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Examining Price Transmission between Fuels and Food Prices: the Brazilian Sugar-Ethanol Market

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Abstract:

Nowadays, Brazil is the world's biggest sugar producer and exporter, as well as the world's largest producer and consumer of sugarcane ethanol as a transportation fuel. The growth of this market has occurred due to a combination of government policies and technical change, both in the sugarcane processing into ethanol and in the manufacturing of flex-fuel vehicles. However, in recent years, the ethanol production has been questioned due to the possible impact on food prices. This work aims to explore the impact of Brazilian ethanol prices on sugar and gasoline prices. The relationships among these series are investigated using vector error corrections (VECM). Impulse response functions and forecast error variance decompositions are also computed in order to investigate the interrelationships within the series. Results suggests that ethanol prices are affected by both food and fuel price, but there is not strong evidence that changes in ethanol prices affect food prices.

Keywords: Ethanol, Sugar, Gasoline, VECM, Prices.

JEL classification: C5, Q11, Q18.

1. Introduction

The price boom that emerged in the mid-2000s has been especially marked for agricultural commodity. In particular, the prices have been rather stable until the end of 2006, while from 2007 to 2008, they more than doubled, declining again in 2009, reaching the 2006 level. In the second semester of 2010, the price registered again an increase followed by a slight fall in 2011. A vast literature has emerged on the causes of this boom (Abbott et al., 2009; Balcombe 2009; Sarris 2009; Gilbert 2010; Gilbert et al., 2010; De Schutter 2010; Jacks 2010; Huchet-Bourdon 2011; Muller et al., 2011; OECD-FAO 2011; Finco, 2012; Tyner, 2013) some of which have been hotly debated as the role of speculation, the increased energy prices, the export policy changes, the declining US dollar, and especially, in the case of food commodities, the biofuels' role.

This paper focuses on the role of biofuel in the determination of the high agricultural commodity prices. In fact, biofuel may compete for renewable and nonrenewable resources and thus impact its sustainability and that of food (Zhang et al., 2010).

Nowadays, world biofuel markets are dominated by ethanol and biodiesel. In 2012, the combined global production of ethanol and biodiesel fell for the first time since 2000, down 0.4 percent from 2011. Global ethanol production declined slightly for the second year in a row, to 83.1 billion liters, while biodiesel output rose fractionally, from 22.4 billion liters in 2011 to 22.5 billion liters in 2012. Biodiesel now accounts for over 20 percent of global biofuel production (Worldwatch Institute 2014). Today, Brazil is the world's biggest sugar producer and exporter, as well as the world's largest producer and consumer of sugarcane ethanol as a transportation fuel. Consequently, the rapid upward shift in ethanol demand has raised concerns about ethanol's impact on the price level of agricultural commodity. Moreover, the introduction of flex-fuel vehicle that can uses any combination of petrol-ethanol blend, but also pure ethanol, has enhanced considerably the substitution possibilities between gasoline and the demand prospects of ethanol.

Our analysis focuses on assessing links between prices of gasoline, sugar and ethanol from November 2007 to November 2013. The relationships among these series are investigated using co-integration and a vector error corrections (VECM). Impulse response functions and forecast error variance decompositions are also computed from this model in order to investigate the interrelationships within the system. With this analysis, we contribute to the current debate on the impact of ethanol industry on food and gasoline prices, and thereby provide guidance to policy makers for formulating future policies and to economic agents for designing their pricing strategies.

The remainder of this paper is structured as follows. Section 2 presents an overview of Brazilian ethanol market. After offering a brief review of the literature, in section 3 and 4 we discuss in some details the methodology used to assess the price relationships and the data needed for the analysis. The results are shown in section 5. Section 6 concludes.

2. The Brazilian Ethanol Sector: an Overview

Brazil is the most important producer and consumer of ethanol in the world. With 27.5 million of cubic meters of ethanol produced in the partial of 2014, the Brazilian sugarcane ethanol production registered an increase of 18 percent on the basis of the previous year. About 93 percent of the domestic production is concentrated in the Center-South of the country and more than half of it is located in the state of São Paulo. About 90 percent of the country's total ethanol production is for domestic consumption, but exports have been growing for several years (UNICA, 2014).

The growth of the Brazilian ethanol market has been realized due to a combination of factors, including government policies and technical change both in the processing of sugarcane into ethanol and in the manufacturing of vehicles that can use high level blends of ethanol with petrol (Balcombe et al., 2008). The national alcohol programme began in 1975 with the aim of reducing the country's oil import bill. The programme consisted by a number of different policy instruments that included production quotas and institutional setting of the price for ethanol at a level lower than that of petrol, combined with subsidies to ethanol distillers. The ethanol programme was effectively eliminated in the 1990's and a transition to full liberalization took place. Although nowadays the government no longer exercises direct control over ethanol production and exports, it sets an official blending ratio of anhydrous ethanol with petrol to 20-25 percent.

