Variation and links among food and energy international prices. An analysis through VAR models from 2000 to 2012.

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Summary

An adequate understanding of the dynamics that characterize the agri-food market is fundamental for the development of really efficient economic policies, especially after the two recent hikes in the prices of food commodities. The econometric literature provides today advanced analysis tools such as VAR models: these models are based on a system of equations in which each variable is regressed on a set of deterministic variables, on a number of l delays related to each covariate in the model. To test the effectiveness of this analytical tool at dealing with the issues related to agri-food economy we applied a VAR analysis on prices of major food and energy commodities (oil and biodiesel) referred to the period January 2005-December 2012.

Our results identified statistically significant intertemporal relationships between the price of corn, soybeans, rapeseed and oil, and suggested the direction of these relationships; we could conclude that the price of corn and soybeans are generated in the energy market only. Moreover, we used as variables the share of commodities used for the production of biofuels, and we could observe that important alterations on the food market are due to the convenience in producing ethanol and biodiesel, since the portion of the crops used for energy is in direct competition with that devoted to the feeding. This kind of models, therefore, deal adequately with datas and issues of the agri-food system and provide an analytical basis to develop economic policies that take into account the complexity of the global food system.

Keywords: alternative energy source, biofuels, var.
JEL Classification codes: C32, Q16, Q42.

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1. INTRODUCTION

Over the past 15 years, the use of biofuels derived from agricultural products (bioethanol, biodiesel, vegetal oils, etc..) has grown rapidly, although in Brazil and the United States, driven by the energy crisis of 1973, bioethanol was used for commercial purposes already from the '70s. In the last years the international debate focused on agricultural products that can also be exploited fir the production of biofuels (corn, sugar cane, soybean oil, canola oil): the question concerns the opportunity to allocate larger and larger shares of agricultural production for energetic purposes rather than for food. On one hand it is argued that the increasing use of biofuels would reduce emissions of carbon dioxide in the atmosphere; on the other, there are some evidence that the impact on gas emissions would be modest (Esposti, 2008) while that on food supply may be considerable, given the competition for the use of land and resources.

This article has two main objectives: on one hand it aims to investigate a central issue in this debate, that is, the interaction between the price of oil, the production of bio-ethanol and the price of food commodities used in the production of biofuels; on the other, it seeks to identify a statistical and econometric method that allows to analyze adequately the dynamics and interactions of food prices.

We decided to proceed using vector autoregressive models (VAR), seeking first to understand whether these models were suitable to treat the data, and then analyzing the results from an economic perspective, in order to catch the intertemporal relationship between these variables, and the extent to which they act on each other: the aim is to understand if the price of food commodities involved in the production of biofuels is mainly generated on the energetic market or on agrifood market.

Our work has the following structure:

- In the beginning a first introductory chapter gives a brief overview on prices of agricultural commodities and energy, their variability and possible interactions; we present a review of the recent history and current situation of the agro-food and energy markets and propose a recognition of the scientific production currently available on the topics in question;
- The following chapter is dedicated to our analysis: the first and second paragraphs contain a methodological recognition on VAR models, while the third section is devoted to the analysis we carried out. In particular, we first of all provide a brief presentation of the data selected, then a description of the models built, and of the results obtained, all followed by comments, possible justifications and empirical, theoretical and legislative validation, and finally an interpretation in the light of which they can be read;
- The research ends with a conclusion, where we try to recompose the evidences and to draw an overall picture of the results obtained, and their possible implications for the present and the future of the global food industry.

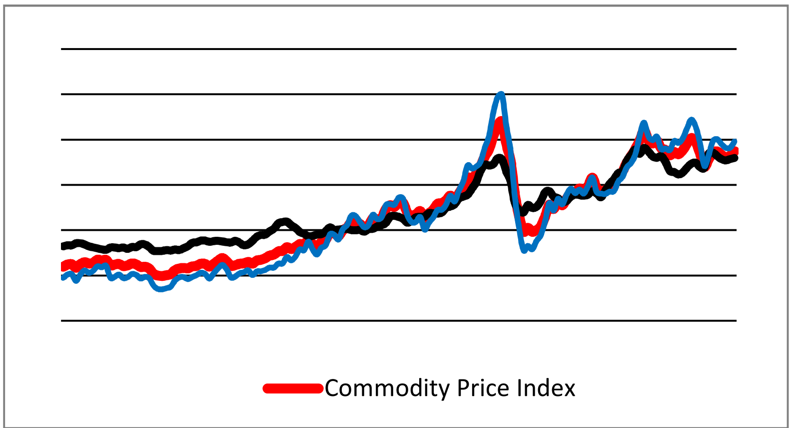
2. AGRICULTURAL COMMODITIES AND BIOFUELS: AN OVERVIEW

2.1 The market of biofuels

The biofuels market is rapidly expanding, and recent forecasts suggest that this growth is likely to continue in the future (Rosegrant, 2008; Frondel and Peters, 2007). This is mainly due to the fact that, being alternative energy sources to fossil fuels, the increase in oil prices and the introduction of environmental policies for the reduction of CO_2 emissions have contributed to their growth (Zezza, 2007).
The European Commission, with the recent strategy "20-20-20" (20% cut in greenhouse gas emissions, reduction of energy consumption by 20% and 20% of energy produced from renewable sources), is working to replace 10% of the demand for fossil fuels from the transport sector, and in order to succeed it is focusing on tax breaks and subsidies that incentive the production of biofuels. The United States and Brazil, the world's major producers and consumers of biofuels, have disposed an increase of the subsidies for this sector: the United States, with the misures included in the 2008 Farm Bill, have increased the production of biofuels, created new refineries and encouraged the search for alternative energy sources; Brazil has stimulated the production of biofuels through the proclamation of policies for agricultural development and of laws requiring the use of a minimum quantity of biofuel in blends.

