A dynamic analysis of causality between prices of corn, crude oil and ethanol

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Abstract. The objective of the paper is to analyse causality among prices of corn, crude oil and ethanol. The analysis conducted in this paper is a dynamic one, and the data used consist of weekly futures prices of crude oil, corn, and ethanol from January 5, 2007 till April 11, 2014. The assessment of causal links between prices of corn, crude oil and ethanol is carried out with the use of rolling regression applied to augmented-VAR framework proposed by Toda and Yamamoto [22]. The application of the rolling regression procedures into the modified Wald (MWALD) causality test allows for the investigation of the persistence of stability in causal relations between analysed prices. The results obtained indicate that the linkages between energy prices and agricultural commodity prices change in the period analysed. The results of Granger causality tests reveal that in the analysed period the price of corn influences the price of energy (crude oil and ethanol). Also crude oil prices influence corn prices and ethanol prices. However, the influence of ethanol prices on crude oil prices and corn prices has not been observed.

Keywords: Granger causality, rolling regression, Toda -Yamamoto tests, commodity prices.

JEL Classification: C32, Q13, Q41
AMS Classification: 91B84, 62M10

1 Introduction

Limited fossil fuel resources and the fact that the demand for them is growing continuously coupled with the economic development and excessive pollution of the environment lead to the increase in the significance of renewable energy source. Additionally, the European Commission has set an overall binding target to satisfy 20% of the EU energy needs from renewable sources, such as biomass, hydro, wind and solar power by 2020. As part of the overall target, each member state has to achieve at least 10% of their transport fuel consumption from renewable sources (including biofuels). The factors mentioned above have resulted in the growth in the production of ethanol in the period 2007 - 2013 by about 70%. However, such increased demand for ethanol fuel translates into greater demand for corn, which, in turn, increases the prices of corn. On the other hand, the increase in the production of biofuels changes the structure of energy sources, which affects the prices of fossil fuel, including crude oil prices. What is more, Kilian and Park [8] claim that the price of crude oil has the greatest influence on food prices because its increasing price raises both transport costs and food production costs through the growth of fuel costs for mechanized farming. Additionally, growing prices of crude oil increase the economic motivation for the production of biofuels (corn, soybean, sugar cane, oil palm, etc.).

Hence, one of the most important effects of the growing biofuel production has been the change in the nature of the linkages between agricultural commodity markets and energy markets. Thus, it is interesting to investigate how the prices of biofuels affect fossil fuel prices and food prices and vice versa. In this study we analyse causality between corn prices representing the food prices, crude oil prices representing the fossil fuel prices, and ethanol prices representing the biofuel prices.

The investigation of related issues can be seen in numerous recent studies, although their conclusions are inconclusive. Some researchers analyse only the relations between food and fossil fuel prices generally ignoring biofuel prices. Some studies confirm the linkages between food prices and crude oil prices (e.g: Chen et al. [1], Ciaian and Kancs [2], Ciaian and Kancs [3], Harii et al. [7], Natanelov et al. [11], Nazlioglu and Soytas [14]; Nazlioglu [13], and Papież and Śmiech [16]). Other empirical studies report no evidence regarding the oil–food price nexus, thereby supporting the neutrality hypothesis. Nazlioglu and Soytas [15] and Zhang et al. [27] find agricultural commodity prices to be neutral to the effects of oil price changes in the long run.

Subject literature contains a large number of studies on the linkages between the prices of energy sources (fossil fuels and biofuels) and the prices of food. Many of these studies use time-series econometric techniques to quantify the relations between oil, ethanol, and food prices in levels (e.g., Kristoufek et al. [9], McPhail [10],

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Natanelov et al. [12], Qiu et al. [17], Saghaian [19], Serra et al. [20], Wixson and Katchova [24], Zhang et al. [26], and Zhang et al. [27]) or their volatility interactions (e.g., Gardebroek and Hernandez [5], Haixia and Shiping [6], Trujillo-Barrera et al. [23]). However, to the best of our knowledge, dynamic causality in the crude oil–corn–ethanol–nexus analysed with the use of the rolling regression procedures applied into the modified Wald (MWALD) causality test has not been addressed in any of them yet.