Nevertheless, the success of contemporary sugarcane-ethanol as a future energy option to replace gasoline/diesel relates to both its benefits to greenhouse gas emissions and the lowest production cost (Shikida et al., 2014). In particular, the Brazilian ethanol industry is estimated to have the lowest ethanol production costs in the world (Martines-Filho et al., 2006). The average production cost is approximately 0.60-0.71 US dollars per liter, according to Pecege-ESALQ 2013. These costs are strongly determined by costs of sugarcane production and processing and the rate of sugarcane conversion into ethanol. Investments in sugarcane agronomic research that have led to increased sugarcane yields and quality have played a key role in reducing ethanol production costs. These developments have further improved ethanol competitiveness within the fuels market (gasoline) and have increased the amount of sugarcane diverted to ethanol production (Serra, 2011). In fact, sugar and ethanol are produced on an integrated basis. The option to produce more or less of each product is influenced by the relative prices. When sugar prices increase, for example, producers can divert sugarcane production from ethanol to sugar, and vice versa. At last, the introduction of flex-fuel vehicles that can use any combination of petrol-ethanol blends, but also pure ethanol only, has enhanced the substitution possibilities between these fuels and the demand prospects for ethanol (Rapsomanikis et al., 2006).

Therefore, the surge in prices, in conjunction with the continuously increasing substitution possibilities between ethanol and gasoline, provides good economic reasoning for the existence of co-movement in the gasoline-ethanol-sugar price complex in Brazil. Since we aspect feedstock, gasoline and ethanol prices to commove, our analysis will assess these relationships.

3. Brief Literature Review

In recent years, price linkages between the food, energy and biofuels markets therefore become one of the most discussed common topic for energy, environmental and agricultural economists interested in the question of sustainable development of biofuels (Kristoufek et al., 2012). The so-called "food crisis", which was characterized by sharply increasing prices for agricultural commodities and crude oil as well as retail fuels and biofuels, captured a very wide academic and policy attention during 2008 and it continues to form policy attitudes regarding biofuels versus food issues. The matter of food-fuels biofuels interactions gained another dimension and a research on possible squeeze-out effects, i.e. whether the increasing prices of biofuels cause the prices of related agricultural commodities to raise as well, has become very frequent since that time (Vacha et al, 2012).

To date, existing studies distinguish between two bodies of literature: one on the relationship between food-commodity and biofuel prices and another on the impact of the introduction of biofuel on food commodity prices (Zielberman et al., 2012). Relatively to the first body of literature, a large of studies and reports investigate the dynamic of price level links between commodity and biofuel sector using time series models. In details, predominant methodological approaches consist of co-integration analysis and/or estimation of VECM model, or one of its generalized nonlinear versions (Serra et al., 2013).

Several studies focus on the US ethanol and Brazilian sugarcane market, while others investigate the EU biodiesel sector. However, the US biofuels industry (Zhang et al., 2009; Saghaian, 2010; Serra et al., 2011a; Du et al., 2012; Qiu et al., 2012; Wixson et al., 2012; Gardebroek et al., 2013) has attracted more attention than EU (Busse et al. 2010 and 2012, Peri et al., 2010; Hassouneh et al. 2011, Rajcaniova et al., 2011; Kristoufek et al. 2012 and Vacha et al. 2012; Bentivoglio et al. 2014) and Brazilian markets. In particular, the link between sugar and energy market, ethanol and crude oil/gasoline, was examined by Rapsomanikis and Hallam (2006), Balcombe and Rapsomanikis (2008), Serra, Zilberman, and Gil (2011b) and Serra (2011).

Rapsomanikis and Hallam (2006) and Balcombe and Rapsomanikis (2008) use ethanol, sugar and crude oil prices to investigate the Brazilian ethanol industry. Both articles rely on generalized (non-linear) versions of error-correction models. While sugar–oil and ethanol–oil are found to be nonlinearly co-integrated, ethanol–sugar prices are linearly co-integrated. Both articles provide evidence that crude oil prices drive long-run feedstock price levels, while the latter drive long-run biofuel prices. The Brazilian ethanol industry is not found able to influence crude oil long-run price levels. A study on Brazil by Serra, Zilberman, and Gil (2011b) used weekly international crude oil and ethanol and sugar prices, observed from July 2000, to February 2008, to assess volatility spillovers in Brazilian ethanol and related markets. They found that the ethanol prices are positively related to both sugar and oil prices in equilibrium. Markets transmit the volatility in the oil and sugar markets to ethanol markets with minimal transfer of volatility in the other direction. Another study on Brazil by Serra (2011) uses nonparametric correction to time series estimations and supports the long-run linkage between ethanol and sugarcane prices and finds that crude oil and sugarcane prices drive ethanol prices and not vice versa.