Globally, the production and consumption of biofuels differs depending on the country concerned. In the United States the biofuels market is dominated by bioethanol obtained from corn processing: about 14% of the corn crop in 2006 was used to produce bioethanol, which corresponds to 4% of the total fuel used in the country (S. Kent Hoekman, 2009). In Brazil, in 2011 the 90% of biofuels used consisted of bioethanol from sugar cane, and 10% of biodiesel made mainly from soybean oil; currently about 45% of the total energy and 19% of the fuels used in Brazil comes from renewable sources (ANP - Agencia Nacional de Petroleo, Gas Natural and Biocombustíveis, 2013). In Europe, about 80% of biofuels used is made up of biodiesel, 19% of bioethanol and the remaining of vegetal oil and biogas; biodiesel is mainly (70%) derived from rapeseed oil (Zezza, 2011).
Between the end of 2007 and beginning of 2008 the world assisted to the first soaring of prices of agricultural commodities, in particular of corn, sugar and soybeans. In general, this increase involved the both cereals and oilseeds: for both the price index passed, in a single year, from 150 to over 280 (Fanfani, 2008). From the second half of 2008 the situation began to stabilize, thanks to the good results of corn production occurred in the world, the appreciation of the dollar against the euro and the decrease in the price of oil. In 2010, however, occurred a new rise in prices of oil, commodities and food products, with the latter reaching a value even higher than in 2008. In the last two years (2011 and 2012), the prices have stabilized but are still relatively high compared to those of 2009 (Figure 1).

Figure 1: Prices of commodities, food and fuel prices (2005 = 100).



Source: IMF Primary Commodity Prices

Generally, a price increase can be attributed to several factors:

- On the supply side possible causes are adverse weather conditions, reduction of stocks, competition in the use of water resources and the rising costs of production and transport;
- On the demand side, the increased demand for biofuels, the change in eating habits and financial speculation (FAO, 2008).

In recent years, in particular, four factors have played an important role in determining the price increase: the growth in global demand for food goods, driven by rising disposable income of several large emerging countries (China, India and Brazil), which has allowed improvements in the living conditions of millions of people, and changed their food habits; the sharp increase in the price of oil, which played a role on the increase in production costs (fertilizer) and transport; poor harvests in exporting countries (Australia, China and many countries in Latin American); and finally financial speculation: in a situation of high global demand, reduced stock and absence of adjustment tools, speculators were attracted by high gains perspective on the futures market, so they begun to bet on it, with heavy consequences on the real market of these goods (Maluf, 2008).

2.2 Literature

The literature concerning this subject is very wide, and many of the most important studies use econometric models to analyze the relations between the prices and the production of agrifood commodities, and those of fuels. According to Hochman *et al.* (2012) the link between fuels and agricultural commodities depends on the market we focus on, on the kind of commodity, on the specification of the model and on the time serie used. Kristoufek *et al.* (2011) analyzed the relations among a wide range of agrifood products and the prices of fuels in the United States and in the European Union and they found out that the interactions vary substantially if they consider time series collected weekly, monthly or quarterly.

Some authors resort instead to time series analysis to study this problem: Serra *et al.* (2011) used auto regressive models to identify the relations among the prices of corn, bioethanol, biodiesel and oil on the United States market between 1990 and 2008, concluding that in the long run these prices are actually bounded, and that when the price of corn reaches high levels, it becomes the main factor on which depends the price of bioethanol. Zhang *et al.* (2009) adopted multivariate autoregressive estimators to study the volatility of the prices of corn, soy, biodiesel and oil on the United States market between 1989 and 2007, discovering that the price of biodiesel influences the price of bioethanol, and that if the latter rises the prices of agrifood commodities are influenced with short term effects. Hertel *et al.* (2010) estimated that, on the United States market, the sharp rise of the prices of biofuels between 2001 and 2006 was mostly due to the increase in the price of oil; the same situation occurred in the european market, but it was mainly explained by the subsidies, and secondly to the oil price trend.

Many studies were based on economic-mathematical models to assess the impact of biofuel production on commodity prices. Goldemberg et al. (2004), through an analysis of bioethanol production in Brazil, found that it increases both the demand and the supply for sugar cane. Mitchell (2008) used a multi-factor analysis model to analyze the growth of prices of food commodities between 2002 and 2008 and concluded that this increase was attributable for 75% to biofuels, together with other factors such as low levels of stocks, speculation and a halt to exports introduced in some countries.

Many, in addition to Mitchell, have attributed to biofuels a strong influence on the price of food commodities. The IMF has estimated that in 2008 the growth in the use of biofuels determined the 70% of the rise in the price of corn and 40% of that of soy (Esposti, 2008). For Trostle (2008) the increased share of corn and sugar cane produced for bioethanol is one of the main causes of the price boost of these commodities. According to the Farm Foundation (2008) the recent increase in oil prices, partly due to the depreciation of the dollar, has been the main cause of the growth of the demand for bioethanol in the United States, while before 2005 the demand for biofuels had a greater impact on the price of corn (because of the subsidies introduced by the U.S. government).