The objective of this study is to investigate dependencies among prices of corn, crude oil and ethanol, using weekly futures data spanning from January 5, 2007 to April 11, 2014. The analysis of dependencies has a dynamic nature and focuses on Granger causality between the variables. The assessment of causal links between the variables is carried out with the use of rolling regression applied to augmented-VAR framework proposed by Toda and Yamamoto [22]. The application of the rolling regression procedures into the modified Wald (MWALD) causality test allows for the investigation of the persistence of stability in causal relations between analysed prices.

The analysis conduced allows us to verify the following hypotheses:

- The dependencies between the prices of energy sources and the food prices are not stable in time.
- The prices of biofuels or fossil fuels affect food prices in the short run.
- Food prices affect the prices of biofuels or fossil fuels in the short run.
- The prices of biofuels affect the prices of fossil fuels in the short run.

This paper contributes to the existing literature mostly due to the application of the dynamic analysis, which allows us to assess the stability of the dependencies between the variables. Additionally, incorporating the rolling regression procedure into causality tests provides more information on the issue of the crude oil–corn–ethanol–nexus. What is more, using a rolled window in the analysis makes it possible to indicate breaking points and facilitates their further interpretation.

The paper is organized as follows. Section 2 presents methodology. Data, the discussion of the methods used and the results obtained are given in Section 3, while Section 4 contains the main conclusions.

2 Methodology

The assessment of causal dependencies between prices of corn, crude oil and ethanol is carried out with the use of rolling regression applied to augmented-VAR framework proposed by Toda and Yamamoto [22] and developed by Rambaldi and Doran [18] and Zapata and Rambaldi [25]. This procedure avoids the problems of testing for Granger causality with respect to the power and size properties of unit root and co-integration tests (Zapata and Rambaldi [25]). The approach suggested by Toda and Yamamoto [22] applies the modified Wald (MWALD) causality test to the model $VAR(k + d_{\max})$, where k is the lag length of the system determined by information criteria (Akaike Information Criterion (AIC) or BIC), and $d_{\max}$ is the maximal order of integration. In a nutshell, the T–Y methodology involves the following stages. Firstly, the lag length (k) of the system VAR and the maximal order of integration $(d_{\max})$ are established. Secondly, the augmented $VAR(k + d_{\max})$s in levels are estimated. Next, for the model $VAR(k + d_{\max})$ the Wald test to the first k VAR coefficient matrix is performed to test for Granger causality. For testing the null hypothesis, Toda and Yamamoto [22] confirm that the Wald statistic has the asymptotic χ^2 - distribution with k degrees of freedom, regardless of whether the generating process is stationary (possibly around a linear trend) or cointegrated.

In our case, T–Y version of $VAR(k + d_{\max})$ can be written as:

$$\begin{aligned} OIL_t = \alpha_{01} + \sum_{i=1}^{k} \alpha_{1i} OIL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \alpha_{2j} OIL_{t-j} + \sum_{i=1}^{k} \beta_{1i} CORN_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \beta_{2j} CORN_{t-j} + \\ + \sum_{i=1}^{k} \gamma_{1i} ETHANOL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{2j} ETHANOL_{t-j} + \varepsilon_{1t} \end{aligned} \quad (1)$$

$$CORN_t = \alpha_{02} + \sum_{i=1}^{k} \alpha_{3i} OIL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \alpha_{3j} OIL_{t-j} + \sum_{i=1}^{k} \beta_{3i} CORN_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \beta_{4j} CORN_{t-j} + \\ + \sum_{i=1}^{k} \gamma_{3i} ETHANOL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{4j} ETHANOL_{t-j} + \varepsilon_{2t} \qquad (2)$$

$$ETHANOL_t = \alpha_{03} + \sum_{i=1}^{k} \alpha_{5i} OIL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \alpha_{6j} OIL_{t-j} + \sum_{i=1}^{k} \beta_{5i} CORN_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \beta_{6j} CORN_{t-j} + \\ + \sum_{i=1}^{k} \gamma_{5i} ETHANOL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{6j} ETHANOL_{t-j} + \varepsilon_{3t} \qquad (3)$$