4. Methodological Approach

Times series models are relevant instrument to characterize price behavior (Wright, 2011). The biofuels-related price transmission literature has focused on studying price level connections using cointegration analysis and VECM-type of models (Serra et al., 2013). Consequently, in order to assess the price linkages between energy and agricultural commodity prices, this study adopts a vector error corrections model (VECM). Before estimating the VEC model, a preliminary analysis of prices is conducted in order to evaluate the time series properties. According to Myers (1994), price series have different common characteristics that are important for statistical analysis. First, commodity price series generally contain stochastic trends and, therefore, are non-stationary. Second, commodity prices may tend to move together over time. In other words, although individual price series may be non-stationary, the price series of interrelated market shares are likely to contain the same stochastic trends. Hence, the co-movements of these variables may be stationary. Co-movement among non-stationary prices is known in econometrics literature through the concept of cointegration. Engle and Granger

(1987) have shown that cointegration involves an error correction representation that allows the assessment of both short-run price dynamics and the adjustment of individual prices to deviations from the long-run cointegration relationship. Standard unit root and cointegration tests were performed so as to determine whether price series are stationary and whether they are co-integrated, respectively. In particular, the standard augmented Dickey and Fuller (1979) test was applied to each price series. Furthermore, the Johansen (1988) test for cointegration was then used to evaluate long-run price linkages. Finally, in order to estimate the effect of each variable on the other and also its magnitude, an impulse response analysis and forecast error variance decomposition analysis was performed. All the analyses were carried out using the statistical software Rats32s (Regression Analysis of Time Series).

4.1 Vector Error Correction Models (VECM)

VECM analysis was performed on the available series in order to investigate the long-run and the short-run relations among the ethanol and agricultural commodity prices. According to the VECM, the dynamics of a multivariate time series can be expressed as the equation below shows.

$$\Delta \boldsymbol{Y}_t = \boldsymbol{\Pi} \boldsymbol{Y}_{t-1} + \sum_{i=1}^{p-1} \boldsymbol{\Gamma}_i \Delta \boldsymbol{Y}_{t-i} + \boldsymbol{\upsilon} + \boldsymbol{\varepsilon}_t$$

The equation expresses the difference of the (multivariate) observation as the contribution of their absolute values ΠY, its lagged values (the linear combination of previous ΔY), a constant and an error. Whilst full details about the mathematics underlying the methodology can be found in references, it is important to stress that the Π matrix, when it is not of full rank, can be decomposed as Π=αβ' with beta being the matrix that expresses the co-integrating relationship. The co-integrating relationships represent linear equations that show the long-term relationships among the variables. Moreover, a VECM specifies the short-run dynamics of each price series in a framework that anchors the dynamics to long-run equilibrium relationships (co-integrates) (Zhang et al., 2009).

4.2. Data

The empirical analysis utilized weekly prices of Brazilian ethanol (USD/liter), gasoline (USD/liter) and sugar (USD/50 kg-bag), which were collected over a period from November 2007 to November 2013. This amount refers to a total of 311 observations. Data sources include the Centre for Advanced Studied on Applied Economics (CEPEA, 2014) that provided Brazilian ethanol and sugar prices, as well as the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP, 2014) that provided gasoline prices. The indexed price series used in the analysis are presented in figure 1.

Figure 1

5. Empirical Results

5.1 Stationary Analysis and Co-integration Estimation

Weekly series were tested for the presence of unit root. A series with a unit root is non-stationary with an infinite unconditional variance, and therefore, it is not possible to generalize it to other time period. In particular, the Augmented Dickey Fuller test (ADF) (1979) was applied to the price series for ethanol, gasoline and gasoline in order to determine whether they have unit roots. The ADF test verifies the null hypothesis of a unit root process against the alternative of a stationary process. The results for all the price series (tab. 1) show that none of them supports the stationariety assumption at all levels (1%).

Table 1

In the case of a non-stationary time series, co-integration provides an appropriate statistical technique to investigate whether there is a significant long relationship between the prices. Two or more price series are said to be co-integrated if prices move together in the long-run. As discussed by Engle and Granger, a linear combination of two or more non-stationary series that shares the same order of integration may be stationary. If such a stationary linear combination exists, the series are said to be co-integrated and long-run equilibrium relationships exist. Although there may be short-run developments that can cause the series to deviate, there is a long-run equilibrium relation represented as a linear combination, which ties the individual price series together (Zhang et al., 2009). The Johansen procedure was applied to the series in order to estimate the number of co-integrating relationships. Moreover, in order to apply Johansen's method (1998), it is useful to know the lag length of the VECM. A lag-structure analysis based on the Hannan Quinn information criterion (HQ) and Schwarz criterion (SC) was conducted, yielding a consistent estimate of the lag length. The result suggests an optimal lag order of 2. The corresponding test statistics is given in table 2.

Table 2

The results provide evidence that the prices considered are co-integrated with a co-integration rank=1. Nevertheless, we will proceed to estimate the VECM model.