Conversely, Zilberman et al. (2012) argue that the price of ethanol is influenced both by the price of agricultural products and by that of fuel, but that the connection between the first two is weak. This is explained with two arguments:

- the studies on the relationship between fuel and food prices estimate *marginal* effects, while most of the literature on the impact of biofuels on the price of the agrifood commodities tries to evaluate the *total* effect on the price change, in the transition from food product to energy product;
- the impact of a change in the price of biofuels on the price of food products is not clear a priori.

3. ENERGY MARKET AND AGRIFOOD MARKET: A VAR ANALYSIS

3.1 VAR models

The agricultural commodities market is characterized by complex dynamics, which require a multivariate approach. Economic variables often appear to be self-correlated and cross-correlated for several time lags. The need to build models that take into account the intertemporal structure of data arises from the complexity of the relations guiding the economic system.

In particular, for the analysis of time series, it is widespread the use of vector autoregressive models, better known as VAR models. VAR approach was first proposed by Sims in 1980, as an alternative to Simultaneous Equations Models, which were the main instrument for macroeconomic analysis until that moment. VAR process are the multivariate generalization of AR models: a VAR is actually a system where every variable is regressed on a set of deterministic variables on *p* lags, referred to every covariates in the model.

The lag operator is usually applied to numeric sequences and allows to transform the X_t sequence (both stochastic or not) in another sequence that has the same values present in X_t, with one lag (Podestà, 2011).

Therefore, the following form of the operator

$$LX_t = X_{t-1}$$

becomes, after repeating *n* times the application of the lag

$$L^n X_t = X_{t-n}$$

L is a linear operator, which means that if *a* and *b* are two constants, we will have

$$L(ax_t + b) = aLx_t + b = ax_{t-1} + b$$

In general a VAR model of rank *p* will assume the following form:

$$y_{t=}\mu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t$$

where A_i are $k \times k$ coefficient matrices; $\mu = (\mu_1, \cdots, \mu_k)$ is a $k \times 1$ vector of intercepts and $u = (u_{1t}, \cdots, u_{kt})$ is a *k*-dimensional white noise process, which variance-covariance matrix is non singular for assumption.

The application of any methodology within VAR models require as a necessary condition the stationarity of the autoregressive representation: a VAR process satisfies such a condition if all the eigenvalues of the *companion* matrix fall into the unit circle, that is are lower than one.

The *companion* matrix is $Kp \times Kp$ dimensional, it's composed by the A_i matrices and is represented as:

$$A = \begin{bmatrix} A_1 & A_2 & \cdots & A_{p-1} & A_p \\ I_k & 0 & \cdots & 0 & 0 \\ 0 & I_k & \cdots & 0 & 0 \\ \vdots & \cdots & \ddots & \vdots & \vdots \\ 0 & \cdots & 0 & I_k & 0 \end{bmatrix}$$

VAR models, if stationary and well specified, allow to analyze many aspects of time series, and give substantial information about them. Examining the intertemporal links among different variables, these models are appropriate both for forecasting future values of the series, and for a dynamic analysis of present values, in particular for the existence of causality relations among the covariates. This particular analysis is based on the concept of Granger causality (1969).

3.2 Analysis of Granger causality

In empirical analysis of economic data it is often of much interest to establish cause-effect relationship, though it might also result quite difficult. In general, if two variables X and Y show an important correlation, we might assume that they tend to follow the same trend, but in absence of further information, we can't add more observations about the direction of the causality. Given an estimate VAR model, we can also take a test to verify the joint significance of the lags structure of y_{1t} in the equation referred to y_{2t}. The test itself is built as a maximum likelihood ratio, or a simple F statistic.

The most appropriate way to interpret this kind of test is to see it as graphic analysis, that can show whether the trend of a variable follows or foreruns that of another variable.

Some interpretation problems often arise, mostly because the representation on a reduced form of VARs does not apply very well to drow general conclusions. These considerations are actually based, within VAR analysis, on the results obtained from the Impulse Response Functions.

The purpose of the analysis of Granger causality is to evaluate the predictive capacity of a single variable on the other ones of the system. If a variable, or a group of variables, y_{1t} fosters the forecasts of another variable y_{2t} or group, then y_1 Granger-causes y_2. Formally:

- let $y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix}$ be a multivariate time serie where the K components are divided in two groups y_{1t} and y_{2t};
- let $F_t = \{y_t, y_{t-1}, \cdots\}$ be the set of all the observation until time *t*;
- let $y_{2,t+h/t}$ be the optimal predictor of $y_{2,t+h}$ based on F_t, and with $\sum_2(h/F_t)$ its mean square error;

then y_{1t} Granger-causes y_{2t} if $\sum_2(h/F_t) < \sum_2(h|F_t/\{y_{1s}|s \leq t\})$ for at least one $h = 1, 2, \cdots$.