The directions of Granger causality can be detected by applying standard Wald tests to the first k VAR coefficient matrix. For example, for Eq. (1): $H_0 : \beta_{11} = \beta_{12} = ... = \beta_{1k} = 0$, implies that corn prices (CORN) do not Granger cause crude oil prices (OIL), and $H_0 : \gamma_{11} = \gamma_{12} = ... = \gamma_{1k} = 0$, implies that ethanol prices (ETHANOL) do not Granger cause crude oil prices (OIL).

The changes in dependencies between the variables over time are investigated with the use of rolling analysis (Smiech and Papież [21]). We apply the fixed window rolling regression to the level VAR model. The first model is built using the data covering observations from 1 to n, the second model covers observations from 2 to n+1, etc.. Every time AIC is used to fix the number of lags of VAR model. Next, we estimate the parameters of VAR models, and, finally, we use the MWALD test statistic to test Granger causality. This allows us to observe whether and how the dependencies between the variables change for consecutive rolling windows.

3 Data and empirical results

The data used in this study consist of weekly prices of crude oil (OIL), corn (CORN), and ethanol (ETHANOL) from the period between 5 January 2007 and 11 April 2014 (380 observations). The data used in the analysis include the prices of futures contracts traded on the New York Mercantile Exchange (NYMEX) and the Chicago Board of Trade (CBOT). The present study uses nominal data because weekly consumer price index is unavailable. The detailed description of variables and descriptive statistics for weekly time series data are presented in Table 1. Next, for the purpose of the study, all the variables are converted to their natural logarithm form.

Variable	Symbol	Unit	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis
Crude oil	NYMEX:CL	$/bbl	86.47	89.30	141.73	37.93	19.01	-0.21	3.35
Corn	CBOT:C	$/bu	5.20	4.87	8.14	3.09	1.43	0.31	1.69
Ethanol	CBOT:EH	$/gal	2.10	2.14	2.94	1.42	0.39	-0.09	2.09

Table 1 Summary statistics for weekly time series

To investigate the stationarity issue and the possible presence of unit roots in series, univariate analysis of each of the time series is carried out. Augmented Dickey–Fuller (ADF) unit root tests (Dickey and Fuller [4]) for individual time series and their differences are used. ADF statistic testing for unit root shows the rejection at 1% significance level, implying the stationarity of each return series for each analysed period[2]. The number of lags in the test is established using AIC criterion.

Conducting the analysis within the rolling regression requires obtaining the window size (VAR models with fixed sample size each time, i.e. a fixed window size). The VAR models are calculated for a rolling 104 observations (approximately 2 calendar years) time window by adding one observation to the end and removing the first observation and so on. That is, starting with observations 1–104, we calculate the first VAR model. Then, we calculate the VAR model for observations 2–105, 3–106, etc. Using AIC, we determine k – the number of lags in VAR models for each window.

[2] The results can be obtained from the author on request.