5.2 VECM Estimation

The presence of co-integration between variables suggests a long-term relationship among the variables under consideration. Then, the VEC model can be applied. By normalizing with respect to the ethanol price, this co-integration relationship (co-integration vector) can be expressed as follows:

$$\boldsymbol{LPetanolo = +0.189LPsugar + 0.699LPgasoline - 0.965}$$

$$(\mathbf{2,389}) \qquad (\mathbf{2,959}) \qquad (\mathbf{4.339})$$

Coefficients in parentheses are the statistical significance. All the parameter coefficients are significant at 1% level. The parameters indicate that ethanol is positively related with sugar and gasoline in the long-run. More specifically, the co-integration relationship suggests that, when sugar or gasoline prices change by 1%, ethanol prices change by 0,2% and 0,7%, respectively. The positive relationship between ethanol and sugar prices is expected, given that feedstock costs represent a considerable part of ethanol production costs (60%). Further, the long-run positive link between ethanol and gasoline prices may, on the one hand, arise due to the fact that ethanol serves as a substitute for gasoline. Hence, if gasoline prices rise, the demand for ethanol increases, which causes an increase in ethanol prices. Once the VECM has been estimated, short-run dynamic can be examined by considering an impulse response analysis and a variance decomposition.

5.2.1 Impulse Response and Variance Decomposition

In order to estimate the effect of each variable on the others, an impulse response analysis was carried out. Impulse response analysis allows to quantify the effect of a unitary increase of one variable (the impulse) on other variables (response), also at prospective values. In particular, figure 2 shows the accumulated impulse response function of the ethanol price to a shock to sugar prices.

Figure 2

As showed in figure 2, an increase in sugar prices causes a change in ethanol price of the same sign. In details, a shock of 1% in the sugar price induces an increase in the ethanol price from the first week. The magnitude of the response increased over the time, reaching a peak after ten weeks (0.9%) and, then, persists in the following periods. This is not surprising given that the difference in the level of ethanol price is associated mainly to the quantity of sugarcane produced as well as the allocation of such material for the sugar or ethanol production. Moreover, given the relevance of feedstock costs within the total costs of producing ethanol, it is not surprising to find that higher prices for sugar will lead to higher ethanol prices.

At the contrary, an increase in the gasoline price is found to cause a decrease in ethanol prices (Fig. 3).

Figure 3

Hence, if gasoline prices rise, its consumption decreases. This effect is reflected in the consumption of anhydrous ethanol, which is used in blends with gasoline (25%). Consequently, anhydrous ethanol price drops and this lower price is transmitted at pure ethanol due to the high correlation between the two markets (Bacchi et al., 2011).

At the same time, figure 4 illustrates the accumulated impulse response function of the sugar and gasoline price to a shock (1%) to the ethanol price. An increase of ethanol price does not seem to produce an impact of both sugar and gasoline prices.

Figure 4

Provided evidence of these results are supports in the next variance decomposition analysis. The variance decomposition provided further evidence of relationships among the variables under investigation. The variance decomposition showed the proportion of the forecast error of one variable due to the other variables. Therefore, the variance decomposition makes possible to determine the relative importance of each variable in creating fluctuations in other variables (Ratanapakorn and Sharma, 2007).

As indicated in table 3, the variability of sugar prices constitutes 11% of the variance for ethanol prices, while gasoline prices account for 66% after 12 weeks.

Table 3

At the same time, the variability of the price of sugar (tab. 4) and gasoline (tab. 5) after 12 weeks depend exclusively on the price of sugar and gasoline itself (78% and 97%, respectively).

Table 4

Table 5

This variance decomposition analysis, on the one hand, supports the significant influence of both gasoline and sugar prices on ethanol prices; on the other hand, it confirms that rising ethanol prices are not directly causing inflated agricultural commodity prices (Chagas, 2010).

6. Concluding Remarks

This paper examined price transmission patterns between the Brazilian ethanol and related agricultural and energy markets. Links of this renewable market to fossil energy markets, on the one hand, and to agricultural raw product markets, on the other hand, are analyzed using weekly prices of ethanol, sugar and gasoline between November 2007 and November 2013. To investigate the relationships among these series, a co-integration analyses and a vector error corrections model (VECM) are carried on. Moreover, impulse response functions and forecast error variance decompositions are computed in this model in order to investigate the interrelationships within the sector.

Our results suggest that ethanol and gasoline, as well as ethanol and sugar price levels, are linked in the long-run by equilibrium parity. These long-run price links show that ethanol prices increase with an increase in both gasoline and sugar prices. The positive relationship between ethanol and sugar prices is not surprising, given the relevance of feedstock costs within the total costs of producing ethanol (60%). On the other hand, gasoline prices may affect ethanol prices due to the fact that ethanol serves as a substitute for gasoline. The empirical results also show that sugar and gasoline prices drive ethanol prices in the short-run.

Conversely, ethanol prices show limited capacity to influence food and energy prices. In fact, nowadays the variability of sugar prices especially depends on international sugar markets, while the Brazilian government establishes gasoline prices. In particular, sugar prices will also increase, as Brazil, world's major sugar producer and exporter, influences the world sugar balance.