Considering, for example, the following stationary VAR(p):

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} \phi_{11,1} & \phi_{12,1} \\ \phi_{21,1} & \phi_{22,1} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \cdots + \begin{bmatrix} \phi_{11,p} & \phi_{12,p} \\ \phi_{21,p} & \phi_{22,p} \end{bmatrix} \begin{bmatrix} y_{1,t-p} \\ y_{2,t-p} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}$$

with $u_i \sim WN(0, \Sigma)$ and Σ non singular, then

$$\textstyle\sum_2(h|F_t) < \sum_2(h|F_t/\{y_{1s}|s \leq t\}),\ h = 1, 2, \cdots \Leftrightarrow \phi_{21,i} = 0$$

then y_{1t}doesn't Granger-cause y_{2t} if $\phi_{21,i} = 0$, while if $\phi_{12,i} = 0$ for $i = 1, 2, \cdots p$, y_{2t} does not Granger- cause y_{1t}. It is important to note that if the VAR is stationary, the hypothesis "Y_1 does not cause Y_2" can be tested by a simple F-test: in fact, the hypothesis of absence of Granger causality is equivalent to the following linear restriction on the parameters:

$$H_0: A_1 = A_2 = \cdots = A_p = 0$$

3.3 Application of the VAR model to commodity market

The objective of the research is to identify causality and connections between agrifood and energy markets, focusing in particular on prices: in the first part the analysis was centered on the relationship among the prices, so we chose as variables time series of the prices of agricultural commodities and fuels, in particular the world current prices, recorded monthly, from January 2000 to December 2012[1]. This period was selected since it is large enough to show how the trend of the agricultural commodities prices, which until the beginning of 2000 had been of relatively slow and steady decline, has been reversed from 2003, assuming a positive trend but becoming extremely volatile (FAO, 2011). This time, however, is not so extensive as to make the intertemporal comparison among prices prove meaningless without adjustments that take into account inflation and global economic trends: inflation, however, was not considered because difficult to assess, on a global level, in our model.

The products chosen as variables for our analysis are corn, rapeseed oil, sugar cane and soybean oil as regards agricultural commodities, and oil, bioethanol and biodiesel as fuels. The choice of oil is almost obliged, since it is the most widespread and used fossil fuel; the trend of its price is closely linked to that of other competitor energy goods, and also represents the main cost of production for most of the commodities, being the fuel for agricultural machinery and a component of nitrogen fertilizers. Bioethanol and biodiesel are, on the other hand, the two most widely used biofuels in the world. Corn, rapeseed oil, soybean oil and sugar cane are the raw materials used to obtain these fuels. In particular, it is noted globally a geographic specialization of production: corn is the main product for bio-ethanol in the United States, while Brazil uses sugar cane; as regards biodiesel, rapeseed oil and soybean oil are the most commonly used raw materials, especially in the EU. These three countries can be taken without any question as the target market for these biofuels: together they produce more than 90% of the global share of bioethanol, and more than 80% of biodiesel (Esposti, 2008).

The first part of the analysis was conducted using as variables the time series of monthly world prices of corn, oil, biodiesel, soybean oil, sugar cane and rapeseed oil[2]. The period covered goes from January 2000 to December 2012. The second part of the analysis has been restricted to the case of the U.S. market: this time we used as variables the share of corn and soybean oil intended, respectively, to produce bioethanol and biodiesel; the portion of corn and soybean oil destined for the domestic market; and world prices of corn, soybean oil, biodiesel and petroleum.

The vector autoregressive models have been particularly useful for the achievement of our objectives: the structure of the data provides indeed, through the VAR analysis, the generating process of the same, useful to forecast and explain the links between economic variables. The analysis consists of the following phases:

- identification of the number of parameters *p* of the VAR;
- OLS estimation of the parameters of the VAR (*p*);
- control of the adequacy of the estimated model through the diagnostic of residual;
- Granger causality.

In order to identify the number of parameters we used Akaike information criteria (AIC), Hannan-Queen (HQ), Schwarz (SC) and the final prediction error (FPE); for the diagnostic of residuals were used the Portmanteau test, the Breusch-Godfrey and the Jarque-Bera test, to verify the absence of autocorrelation of residuals and normality distribution of the latter[3].

Initially, the analysis began with the construction of a correlation matrix which uses as variables the price of agricultural commodities involved in the production of biofuels (corn, canola, soybean oil and sugar cane) and the price of oil. The observed correlations justify the construction of a VAR model, that results as a system of five equations with *m* indicating the price of corn, *s* the price of soybean oil, *r* that of rapeseed oil, *c* the sugarcane price and *p* the price of oil. The constructed VAR is of the following type:

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[1] The reference period applies to the prices of all commodities analyzed, only exception is the biodiesel prices, which are only available from July 2006, so VARs built with these data as variables were constructed considering only the period from 2006 to 2012.

[2] The time series used for the analysis of corn and ethanol range from January 2000 to December 2012, while the period considered for the analysis of soy from July 2006 to December 2012. This choice is based on the availability of data.

[3] The statistical software used is R 2.14.2; analysis was implemented using the R packages *Tseries* and *vars*.

