contracts (only) assuming that $\sigma_{R,fe_r} = 0$ e $\sigma_{fe_r,e} = 0$.

$$RR_c = -\frac{\sigma_{R,e}}{\sigma_e^2} \quad (9.3)$$

Equations 9.1 through 9.3, are the basis for the comparative analysis of three different hedging strategies: i) hedge prices only using commodity futures contracts; ii) hedge exchange rate only using currency futures contracts; iii) or the simultaneous hedge using both commodity futures prices and currency futures contracts.

DATA

The first part of the analysis consists on estimating models to investigate ethanol prices relationships and the linkage between the U.S. and the Brazilian markets. The dataset consists of daily cash prices for ethanol (USA and Brazil), corn (USA), sugar (Brazil) and oil (brent crude futures) for the period between January 2010 and December 2016. The U.S. cash ethanol and corn prices correspond to the average of the main producing regions in the Midwest, as well as the cash ethanol and sugar prices in Brazil, whose are referenced in the average price for Sao Paulo State (largest sugarcane producer in Brazil). All prices were treated in similar scale, i.e., corn and sugar were changed to USD/ton, and ethanol (both countries) and oil prices to USD/m^3. We also used the natural log of prices in our analysis.

The second step is the assessment of hedge effectiveness of cash ethanol with ethanol futures contracts in the Brazilian (BMFBovespa) and U.S. exchanges (CME and NYMEX). The cash ethanol prices in the both markets are the same included in the time series models described above. Futures prices in Brazil and USA are related with the hydrous ethanol futures prices (BMFBovespa), Ethanol Futures (CME/CBOT) and Chicago Ethanol (Platts) Futures (NYMEX). The data set comprises daily prices from January 2010 to December 2016, considering the first expiration day of each futures contract. For the simultaneous hedge analysis, we have also included the exchange rate futures contract at BMFBovespa (BRL/USD), considering the foreign futures contract operation by Brazilian hedgers[1].

RESULTS

[1] Given de low liquidity of BMFBovespa in comparison to the CME and NYMEX ethanol futures contracts, the simultaneous hedge of commodity and exchange rate futures contract is taken just in terms of the cash ethanol prices in Brazil with CME and NYMEX ethanol futures. In this sense, we do not apply the same procedure to U.S. cash ethanol prices in terms of BMFBovespa ethanol futures.

Before exploring the main findings from the time series models estimation, we present Figure 1 to illustrate historical ethanol, oil, corn and sugar prices in the U.S. and the Brazilian markets from 2010 to 2016. All prices seem to follow similar patterns, with the exception of oil prices, that show a significant decreasing between 2014-2016. Ethanol prices follow similar trend lines, but it seems that the Brazilian ethanol prices assume lower levels than the U.S. ethanol between 2012-2015. This pattern is probably a consequence of the federal domestic intervention in gasoline prices, establishing maximum baselines for the ethanol prices variation.