Therefore, this analysis suggests that ethanol prices are affected by both food and fuel prices, but there is not strong evidence that changes in biofuel prices affect food prices. Hence, our analysis suggests that promoting ethanol in Brazil can be a useful tool to reduce both dependence of crude oil and GHG emissions. The competitive advantage taken by sugarcane ethanol, in terms of economic and environmental sustainability, also represents an opportunity to promote rural economies.

References

Abbott, P., de Battisti B. A., 2009. Recent Global Food Price Shocks: Causes, Consequences and Lessons for African Governments and Donors. Paper presented at the International Agricultural Trade Research Consortium; June 22-23, 2009 Seattle, Washington.

Agência Nacional do Petróleo, Gás Natural e Biocombustíveis – ANP, 2014. http://www.anp.gov.br/preco/.

Bacchi, M. R. P., Lima L. M., Bragato, I., 2011. Preco do etanol no mercado domestico: variabilidade e fundamentos. In: Marta Cristina Marjotta-Maistro. (Org.). Desafios e perspectivas para o setor sucroenergético do Brasil. 1a. ed. São Carlos: EdUFSCar, 2011, p. 151-165.

Bentivoglio, D., Finco, A., Bacchi, M. R. P., Spedicato, G., 2014. European biodiesel market and rapeseed oil: what impact on agricultural food prices? Int. J. Global Energy Issues - Special Issue on Bio-Energy, Economics and Policy; Vol. 37 No. 5/6. DOI: 10.1504/IJGEI.2014.067667.

Balcombe, K., Rapsomanikis, G., 2008. Bayesian estimation of nonlinear vector error correction models: the case of sugar-ethanol–oil nexus in Brazil. Am. J. Agric. Econ. 90, 658–668.

Balcombe, K., 2009. The nature and determinants of volatility in agricultural prices: an empirical study from 1962-2008. A report to the Food and Agriculture Organization of the United Nations.

Busse, S., Brümmer, B., Ihle, R., 2010. Interdependencies between fossil fuel and renewable energy markets: the German biodiesel market. Diskussions papiere//Department für Agrarökonomie und Rurale Entwicklung, No. 1010

Busse, S., Brümmer,B., Ihle, R., 2012. Price formation in the German biodiesel supply chain: a Markov-switching vector error correction modeling approach. Agric. Econ. 43, 545–560.

Center for Advanced Studies on Applied Economics (CEPEA), 2014. Center for Advanced Studies on Applied Economics (CEPEA), Alcohol and sugar prices datasets. http://cepea.esalq.usp.br/alcool/ (2014) Accessed April 2014.

Chagas, A. L. S., (2010). Etanol ou alimento: existe esse trade-off?. Informaçoes FIPE, Sao Paulo, p. 11-16, 01 mar. 2010.

De Schutter O., 2010. Food commodities speculation and food price crises: regulation to reduce the risks of price volatility. Briefing note by the Special Rapporteur on the right to food, September 2010.

Dickey, D.A., Fuller W.A., 1979. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. J. Am. Stat. Assoc. 74, 427- 431.

Du, X., McPhail, L., 2012. Inside the black box: the rice linkage and transmission between energy and agricultural markets. Energ. J. 33, 171–194.

Engle, R., Granger, C., 1987. Cointegration and error correction representation, estimation and testing. Econometrica 55, 251–276.

Finco, A. 2012. Biofuels economics and policy – Agricultural and Environmental sustainability. In Finco A., (Eds), Franco Angeli, Milano.

Gardebroek C., Hernandez M. A., 2013. Do energy prices stimulate food price volatility? Examining volatility transmission between US oil, ethanol and corn markets. Energ. Econ. 40(C), 119-129.

Gilbert, C. L., 2010. How to Understand High Food Prices. *J*. Agr. Econ. 61, 398-425.

Gilbert, C.L., Morgan C.W., 2010. Has food price volatility risen?. Revised version 8 April 2010. Workshop on Methods to Analyse price volatility. Seville. Spain. January 2010.

Hassouneh, I., Serra, T., Goodwin, B.K., Gil, J.M., 2012. Non-parametric and parametric modeling of biodiesel, sunflower oil, and crude oil price relationships. Energ. Econ. 34, 1507-1513.

Huchet-Bourdon, M., 2011. Agricultural commodity Price volatility: An Overview. OECD Food, Agriculture and Fisheries Working Papers, No. 52, OECD Publishing.

Jacks D. S., O'Rourke H. K., Williamson J. G., 2010. Commodity Price Volatility and World Market Integration since 1700. HIPOD Working Paper, August 2010.

Johansen S., 1998. Statistical analysis of cointegration vectors. J. Econ. Dynam. Control. 12, 2–3, 231–254.

