Biofuel-food market interaction: exploring the price link in the European and Brazilian context

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Abstract

The last decade has seen a rapid increase in the production and consumption of biofuel at global level. Nowadays, world biofuel markets are dominated by ethanol (79%) and biodiesel (21%). The European Union is the leader in biodiesel production and consumption, while Brazil is the world's biggest sugar producer and exporter, as well as the world's largest producer and consumer of sugarcane ethanol as transportation fuel. However, first generation biofuels are questioned due to the possible link with food prices. This study contributes to this debate, investigating the relationship between the price of biofuels and related fuels and agricultural commodities in the European and Brazilian context. The problem has been addressed using a Vector Error Corrections Model. The results show that there are evidences of long-run equilibrium relation among the analyzed price series in both scenarios. In particular, EU biodiesel price is connected with feedstock price; while Brazilian ethanol price is connected to fuel price.

Keywords
Biodiesel, Ethanol, Prices, VECM

Introduction

The production and use of biofuels, mainly ethanol based on cereals and sugar crops and biodiesel based on vegetable oils such as rapeseed, have grown rapidly over the past few years. In 2012, the combined global production of ethanol and biodiesel was equal to approximately 106 billion liters. Biodiesel fuels represent 21% of the total biofuels production worldwide, the remaining 79% is ethanol. Compared to 2011, the global production of ethanol decreased from 86.1 to 83.1 billion liters (-4%), while biodiesel production increased slightly from 22.4 billion liters in 2011 to 22.5 million liters in 2012 (+5%).
Biofuels expansion is only one of the many causes held responsible for the price boom in the agricultural sector in the last years, along with the role of speculation, the increased energy prices, the export policy changes and the declining US dollar (Abbott and de Battisti, 2009; Balcombe 2009; Sarris 2009; Gilbert 2010; Gilbert et al., 2010; De Schutter 2010; Jacks et al., 2010; Huchet-Bourdon 2011; Muller et al., 2011; OECD-FAO 2011; Finco, 2012; Tyner, 2013).
The rapid upward shift in ethanol demand over the years has raised concerns about ethanol's impact on the price level of agricultural commodities. Moreover, the introduction of

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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. At the same time, the increasing use of biodiesel, which is mainly driven by policy interventions, has stimulated the demand for vegetable oils for biodiesel production, introducing a new factor able to affect agricultural and food market price formation (Busse et al., 2012).
This paper seeks to investigate the potential existence of long term relationship between biofuels prices and food commodity prices in Europe (the largest producer, consumer and importer of biodiesel) and Brazil (the world's largest producer and consumer of sugarcane ethanol). The problem has been addressed with a Cointegration Analysis and a Vector Error Corrections Model (VECM), making use of weekly prices of EU biodiesel, diesel and rapeseed oil (from 2007 to 2013) and Brazilian ethanol, sugar and gasoline (from 2008 to 2013).

The biofuels sector: an overview

According to the Worldwatch Institute (2014), to date biofuels for the transport sector, represent approximately 0.8% of the global energy consumption, 8% of the world primary energy derived from biomass, 3.4% of fuels for road transport in the world, and 2.5% of fuels for any kind of transport.
Ethanol fuels represent the largest share in global biofuels production. The top five ethanol producers countries in 2013 were the United States, Brazil, Europe, China and Canada, although the United States and Brazil alone, accounted for 84% (57% and 27%, respectively) of the total global production. Ethanol production in the United States, mainly obtained from corn, amounted to 13.3 billion gallons in 2013, declining by 5% compared to 2011. On the contrary, Brazilian ethanol production, whose main feedstock is sugarcane, rose by 12% reaching 6.3 billion gallons. All the other main producers deal with much lower volumes: at the third place we have the European Union (EU) with 1.3 billion gallons of ethanol in 2013, China and Canada follow with 0.7 billion gallons and 0.5 billion gallons, respectively.
As for the global production of biodiesel, we observe a steady increase since 2008. The EU is the world leader in biodiesel production (using rapeseed oil as the main feedstock) with a 40% share on the global output, equal to 10.5 billion liters. United States, Brazil and Argentina cover a minor role in this sector. In 2013, the United States increased the production of biodiesel up to 4.8 billion liters, while Argentina lost the second place (2.3 billion liters), displaced by Brazil with 2.9 billion liters.
The growth of the Brazilian ethanol market was 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 and Rapsomanikis, 2008). The national alcohol programme began in 1975 with the aim of reducing the country's oil import bill. The programme consisted of a number of different policy instruments that included production quotas and institutional setting of ethanol price 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.