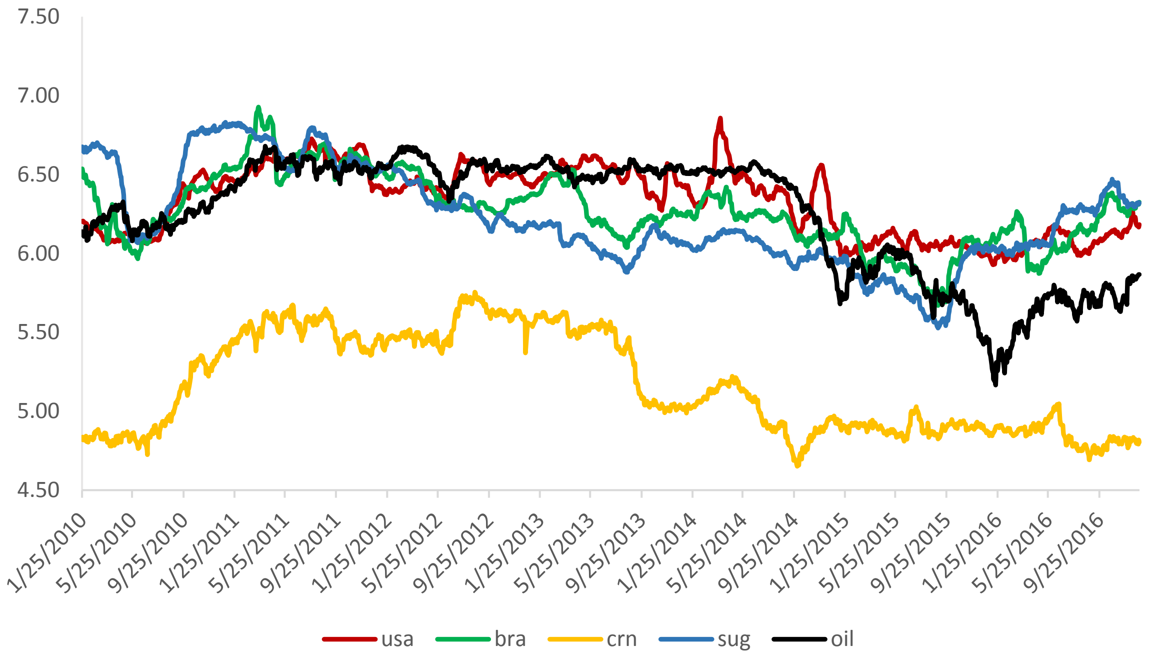

Figure 1 - Daily commodities prices (logarithmical scale), 2010-2016

Note: *usa* is the ln Price of U.S. ethanol (US$/$m^3$); *bra* is the ln Price of Brazilian ethanol (US$/$m^3$); *crn* is the ln Price of Corn in U.S. (US$/ton); *sug* is the ln Price of sugar in Brazil (US$/ton); *oil* is the ln brent crude oil futures prices (US$/$m^3$).

We used the augmented Dickey-Fuller (ADF) unit root test to check for stationarity. We found all log-prices series were nonstationary. All log-price series were found to be stationary after we run the same test in the first difference.

Since all log-price series were found to be I(1) process we used the Johansen cointegration test. The results the test revels the presence of cointegrating relations in a model including the intercept and no trend in the cointegrating equation. The results for a multiequation cointegration test with the inclusion of two lags pointed out to the presence of one cointegration vector, at the 1% significance level. To investigate the long-run relationship among the variables, as well as their particular short-run interactions, the VECM was estimated[2].

The Granger causality test for each pair of variables was used to identify how domestic prices are related. First, in the U.S. market, causality tests were applied between ethanol-corn prices and ethanol-oil prices. Table 1 shows that ethanol prices causes corn prices, but corn prices does not cause ethanol prices, suggesting that ethanol prices seem to lead feedstock prices[3].

Table 1 – Granger causality between commodities prices in Brazil and the U.S., 2010-2016

Null Hypothesis:	Lag	F-Statistic	Prob.
DBRSUG does not Granger Cause DBRETH	3	11.9503	0.0000*
DBRETH does not Granger Cause DBRSUG	3	0.50975	0.6756
DOIL does not Granger Cause DBRETH	3	4.02713	0.0072*
DBRETH does not Granger Cause DOIL	3	2.05987	0.1036
DUSCRN does not Granger Cause DUSETH	4	0.74858	0.5589
DUSETH does not Granger Cause DUSCRN	4	8.70966	0.0000*
DOIL does not Granger Cause DUSETH	3	4.29508	0.0050*
DUSETH does not Granger Cause DOIL	3	1.24977	0.2902
DUSA does not Granger Cause DBRA	5	1.34133	0.2440
DBRA does not Granger Cause DUSA	5	2.93503	0.0121**

* Statistically significant at 1% level; ** statistically significant at 5% level.

Note: *DUSETH, DBRETH, DUSCRN, DBRSUG*, indicates cash prices in the Δ1st difference of U.S. ethanol, Brazilian ethanol, U.S. corn, Brazilian sugar, respectively. *DOIL* is the 1st difference for international futures oil prices (brent).

According to the results in Table 1, ethanol prices seem to be caused by oil prices in the U.S. market, indicating that fossil fuels prices are relevant to explain the dynamics of biofuels prices. Similar results were found in the Brazilian market between oil and ethanol prices. In this case, ethanol prices are caused by oil prices. In addition, we found a causality relationship from sugar prices through ethanol prices, which means that the feedstock (substitute goods) are relevant in determining of ethanol prices in the Brazilian market. Lastly, the causality test for

[2] The results obtained by DFA unit root test and Johansen cointegration test are available upon request.
[3] This is not consistent with other studies, although can be relieved once this period witnessed a very significant raise of the U.S. ethanol production, as well as dramatic impact in the corn production and stocks after de 2013 drought in the Mid-West.

ethanol prices in both countries exhibit one direction, from Brazilian ethanol prices to the U.S. ethanol prices.