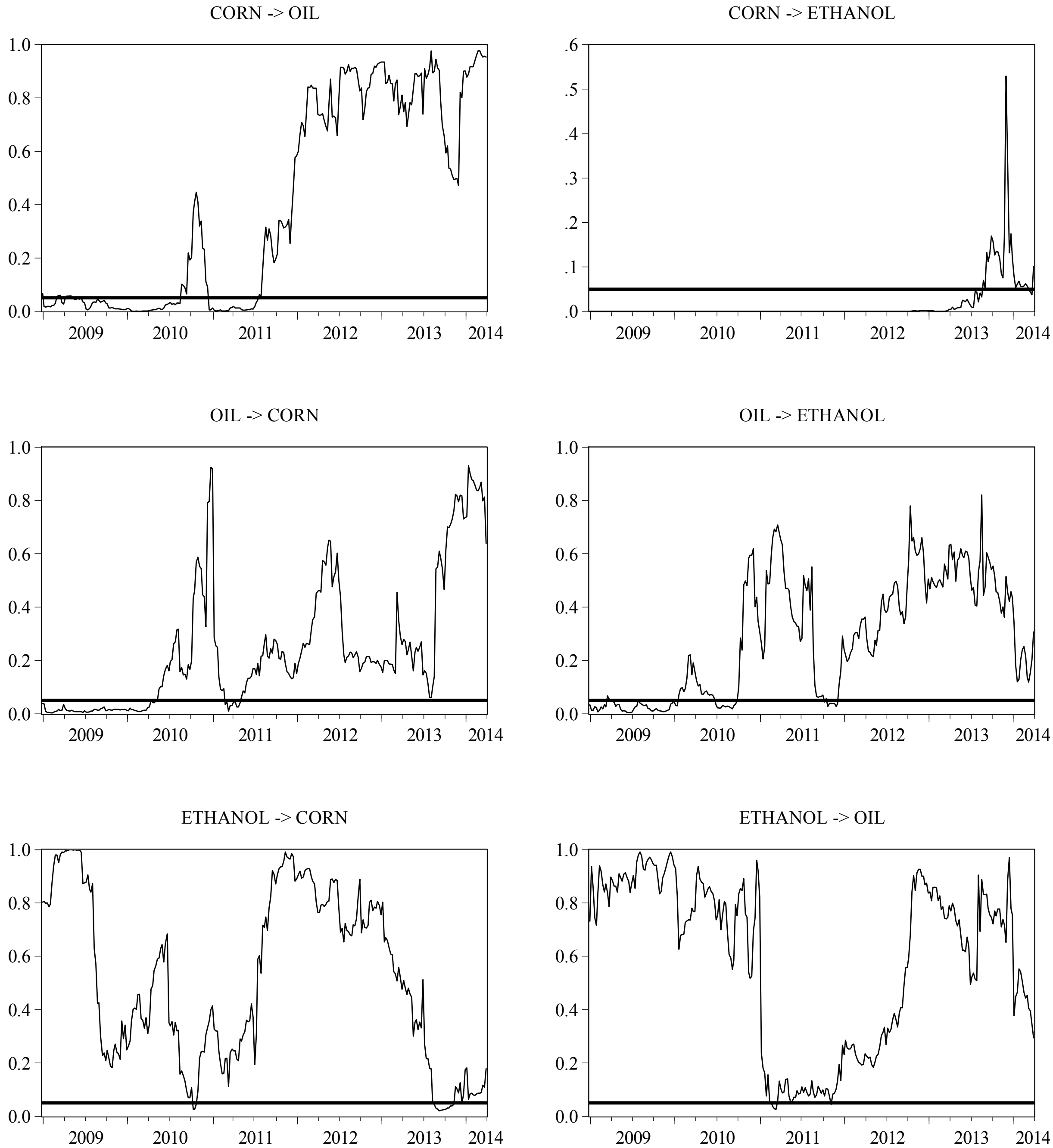

Figure 1 Rolling Granger causality test - the value of p-value of MWALD test.

Granger causality tests can be applied via a MWALD test statistic on the first *k* coefficients. Figure 1 presents *p*-value for Granger causality tests. The horizontal axis indicates the ending point of the window of analysis. (We report the test statistics on the last day of the rolling sample period from which they are derived) The first value represents the *p*-value for Granger causality tests for the model estimated for the period from 5 January 2007 to 26 December 2008. The last one represents the *p*-value for Granger causality tests in VAR estimated for the window 20 April 2012 – 11 April 2014. The horizontal line in the chart indicates the significance level of 5%. The values below this line mean that for a given subperiod variable A Granger causes variable B (A → B).