Kristoufek, L., Janda, K., Zilberman, D., 2012. Mutual Responsiveness of Biofuels, Fuels and Food Prices. Working paper, Centre for Applied Macroeconomic Analysis. Australian National University, Canberra.

Martines-Filho, J., Burnquist, H.L., Vian, C.E.F., 2006. Bioenergy and the rise of sugarcane based ethanol in Brazil. Choices 21, 91-96.

Myers, R.J., 1994. Time series econometrics and commodity price analysis: a review. Rev. Marketing Agr. Econ. 62, 167–181.

Muller, S. A., Anderson, J. E., Wallington, J.T., 2011. Impact of biofuels production and other supply and demand factors on food price increases in 2008. Biomass and Bioenergy 35, 1623-1632.

OECD-FAO, 2011. Agricultural Outlook, 2011-2020.

Peri, M., Baldi, L., 2010. Vegetable oil market and biofuel policy: an asymmetric cointegration approach. *Energ. Econ*. 32, 687–693.

Qiu, C., Colson, G., Escalante, C., Wetzstein, M., 2012. Considering macroeconomic indicators in the food before fuel nexus. Energ. Econ. 34, 2021–2028.

Rajcaniova, M., Pokrivcak, J., 2011. The impact of biofuel policies on food prices in the European Union. J. Econ. (Ekonomicky Casopis) 5 (2011), 459–471.

Ratanapakorn, O., Sharma S.C., 2007. Dynamic analysis between the US stock returns and the macroeconomic variables. Appl. Finan. Econ. 17(5), 369-377.

Rapsomanikis, G., Hallam, D., 2006. Threshold Cointegration in The Sugar–Ethanol–Oil Price System in Brazil: Evidence from Nonlinear Vector Error Correction Models. Commodity and Trade Policy Research Working Paper no 22.FAO, Rome.

Saghaian, S.H., 2010. The impact of the oil sector on commodity prices: correlation or causation? J. Agr. Appl. Econ. 42, 477–485.

Sarris, A., 2009. Evolving structure of world agricultural trade and requirements for new world trade rule. Paper presented at the FAO Expert Meeting on "How to Feed the World in 2050" FAO, Rome, June 24-26, 2009.

Serra, T., 2011. Volatility spillover between food and energy market: A semiparametric approach. Energ. Econ. 33, 1155-1164.

Serra, T., Zilberman, D., Gil, J.M., Goodwin, B.K., 2011a. Nonlinearities in the US corn–ethanol–oil-gasoline price system. Agr. Econ. 42, 35–45.

Serra, T., Zilberman, D., Gil, J., 2011b. Price volatility in ethanol markets. Europ. Rev. Agr. Econ. 38, 259–280.

Serra, T., Zilberman, D., 2013. Biofuels-related price transmission literature: A review. Energ. Econ. 7, 141–151.

Shikida, P. F. A., Finco, A., Cardoso, B. F., Galante, V. A., Rahmeier, D., Bentivoglio, D., Rasetti M. 2014. A comparison between ethanol and biodiesel production: the brazilian and european experiences', in Padula, A. D., Antonio, S.S., Manoela, B.S., Inácio O.S. and Benedetti, B. (Eds), Liquid Biofuels: Emergence, Development and Prospects, Vol 27, ISBN: 978-1-4471-6481-4, 978-1-4471-6482-1, Springer.

Tyner, W. E., 2013. Biofuels and food prices: Separating wheat from chaff. *Global Food Security.* 2, 2,126–130.

Zhang, Z., Lohr, L., Escalante, C., Wetzstein, M., 2009. Ethanol, corn, and soybean price relations in a volatile vehicle-fuels market. Energies 2, 230–339.

Zhang Z., Lohr L., Escalante C., Wetzstein M. 2010. Food versus fuel: What do price tell us?. Energy Policy 38, 445-451.

Zilberman, D., Hochman, G., Rajagopal, D., Sexton, S., Timilsina, G., 2012. The impact of biofuels on commodity food prices: Assessment of Findings. Am. J. Agric. Econ.. http:// dx.doi.org/10.1093/ajae/aas037, June 7, 2012.

UNICA, 2014. Detalhamento das exportações mensais de etanol pelo Brasil. http://www.unicadata.com.br/listagem.php?idMn=23. Accessed July 2014.