We then use a structural VECM to identify the short-run dynamics of prices. Basically, the structure of the SVECM was built simulating the influence of cash ethanol from Brazil to the U.S. prices, and vice-versa. We also investigate the relationships between corn and sugar prices in the U.S. and in Brazil, as well as the influence of oil prices on domestic ethanol prices. The variance decomposition of forecast errors for U.S. ethanol show evidences of the influence of several variables on prices, i.e., corn and oil prices can explain about 35% of ethanol prices in the U.S., while the Brazilian ethanol and sugar price influence close to 17% of U.S. ethanol market. Alternatively, the Brazilian ethanol prices are more independent, explaining almost 80% of its own price. Sugar prices (7.9%), U.S. ethanol prices (7.3%) and oil prices (2.9%) exhibited weaker connection with the Brazilian ethanol prices. The results for the variance decompositoon are presented in Tables 2 and 3.

Table 2 – Decomposition of variance for U.S. ethanol (%)

Step	Std Error	DUSETH	DBRETH	DUSCRN	DBRSUG	DOIL
1	0.006	88.640	4.205	7.153	0.002	0.000
2	0.007	72.090	9.425	10.216	3.382	4.887
3	0.009	57.404	8.049	20.830	5.307	8.410
4	0.009	53.135	8.696	20.443	6.653	11.074
5	0.009	50.020	8.593	19.530	7.802	14.055
6	0.009	48.760	8.490	19.457	8.210	15.084
7	0.009	48.330	8.564	19.306	8.411	15.389
8	0.009	48.175	8.574	19.214	8.514	15.523
9	0.009	48.133	8.576	19.184	8.551	15.555
10	0.009	48.123	8.579	19.175	8.565	15.558
11	0.009	48.124	8.578	19.173	8.569	15.556
12	0.009	48.125	8.578	19.173	8.570	15.554
Average	0.009	54.922	8.242	17.738	6.878	12.220

Note: *DUSETH*, *DBRETH*, *DUSCRN*, *DBRSUG*, indicates cash prices in the Δ1st difference of U.S. ethanol, Brazilian ethanol, U.S. corn, Brazilian sugar, respectively. *DOIL* is the 1st difference for international futures oil prices (brent).

Table 3 – Decomposition of variance for Brazilian ethanol prices (%)

Week	Std Error	DUSETH	DBRETH	DUSCRN	DBRSUG	DOIL
1	0.012	4.379	95.214	0.353	0.054	0.000
2	0.013	8.344	85.481	0.270	5.894	0.011
3	0.014	7.983	83.344	1.102	6.518	1.053
4	0.014	7.623	80.913	1.063	8.143	2.258
5	0.014	7.458	79.216	1.235	8.742	3.349
6	0.014	7.376	78.463	1.340	9.131	3.691
7	0.014	7.380	78.063	1.332	9.320	3.906
8	0.014	7.404	77.823	1.327	9.426	4.020
9	0.014	7.418	77.741	1.326	9.464	4.051
10	0.014	7.435	77.696	1.329	9.481	4.059
11	0.014	7.445	77.677	1.330	9.487	4.061
12	0.014	7.450	77.669	1.332	9.489	4.060
Average	0.014	7.308	80.775	1.112	7.929	2.877

Note: *DUSETH*, *DBRETH*, *DUSCRN*, *DBRSUG*, indicates cash prices in the $\Delta 1^{st}$ difference of U.S. ethanol, Brazilian ethanol, U.S. corn, Brazilian sugar, respectively. *DOIL* is the 1^{st} difference for international futures oil prices (brent).

The impulse-response function estimates provides new findings regarding the ethanol prices behavior after the simulated shocks on each price. The impulse response functions are presented in Figure 2.