In the European context, two political decisions have had a fundamental role in biofuel expansion: Directive2003/30/EC and Directive 2009/28/EC (Renewable Energy Directive-RED). The objectives of the RED policy in 2009 included: increasing farm income, improving environmental quality, and increasing national energy security. The RED also includes legally binding national targets for 2020: the EU should reach a 20% share of renewable energy and a 10% share of renewable fuels for transportation. Since biofuels production costs are higher than those of fossil fuels, different biofuel policies have been put in place within different EU Member States, ranging from command and control instruments, such as standards and shares, to economic and fiscal measures, such as tax exemptions (tax credit). In particular, there are two main policy instruments: either prescription of a mandatory production or subsidization. The first approach consists of prescribing a specific quantity of biofuels to be supplied by fuel suppliers on an obligatory basis (blending or using target mandates). The second solution allows to lower biofuels prices, becoming more competitive compared with those of fossil fuels. This is possible through the implementation of: a) a tax reduction scheme (tax credit) which has proved successful although it has caused important revenue losses for the government; and b) support for the cultivation of agricultural feedstock by the Common Agricultural Policy (CAP). In 2011, these budgetary support measures were removed, making control instruments the only ones still standing (Finco et al., 2012; Gerasimchuk, 2013; Shikida et al., 2014).

Methodology

Time 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 (Rapsomanikis and Halleman, 2006; Hassouneh et al., 2012; Gardebroek and Hernandez, 2013; Serra and Zilberman, 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. All the analyses were carried out using the statistical software Rats32s (Regression Analysis of Time Series).

Data description

In order to verify if agricultural prices are influenced by the prices of biofuels and vice versa, we analyzed two different scenarios: the European biodiesel context and the case of Brazilian ethanol. Since our focus is on biodiesel and ethanol, we include only relevant agricultural commodities, which are used for their production, and only relevant fossil fuels, which are their respective natural substitutes. Our dataset thus contains:

- 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;
- weekly prices of the EU biodiesel blend (Euro/m3), diesel (USD/gallons) and rapeseed oil (USD/MT), which were collected over the period from January 2008 to March 2013. These amount to a total of 270 observations. Biodiesel prices are German consumer prices at the pump and they were obtained from the Bloomberg database; diesel prices were collected from the Energy Information Agency (EIA); rapeseed oil prices were taken from the Data Stream database.

The price series used in the analysis are presented in table 1.

Table 1. Analyzed price series

	VARIABLE	MEASUREMENT UNIT	SOURCE
	Biodiesel	EURO/m^3	Bloomberg
1° MODEL	Rapeseed oil	USD/MT	Data Stream
	Diesel	USD/gallon	EIA
	Ethanol	USD/liter	CEPEA
2° MODEL	Sugar	USD/liter	CEPEA
	Gasoline	USD/bag of 50kg	ANP

Source: own elaboration, 2014

Results

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 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. 2) show that none of them supports the stationarity assumption at all levels (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).

Table 2. Unit root tests (ADF) for the weekly prices

PRICE SERIES	TEST STATISTIC	1%
Biodiesel	-0.553	-2.58
Rapeseed oil	-0.678	-2.58
Diesel	-1.041	-2.58
Ethanol	-0.985	-2.58
Sugar	-0.269	-2.58
Gasoline	-1.541	-2.58

Source: processing Rats32s, 2014

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 results provide evidence that the prices considered are co-integrated with a co-integration rank=1 in both model (Tab. 3 and Tab. 4).