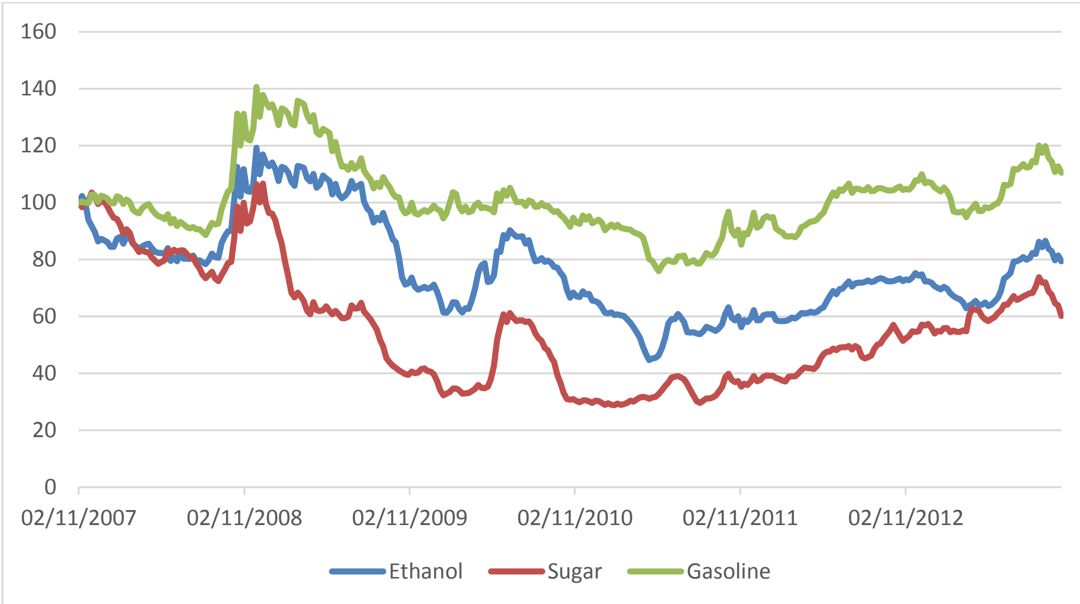
Vacha, L., Janda, K., Kristoufek, L., Zilberman, D., 2012. Time–Frequency Dynamics of Biofuels Fuels–Food System. http://arxiv.org/abs/1209.0900.

Wright W., 2011. The economics of grain price volatility. Applied Economic Perspectives and Policy 33, 32–58.

Wixson, S.E., Katchova, A.E., 2012. Price asymmetric relationships in commodity and energy markets. Paper presented at the 123th European Association of Agricultural Economists' Seminar, Price Volatility and Farm Income Stabilisation, Dublin, February 23–24, 2012.

Worldwatch Institute, 2014. http://www.worldwatch.org/biofuel-production-declines-0.

Figure 1: Indexed price series



Source: CEPEA and ANP, 2014

Table 1: Unit root tests (ADF) for the weekly prices

Price series	Test Statistic	1%
Ethanol	-0.985	-2.58
Sugar	-0.269	-2.58
Gasoline	-1.541	-2.58

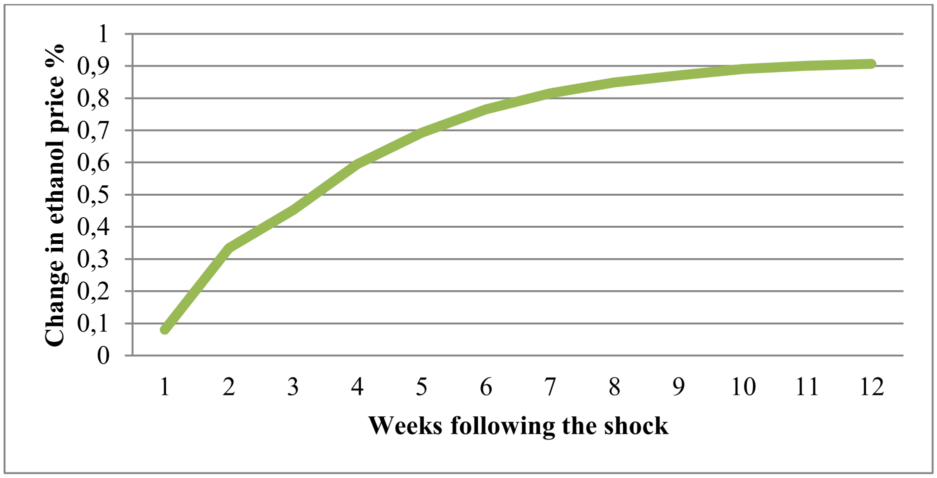
Source: Processing Rats32s

Table 2: Johansen test ethanol database

p-r	r	Eig.Value	Trace	Trace*	Franc95	P-Value	P-Value*
3	0	0.070	34.059	33.911	35.070	0.065	0.067
2	1	0.022	11.514	11.484	20.164	0.502	0.504
1	2	0.015	4.651	4.647	9.142	0.335	0.336