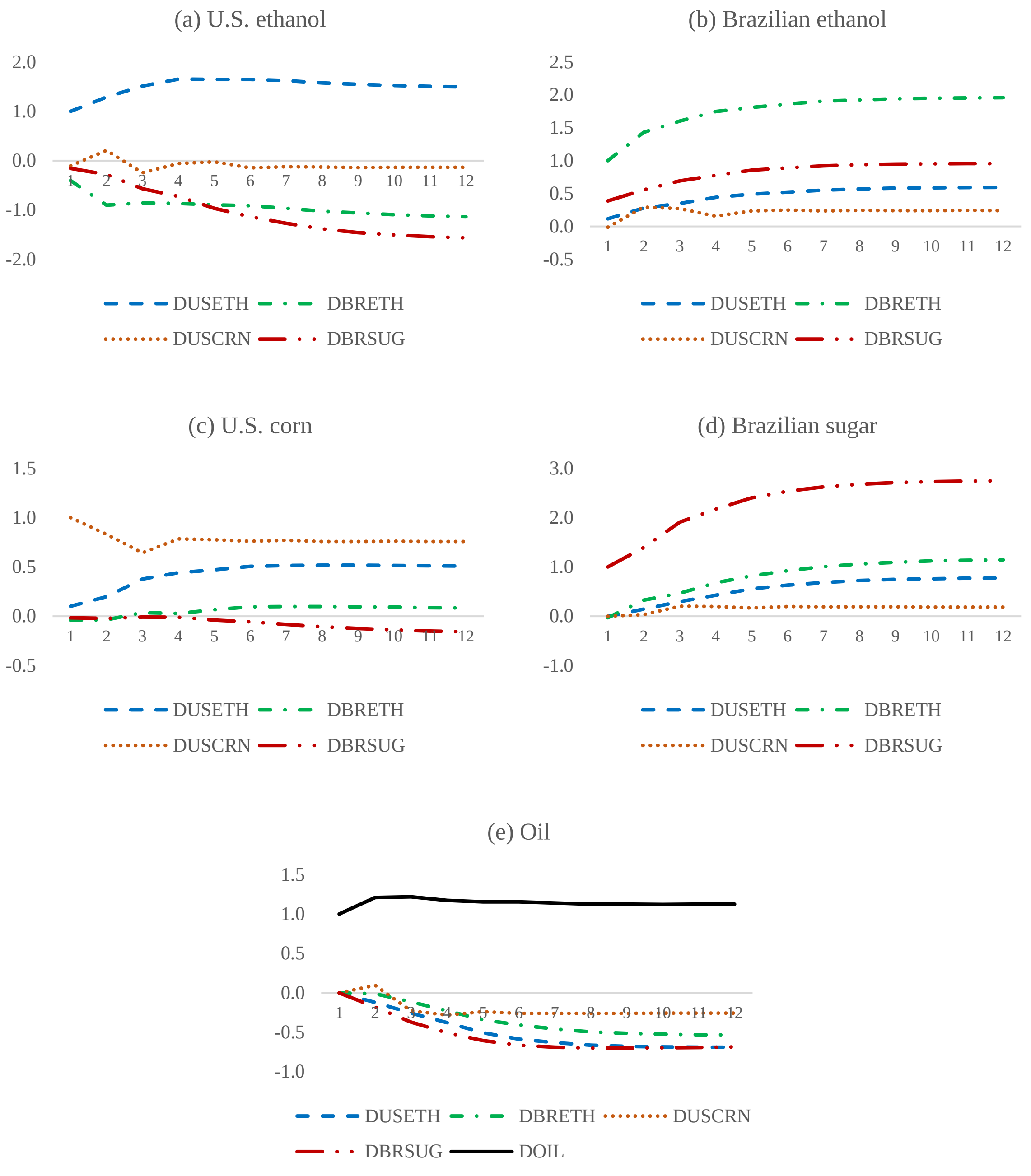

Figure 2 – Cumulative shocks from the estimated Impulse-response functions for commodities prices (%)

Note: *DUSETH*, *DBRETH*, *DUSCRN*, *DBRSUG*, indicates cash prices in the Δ1st difference of U.S. ethanol, Brazilian ethanol, U.S. corn, Brazilian sugar, respectively. *DOIL* is the 1st difference for international futures oil prices (brent).