Table 3. Johansen test biodiesel database

P-R	R	EIG.VALUE	TRACE	TRACE*	FRANC95	P-VALUE	P-VALUE*
3	0	0.069	35.272	34.708	35.070	0.047	0.055
2	1	0.040	16215	14.645	20.164	0.167	0.253
1	2	0.019	5252	4.813	9.142	0.266	0.315

Source: processing Rats32s, 2014

Table 4. Johansen test ethanol database

P-R	R	EIG.VALUE	TRACE	TRACE*	FRANC95	P-VALUE	P-VALUE*
3	0	0.070	34.058	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, 2014

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 and biodiesel price, these co-integration relationship (co-integration vector) can be expressed as follows:

$$\text{Ln } P_{biodiesel} = + \underset{(2.934)}{0.531} \text{ Ln } P_{rapeseedoil} + \underset{(0.338)}{0.045} \text{ Ln } P_{diesel} + \underset{(2.878)}{3.352} \qquad (1)$$

$$\text{Ln } P_{etanolo} = + \underset{(2.389)}{0.189} \text{ Ln } P_{sugar} + \underset{(2.959)}{0.699} \text{ Ln } P_{gasoline} - \underset{(4.339)}{0.965} \qquad (2)$$

Coefficients in parentheses are the statistical significance. All the parameter coefficients are significant at 1% level, with the exception of the diesel coefficients.
In the first case, the parameters indicate that biodiesel is positively related with rapeseed oil and diesel in the long-run. More specifically, the cointegration relationship suggests that an increase in rapeseed oil prices in the order of 1% will be followed by an increase in biodiesel prices in the order of 0.5%.
In the second case, 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.

Discussion and conclusion

The sustainability of biofuels derived from agricultural biomass is widely debated nowadays. On the one hand the production of biofuels should ensure energy security for the historically non-oil producing countries, on the other hand it turns on the food versus fuel debate and the land use chance issue, generally responsible for a net loss in GHG emissions savings related to biofuels production and consumption. Concerns over competition between biofuels and food production have been particularly acute, given the overwhelming use of food and feed crops for biodiesel production (Serra, 2011; HLPE, 2013). To date, the literature has been very wide-ranging (Serra et al., 2011; Zilberman et al., 2012; Vacha et al., 2013). According to Hochman et al. (2012) and Kristoufek et al. (2013), the relationship between fuels and agri-food commodity prices depends on the market analysed (EU, US and Brazilian context), on the types of commodities, on the specification of the model and on the time series data and observation period (weekly, monthly or quarterly). Moreover, the dynamics of commodity prices are complicated and different factor may be affecting these markets (Nazlioglu et al., 2012).
This paper has investigated the relationships between the principal agri-food commodity prices for the production of biofuels. The versatility of agry-food commodity, especially sugar and rapeseed oil, allows it to be used for both human and animal nutrition thereby creating

competition between the energy and the food markets in the exploitation of this raw material. The perception that the demand for biofuels is driving up food prices has resulted in the widely voiced contention that governments should lift biofuel mandates and remove the associated subsidies.
At the European level, the cointegration test provides evidence of a single long-run equilibrium relationship between the prices considered, suggesting a positive correlation between biodiesel and rapeseed oil and diesel prices in the long-run, although the relationship with diesel prices is not significant. The positive relationship between biodiesel and rapeseed oil prices is not surprising given the relevance of feedstock costs on the total costs for producing biodiesel (80%). On the other hand, diesel does not seem to affect the price of biodiesel in the long-run. This may be due to the fact that, unlike hydrate ethanol which is widely used in the Brazilian context, European biodiesel is not usually used in its pure form, but is always blended with diesel (7%) and therefore it does not compete directly as a substitute for fossil fuel (Bentivoglio et al., 2014).
At the same time, our results suggest that Brazilian 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. In particular, Brazilian ethanol price is lowly correlated with feedstock price, but strongly connected to fuel price. 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. Summarizing, at least for the market and time span considered, EU biodiesel price is connected with feedstock price; while Brazilian ethanol price is lowly correlated with feedstock price, but strongly connected to fuel price.
This analysis is intended to contribute to the current debate on the relationship between the biodiesel industry on food and fuel prices, and thereby provides guidance to policy makers for formulating future policies and to economic agents for designing their pricing strategies. Moreover, our results contributed to the policy debate about biofuels as possible source of rises in food prices leading to food crises. According to Kristouferk et al., (2012) we confirmed positive correlations among the prices of biofuels and food, but we showed that the distinction should be made between different biofuels.

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