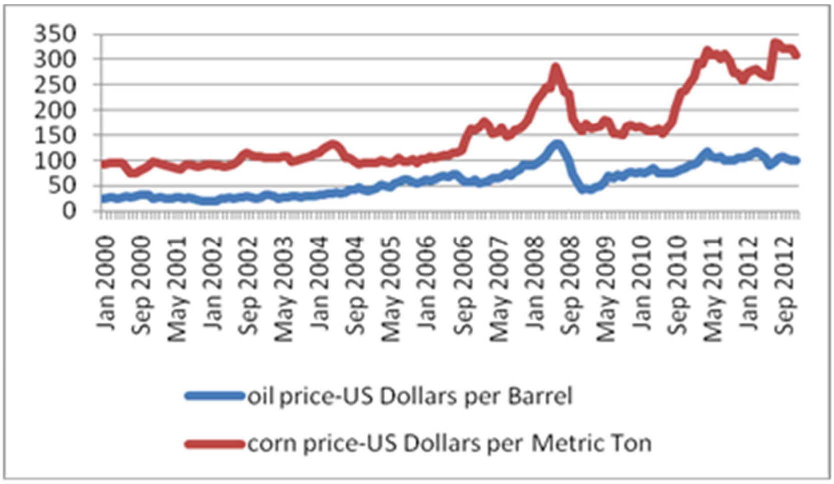
$$\begin{cases} p_t = \beta_1 p_{t-1} + \beta_2 m_{t-1} + \beta_3 r_{t-1} + \beta_4 b_{t-1} + \beta_5 s_{t-1} + \beta_6 c_{t-1} + \varepsilon \\ m_t = \beta_1 p_{t-1} + \beta_2 m_{t-1} + \beta_3 r_{t-1} + \beta_4 b_{t-1} + \beta_5 s_{t-1} + \beta_6 c_{t-1} + \varepsilon \\ r_t = \beta_1 p_{t-1} + \beta_2 m_{t-1} + \beta_3 r_{t-1} + \beta_4 b_{t-1} + \beta_5 s_{t-1} + \beta_6 c_{t-1} + \varepsilon \\ b_t = \beta_1 p_{t-1} + \beta_2 m_{t-1} + \beta_3 r_{t-1} + \beta_4 b_{t-1} + \beta_5 s_{t-1} + \beta_6 c_{t-1} + \varepsilon \\ s_t = \beta_1 p_{t-1} + \beta_2 m_{t-1} + \beta_3 r_{t-1} + \beta_4 b_{t-1} + \beta_5 s_{t-1} + \beta_6 c_{t-1} + \varepsilon \\ c_t = \beta_1 p_{t-1} + \beta_2 m_{t-1} + \beta_3 r_{t-1} + \beta_4 b_{t-1} + \beta_5 s_{t-1} + \beta_6 c_{t-1} + \varepsilon \end{cases}$$

Most of the parameters resulted not significant; this model, however, allowed to identify some relations, which we subsequently deepened through the construction of bivariate VARs. First or all, anyway, we built two separate models, one for the prices of food products and one for the prices of the two energy commodities, with the aim of identifying the relationships that bind intertemporally prices of products belonging to the same market.

Most of the VAR parameters built only with the prices of food commodities are not significant: this is an indication of a lack of intertemporal relationship between the prices of these products; the same results were obtained from the model containing as variables the price of oil and biodiesel. This outcome shows that probably the prices of energy commodieties and those of food commodities are interrelated, therefore it is appropriate to consider the construction of bivariate models using as dataset the prices of products belonging to the food market and those belonging to the energy market.

The first bivariate model analyzed has been built using world prices of corn and oil. In Figure 2 are represented the two series and we can see that prices trends are similar.

Figure 2: Corn Price and Oil Price, 2000-2012.



Elaboration from World Bank dataset

From these dataset we esteemed a VAR with two lags that produced two equations; one that uses as response variable the price of corn (*m*) at time *t* and the other that uses as response variable the price of oil (*p*) at time *t*:

$$p_t = 1.29p_{t-1} + 0.12m_{t-1} - 0.37p_{t-2} - 0.1m_{t-2} + 2.7$$
$$m_t = 0.02p_{t-1} + 1.12m_{t-1} - 0.04p_{t-2} - 0.16m_{t-2} + 2.7$$

All esteemed parameters are significant, i.e. there is a intertemporal relationship among these two prices. After that, we have made Granger causality test (Table 1) and we found the direction of this relationship: corn price Granger-causes oil price, and not viceversa.

Table 1: Granger causality test-null hypothesis – Corn and oil prices (2000-2012).

TEST 1	H_0 : oil price doesn't cause corn price	p-value= 0.7644
TEST 2	H_0 : corn price doesn't cause oil price	p-value= 0.0056

We have divided the period 2000-2012 in three time series and made a VAR model for each one. This division is due to economic considerations: the first period (January 2000 – December 2005) is the pre-crisis period without price rises; the second period (January 2006 – December 2008) is the pre-crisis period with the first increase of the prices; and the third period (January 2009 – December 2012) is the post-crisis period. In the VAR model from 2000 to 2005 there is no statistically significant relationship between corn price and oil price, while the following models show statistically significant intertemporal relationship, although with some differences. The VAR model with two lags from 2006 to 2008 introduces, in the equation with oil price as response variable, a not significant reported parameter to the corn price at time *t-2*, while the VAR model with one lag from 2009 to 2012 has significant parameters. In the second VAR model (2006-2008) the Granger causality test result of difficult interpretation: p-value of null-hypothesis "*oil price doesn't cause, in the Granger sense, corn price*" is equal to 0.049, near to the threshold of significance; we can't neither reject neither accept this hypothesis. The second test, instead, has a p-value equal to 0.0049, i.e. we can't accept H_0 and we say that corn price causes, in the Granger sense, oil price.