A positive shock of 1% on corn prices could affect the U.S. ethanol prices for more than one week, increasing the biofuel prices by close to 0.5%. This result is similar to the cumulative shocks on the own variable (corn prices), that after 12 weeks represents a cumulative increase of 0.75% in the price (Figure 1c). In addition, there is no significant connection between the U.S. corn prices with Brazilian ethanol prices, suggesting that corn is only important as feedstock to the U.S. ethanol production.

Alternatively, a shock in sugar prices can result on significant change on ethanol prices in both markets (Brazil and USA). A simulated sock of 1% in sugar prices in Brazil can result in an increase of sugar prices close to 2.75% in later periods. The result of this shock is also relevant on ethanol prices in Brazil and in the U.S., accounting into a possible raise of 1.15% and 0.77% respectively (Figure 1d). These results are closely related to the Granger causality analysis for ethanol prices in both markets, with the Brazilian ethanol causing U.S. ethanol prices.

Similar results were also observed after simulating a 1% shock in Brazilian ethanol prices. As a result of the simulated shock, we could expect an increases in the U.S. ethanol price of 0.60%, an increase in sugar price of 0.95%, and an increase in the Brazilian ethanol price itself close to 1.95% after 12 weeks (Figure 1b). According to the impulse response functions analyses, a shock in the U.S. ethanol prices does not seem to cause the expected effect, reducing Brazilian ethanol prices (Figure 1a). However, this result must be relativized due to the apparently highest effect of domestic issues on the U.S. ethanol prices.

Finally, the response from a 1% shock in oil prices seem to have an opposite effect on commodities prices, showing that prices can decrease over time (Figure 1e). This result can be associated to an exogoenous effect of oil prices as direct components of fuels and feedstock prices. The opposite effect on commodity prices can also be related to an impact on commodities produtions costs, as well as to the regulation of fuels markets that can mitigate the impact of prices in the local markets.

Hedging effectiveness

Our hedging effectiveness analysis was based on Nayak and Turvey (2000) methodological approach and consists in two parts. First, we calculated the hedge effectiveness considering a Brazilian hedger trading ethanol futures contracts at each of the three different exchanges, at the same time he hedged his currency risk trading currency futures contracts at the BMFBovespa. Second, we analyze the position of a hedger in the U.S., trading ethanol futures contracts at the CME Group and NYMEX. We analyze the effectiveness of different hedging strategies for different crop years.

The results for the hedging effectiveness analysis are presented in Table 4. Each column shows the results for different hedgers in Brazil and in the U.S. trading futures contracts from different exchanges, in different crop years. Brazilian hedgers who traded futures contracts at the BM&FBovespa expected to reduce between 89% and 98% of their revenue risk hedging their cash prices, only. The simultaneous hedging strategies for Brazilian hedgers trading ethanol futures contracts at the CME Group or NYMEX seems to have poorer expected results for all years. For most of the crop years, the expected results were significantly lower than the first hedging strategy (BM&FBovespa ethanol futures only).

Table 4 – Results of hedge efficiency for strategies of cash ethanol and futures contracts in the CME Group, NYMEX and BMFBovespa by crop/year

Crop year	BR BM&F[a]	BR CME[b]	BR NYMEX[b]	US CME[c]	US NYMEX[c]
2010/11	95.06%	80.28%	78.71%	96.51%	97.88%
2011/12	90.52%	42.27%	43.25%	84.03%	92.80%
2012/13	89.41%	22.77%	22.52%	90.36%	90.25%
2013/14	96.08%	20.35%	19.46%	61.46%	71.76%
2014/15	96.26%	28.05%	26.31%	86.23%	89.90%
2015/16	98.06%	57.47%	61.44%	78.08%	79.95%

a: Brazilian hedger using BMFBovespa ethanol futures contracts, only; b: Brazilian hedger using either the CME or the NYMEX ethanol futures contract, with simultaneous currency hedge at the BMFBovespa; c: U.S. hedger using either the CME or the NYMEX ethanol futures contract.

The results for U.S. hedgers using futures contracts either from the CME Group or from NYMEX are similar to the results found for Brazilian hedgers trading only ethanol futures contracts in the Brazilian exchange. The expected hedge effectiveness were higher using the NYMEX ethanol futures contracts for most of the years, except for the 2012/2013.