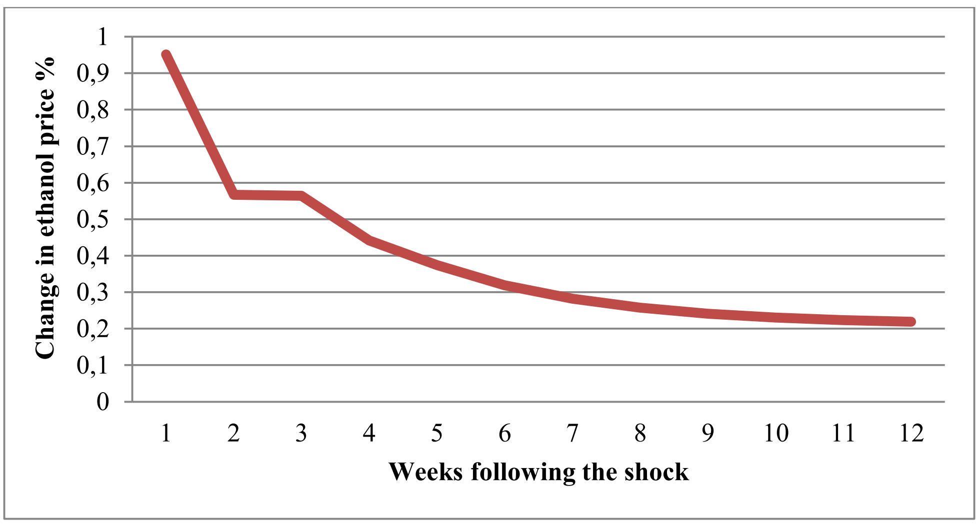
Source: Processing Rats32s

Figure 2: Ethanol response to a shock to the sugar prices



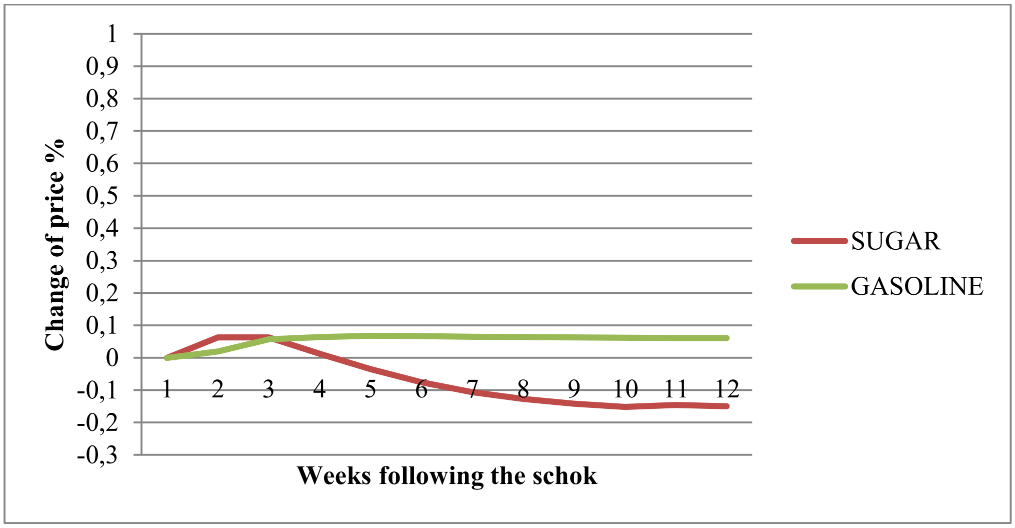
Source: Processing Rats32s

Figure 3: Ethanol response to a shock to the gasoline prices



Source: Processing Rats32s

Figure 4: Sugar and gasoline responses to a shock to ethanol prices



Source: Processing Rats32s

Table 3: Variance decomposition analysis of ethanol after 12 periods (weeks)

Step	Ethanol	Sugar	Gasoline
1	20.980	0.788	78.233
2	22.700	6.777	70.523
3	23.639	7.872	68.489
4	23.146	9.474	67.380
5	22.905	10.211	66.884
6	22.755	10.613	66.632
7	22.687	10.798	66.515
8	22.657	10.882	66.462
9	22.644	10.918	66.438
10	22.638	10.934	66.428
11	22.636	10.940	66.424
12	22.635	10.943	66.422

Source: Processing Rats32s

Table 4: Variance decomposition analysis of sugar after 12 periods (weeks)

Step	Ethanol	Sugar	Gasoline
1	0.000	100.000	0.000
2	0.035	78.783	21.182
3	0.032	79.193	20.775
4	0.049	78.536	21.415
5	0.065	78.417	21.518
6	0.077	78.340	21.583
7	0.083	78.310	21.606
8	0.087	78.297	21.616
9	0.088	78.291	21.620
10	0.089	78.289	21.622
11	0.089	78.288	21.623
12	0.089	78.288	21.623

Source: Processing Rats32s

Table 5: Variance decomposition analysis of gasoline after 12 periods (weeks)

Step	Ethanol	Sugar	Gasoline
1	0.000	0.000	100.000
2	0.008	3.069	96.923
3	0.040	3.055	96.906
4	0,041	3.208	96.751
5	0,041	3.238	96.721
6	0,041	3.259	96.700

7	0,041	3.268	96.692
8	0,041	3.271	96.688
9	0,041	3.273	96.686
10	0,041	3.274	96.685
11	0,041	3.274	96.685
12	0,041	3.274	96.685

Source: Processing Rats32s