Table 2: Granger causality test-null hypothesis – Corn and oil prices (2006-2008).

TEST 1	H_0 : oil price doesn't cause corn price	p-value= 0.049
TEST 2	H_0 : corn price doesn't cause oil price	p-value= 0.0049

Threshold values come up in the two Granger causality test of the last VAR model: p-value is 0.049, i.e. is not possibile to reject or to accept the null hypothesis "*corn price doesn't causes, in the Granger sense, oil price*", while the second test allows to say that "*oil price doesn't cause, in the Granger sense, corn price*".

Table 3: Granger causality test-null hypothesis – Corn and oil prices (2000-2012).

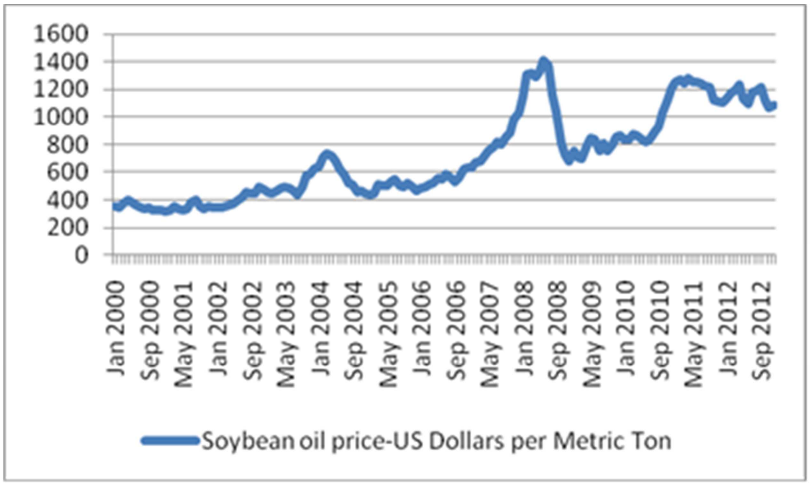
TEST 1	H_0 : oil price doesn't cause corn price	p-value= 0.049
TEST 2	H_0 : corn price doesn't cause oil price	p-value= 0.051

Intertemporal relationship between corn price and oil price is recently and still changing. The importance of corn price to establish the direction of the causality is probably due to the convenience to produce bioethanol: besides, in the VAR models from 2006 to 2008 and from 2009 to 2012 the null-hypothesis "*corn price doesn't causes, in the Granger sense, oil price*" is rejected or is not entirely rejectable.
The same anlysis has been made using world' soybean oil and oil prices from January 2000 to December 2012 and dividing this period in the same three periods used previously. The results obtained are similar to the results of the VAR models for corn price and oil price. Using as response variable the price of soybean oil (*s*) and the price of oil (*p*) at time *t*, the model, with one lag, is:

$$p_t = 0.69p_{t-1} + 0.02s_{t-1} + 1.79$$
$$s_t = -1.69p_{t-1} + 1.08s_{t-1} + 69.74$$

All parameters are significant, stationary VAR and residual-based test gave a negative result.

Figure 3: Soybean oil price, 2000-2012.



Elaboration from World Bank dataset

From the Granger causality test it emerges that soybean oil price cause, in the Granger sense, oil price, and not viceversa. From the first VAR model (from 2000 to 2005) we haven't drawn any statistically significant intertemporal relationship, while in the other periods the situation is modified and from 2006 there is a statistically significant intertemporal relationship. Particularly, there is a mutual causality in the Granger sense between soybean oil price and oil price. Such mutual connection, however, doesn't exist in the following period: from January 2009 to December 2012 soybean oil price causes, in the Granger sense, oil price. We can say that the relationship between these prices is recent and the result "*soybean oil price causes, in the Granger sense, oil price*" has been produced in the last four years of the time series 2000-2012. The relationship can be explained by the increase of the soybean oil use for the prduction of biodiesel.

Table 4: Granger causality test-null hypothesis – Soybean oil and oil prices (2000-2012).

TEST 1	H_0 : oil price doesn't cause soybean price	p-value= 0.065
TEST 2	H_0 : soybean price doesn't cause oil price	p-value= 0.0006

Table 5: Granger causality test-null hypothesis – Soybean oil and oil prices (2006-2008)

TEST 1	H_0 : oil price doesn't cause soybean price	p-value= 0.007
TEST 2	H_0 : soybean price doesn't cause oil price	p-value= 0.0219

Table 6: Granger causality test-null hypothesis – Soybean oil and oil prices (2009-2012)

TEST 1	H_0 : oil price doesn't cause soybean price	p-value= 0.2126
TEST 2	H_0 : soybean price doesn't cause oil price	p-value= 0.0017

With the monthly dataset of biodiesel price (b) and soybean oil price (s)[4] we have made another VAR model:

$$b_t = 0.71b_{t-1} + 0.0007s_{t-1} + 0.02$$
$$s_t = -58.91b_{t-1} + 1.08s_{t-1} + 70.03$$

From the Granger causality test we observe a mutual causality among these two prices: it means that soybean oil price depends on the energy market.