The low effectiveness for Brazilians using simultaneous hedging strategies may indicate the importance of regional variables in the ethanol price formation, both in the U.S. and in Brazil. In addition, during most of the analyzed period, both countries still kept mandatory policies in their biofuels and fuels markets. All these issues could influence prices determination according to their domestic ethanol, feedstock and fuels supply and demand, which maintain a disconnection along biofuels market and explain the weak linkage of ethanol prices in the international market. Moreover, the high variation of the exchange rate BRL/USD may have influenced the results for Brazilian hedgers trading ethanol futures contracts in the U.S.

CONCLUSIONS

This article investigated market integration and hedging efficiency between the two largest ethanol producers, USA and Brazil. In particular, this study focused on price analysis and the use of time series models to assess long run relationship, causality and the linkage level over prices in both domestic and international markets, employing methodological framework as cointegration and causality tests, as well as the estimation of a structural autoregressive vector model with errors correction (SVECM). The structural VECM applied for the most reasonable connections among the considered variables proposes the identification of the main causality effects from positive shocks on variables and the known of the variance decomposition of forecast errors. Additionally, the simulation of several hedging efficiency strategies considering ethanol futures contacts in Brazil and in the U.S. helps to understand weather futures markets could be used as a reference for market participants in both countries or not.

The analysis of the domestic markets shows that ethanol prices are influenced by international oil prices, indicating that fuel markets are still very important to the ethanol price formation in both markets, especially considering the substitution effects of ethanol by fossil fuel, as gasoline or diesel. In Brazil, sugar prices also have significant causality effect on ethanol prices. In the U.S., ethanol prices cause corn prices, but corn prices seems to have no causality effect on ethanol prices. When we analyzed the price causality between countries, we found a causality effect of Brazilian ethanol on U.S. ethanol prices, indicating that the traditional Brazilian production still have relevance to influence the main producer in the World.

The SVECM estimation provides additional insights to understand the market integration in the international level. The variance decomposition of forecast errors indicate that U.S. ethanol prices can be largely influenced by other prices, as corn (domestically), sugar and ethanol (from Brazil), and oil prices (internationally). Together, other variables explain about 46% of ethanol prices in the U.S. market. These findings for the U.S. ethanol market can be associated with the Granger causality tests. For example, oil prices causes U.S. ethanol prices and represent about 12% of its forecasted errors. A similar result was found when we analyzed the Brazilian market. Brazilian ethanol prices, however, are more independent, with only 20% of its forecasted errors explained by other prices, as sugar, U.S. ethanol and oil prices.

Additionally, the impulse response functions from simulated shocks pointing that positive variation of the ethanol prices in Brazil can increase ethanol prices in USA, but not the opposite, which also connect with the previous findings of the influence of the ethanol prices in Brazil over U.S. ethanol prices. Ethanol prices in USA also respond positively from shocks given over corn (USA) and sugar (Brazil) prices. However, Brazilian ethanol prices only oscillates after simulated shocks in the sugar prices.

At last, the hedge effectiveness simulations show that hedgers expect to reduce most of their revenue variance trading ethanol futures in their own country. Brazilian hedgers seem to have higher effectiveness trading only ethanol futures in the Brazilian exchange. U.S. hedgers seem to find higher effectiveness trading NYMEX ethanol futures.

Several issues may explain the weak linkage along the ethanol prices in the international market, as well as the small hedge effectiveness in the use of foreign futures contracts. First, the outstanding raise of the U.S. ethanol production in the past years created a new important player in this market, but still supported by government regulations and mandatory levels of production; (ii) the dramatic drought in U.S. Mid-West over 2013 had affected the domestic corn production and stocks, changing the price dynamics of both corn and ethanol; (iii) the intensification of intervention policies of the Brazilian government in the gasoline prices, especially from 2011-2015, reducing the margins of the ethanol mills; (iv) the decreasing of sugarcane yield in Center-South Brazil from 2011-2014, due to severe climate changes, as well as from the changing of the manual to the mechanical harvesting process; (v) the volatility of the Brazilian exchange rate (BRL/USD), especially in 2015-2016, that could sub estimate the hedge effectiveness coefficients in a simultaneous hedge position.

These issues could be substantial to support the effects of domestic markets in the ethanol price formation, and to explain the reason for the absence of an international reference price. Even the futures contracts traded in larger futures exchanges do not seem to be a good price reference for hedgers outside USA. Considering that, a process of strong price convergence among markets would be possible after the period of the expansion in the ethanol production and trade in the world.

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