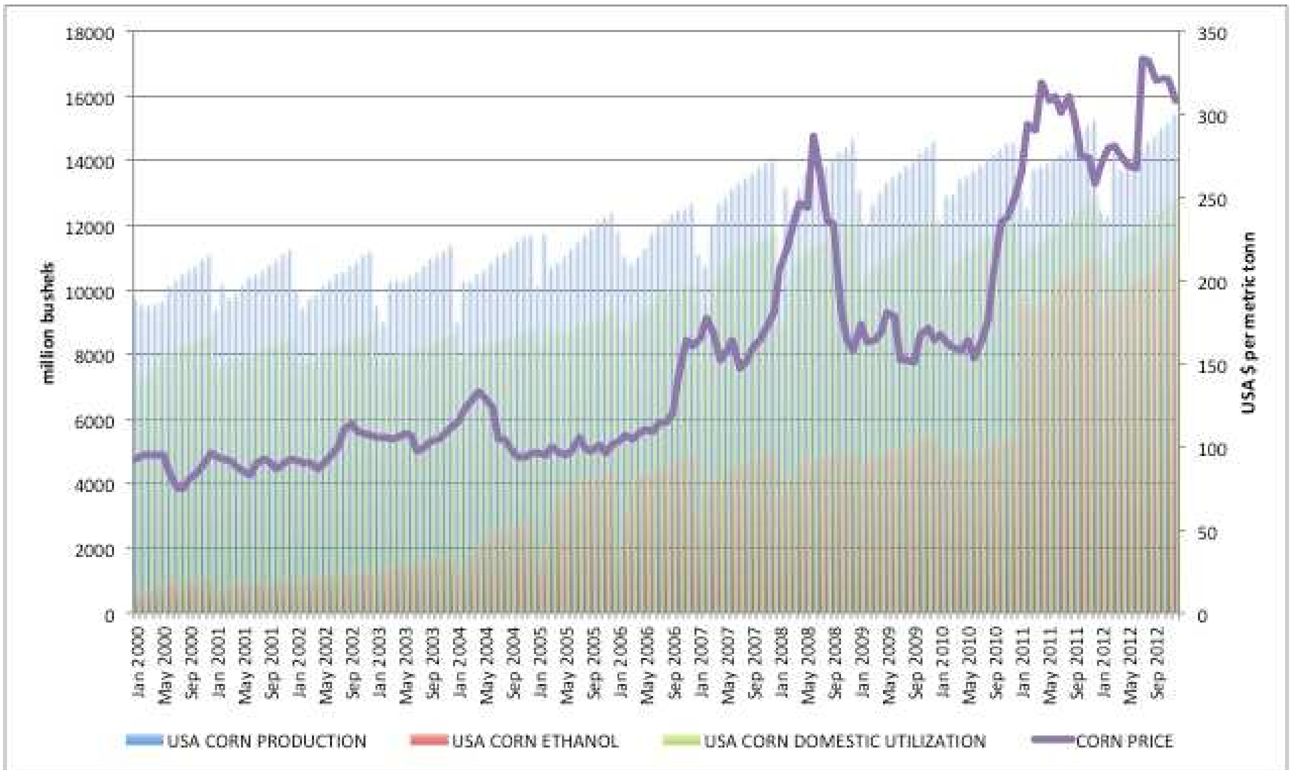
[4] Time series is from July 2006 to December 2012, due to the availability of data.

3.4 The United States market

The choice to analyze the United States market depends on the central role that the country has assumed in the bioenergy market, and in particular in the production of corn for bioethanol. The variables considered in this model are not only related to the prices of corn, soybean oil and energy products, but also to the quantities produced and the share of the crops of these two cereals intended for food use and energy use.

Once again it was decided to deal with the problem by building bivariate VAR. And it's interesting to observe the Figure 3 where, in addition to the price, we reported in the amount of corn produced, that intended for the production of bioethanol and that destined to domestic use from January 2000 to December 2012: all these quantities are characterized by an increasing trend, but that of the amount of corn for the production of bioethanol followed a different evolution compared to the other variables.

Figure 3: Corn: price, total production, domestic and fuel destination.



Elaboration from World Bank dataset

In January 2000, the percentage of corn destined to the energy market was 8%, while at the end of 2012, the share used for ethanol was 59%, and in general the volume of corn production increased by 56% from 2000 to 2012. The most important growth in the amount of corn for the production of bioethanol happened in January 2011: in December 2010, the percentage of corn destined for the energy market stood at 9%, while in the following month it jumped to 67% . This is probably due to the approval, in February 2010, of the RFS2 program (Renewable Fuel Standard 2), which has set ambitious targets for the reduction of greenhouse gases through the use of biofuels and the development of the alternative energies sector: this caused a strong increase in the demand for corn for the production of biofuels. In the same period the price of corn grew sharply, both thanks to the policy factor, and because of forecasts errors in the estimation of crops and reduction of stocks of corn. The scarcity of production might have prompted many farmers to devote the majority of their crop for bioethanol production, since it was more convenient than the food destination.

The first VAR considered in this context is one that uses as variables the price of corn (*m*) and the amount of corn (*qm*) intended to bioethanol:

$$qm_t = 0.91qm_{t-1} + 4.12m_{t-1} - 189.7$$
$$m_t = 0.001qm_{t-1} + 0.94m_{t-1} + 4.05$$

The model was built with one delay and fits the data well; it is important, however, to note that in the equation having the price of corn as a response at time *t*, the parameter related to the amount of corn for the production of bioethanol has a significance level of 1%, therefore, it cannot be considered significant. The Granger causality test, indeed, shows that it is not the amount of corn used for the production of biofuel to cause, in the sense of Granger, the price of corn, but rather the contrary. The direction of this relation explains how the greater or lesser convenience in producing bioethanol determines the grown quantity, causing variations in the portion of corn intended for the energy market rather than for food

Always looking at the Figure 3 we can see that the corn produced for domestic use and employed for bioethanol has increased significantly over time. Therefore, using as covariates the portion of corn destined for domestic use (*d*) and those for the production of bioethanol, let interesting results emerge: only the equation with corn for domestic use as the response variable presents significant parameters, and Granger test shows that it is the amount of corn used for the production of bioethanol to influence, in the Granger sense, the quantity for internal use and not vice versa. This means that the growing demand for biofuels has a considerable impact on the allocation of the production, and that the domestic demand for corn was affected by this influence.

Finally, we decided to proceed with the construction of a vector autoregressive model to identify the existence of a linear intertemporal relationship between the amount of soybean oil (*qs*) for the production of biodiesel and the price of the latter (*b*). The VAR is constructed as follows:

$$qs_t = 0.51ds_{t-1} + 544.82b_{t-1} + 153.97$$
$$b_t = -5.544e^{-0.5}qs_{t-1} + 9.78b_{t-1} + 2.697$$

The first equation presents all significant parameters, while the second equation's only significant parameter refers to the price of biodiesel at time t-1. The Granger causality test has allowed, now, to identify the direction of this relationship: it is the price of biodiesel to determine, in the Granger sense, the amount of soybean oil to be allocated to the production of biofuel. Again, therefore, is the greater or lesser convenience in producing biodiesel that affects heavily the amount of soybean oil produced.

4. CONCLUSIONS

We have analyzed the relationship among the principal agri-food commodities used for the production of biofuels, crude oil and biofuels themselves. Most of these products are made with the same input destined to human and animal nutrition, and this creates a competition in the allocation and the use of raw materials between energy market and food market. Through VAR models we tried to understand how agri-food commodities' prices have been influenced by the energy market rather than food market.

The first conclusion is methodological: the vector autoregressive models resulted to be particularly appropriate to the study of prices, in particular the data are well described by the VAR model which, in all cases, showed very high indices of goodness of fit. The VAR methodology have been particularly interesting since it has allowed to detect the presence or absence of statistically significant relationships between the prices used as variables and, most of all, through the Granger causality, it let us deepen these relationships by identifying the direction of the causality. It is important, however, to emphasize that this kind of test does not claim to identify ever valid relationships, but the ties apply in the context we analyzed, which is, in the VAR we built considering only two variables. In any case, the results obtained allow us to draw some interesting conclusions from an economic point of view.

Considering the global level, corn price and soybean oil price cause, in the Granger sense, crude oil price. It means that, through VAR models, it has been observed that "*corn price*" and "*soybean oil price*" past observations are useful to predict the trend of "*oil*" variable. We have found this casuality between 2009 and 2012: this is probably due to the increasing employment of corn and soybean oil as factors of production for biofuels and to the fact that oil is used both for production of these cereals and substitute good of biofuels. The recent strengthening of this relationship has also been observed by Wisner (2009), who observed a weak relationship between oil price and corn price until 2007, whereas from 2007 to 2009 he notice a consolidation of this link.

We also observed a relationship of mutual causality between biodiesel price and soybean oil price. This relationship can be explained by the use of soybean oil for the production of biodiesel in Brazil and USA, which are both the greatest producers of soybean in the world and the main consumers for biodiesel. In Brazil, the National Program of Production and Use of Biodiesel (PNPB) has stimulated the use of soybean as primary input to produce biodiesel (among 77% and 86% from 2007 to 2011): currently 14% of Brazilian soybean (ANP, 2012) is destined to the production of biofuels. Also in the USA about 14% of soybean production is destined to the production of biodiesel (in 2011) and the 65% of used biodiesel is mainly composed of soybean (Wisner, 2013).

The analysis of the U.S. market has shown that the price of corn causes (always in the Granger sense) the amount of corn used to produce ethanol, which in turn causes the amount of corn for domestic use. The growing importance of the biofuel market clearly emerges here, and evidences in current and future trends in the consumption of biofuels confirm this hypothesis (in the United States the amount of corn used for ethanol production has increased from 5% of the total in 2001 to 30% in 2010 (Hertel and Beckman, 2010)). This growth was influenced by several factors:

- the increase in state subsidies given over the past 10 years;
- the future prospect of an increase in profits related to the production of corn;
- the promotion of "green" policies that fostered the development of biofuels.

Food production destined to human consumption and commodity prices have been influenced by an increase of the importance of bioenergies. Allocation of goods for energetic use interfere on available quantity and price of food products, and therefore it influences food safety, especially in developing countries (Diouf, 2008). On the other hand, to enhance the use of renewable energies could be a good practice to prevent the negative impact of fossil fuels on environment. It is important to discuss about such problems and renew the debate on energy policies' sustainability, to avoid a lack of balance between food production and biofuels production.

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