The results presented in Fig. 1 indicate that in the period analysed the variables influencing other variables change. The analysis of the results presented in Fig. 1 indicates that crude oil prices influence corn prices in the subperiods which start at the beginning of the analysis, that is January 2007 (that is the subperiod from January 2007 till December 2008), until the subperiod beginning in April 2008 (that is, the last dependence subperiod lasted from April 2008 till March 2010). It is the period of considerable increases in oil prices and their rapid drops connected with the global financial crisis after the collapse of Lehman Brothers. In the subperiods which begin after April 2008, the influence of crude oil prices on corn prices is not observed. Similarly, corn prices influence crude oil prices in the subperiods beginning in January 2007. Their influence is longer, however, and the last subperiod for which past values of corn prices improve the forecasts of the crude oil prices is observed from September 2009 till August 2011. The results of the analysis indicate mutual dependence between crude oil prices and corn prices from the beginning of the analysis up to the first quarter of 2010. Later corn prices influence crude oil prices. No dependencies between agricultural commodity prices represented by corn prices and crude oil prices are found for the subperiods which begin in the second half of 2011.

Similarly, the results of the analysis presented in Fig. 1. indicate that crude oil prices influence ethanol prices for the subperiods beginning in January 2007 up to the subperiods beginning in October 2008 (that is, the last dependence period lasted from October 2008 till September 2010). However, the impact of ethanol prices on crude oil prices is not observed in the whole analysed period, which means that, within the energy market, Granger causality tests show that changes in the price of oil are an indicator of future changes in the price of ethanol. This relationship is unidirectional with changes in the price of ethanol unable to help predict future changes in the price of oil.

It can also be noticed that past values of corn prices improve the forecasts of ethanol prices from the beginning of the analysis up to the subperiods which begin in the third quarter of 2011 and last up to the third quarter of 2013. Corn prices do not influence ethanol prices in the subperiods which end from the fourth quarter of 2013 on, whereas in the whole period analysed significant causal relationships between the ethanol prices and corn prices are not observed.

4 Conclusion

The objective of the study is a dynamic assessment of dependencies between prices of corn, crude oil and ethanol using weekly data spanning from January 2007 to April 2014. The analysis which uses the rolling regression to augmented VAR models allows us to disprove or approve the hypotheses posed at the beginning. The results confirm the hypothesis stating that the dependencies between the prices of energy sources and the food prices change in time.

Because the results obtained indicate that dependencies are not stable in time, it is not possible to approve or disprove the next two hypotheses. The results of our analysis indicate that food prices represented by the corn prices influence the prices of energy sources. The corn prices affect fossil fuel prices (that is, crude oil prices) only up to the middle of 2010, while they affect biofuel prices (that is, ethanol prices) up to the third quarter of 2013. In the later period the impact of corn prices on energy sources prices is not observed. Similarly, using monthly data from 1995:01 to 2010:12, Wixson and Katchova [24] show that changes in the prices of corn can be a leading indicator of changes in the prices of oil and ethanol.

The results of Granger causality tests indicate that changes in crude oil prices can be a leading indicator of changes in corn prices only up to the first quarter of 2010 and in ethanol prices up to the third quarter of 2010. In the later period the impact of crude oil prices on corn prices and ethanol prices is not observed.

The results obtain do not confirm the hypothesis stating that the prices of biofuels affect the prices of fossil fuels in the short run. The study indicates that the price of biofuels represented by ethanol prices does not influence either fossil fuel prices represented by crude oil prices or food prices represented by corn prices.

Additionally, it can be concluded that, from the third quarter of 2010 on, the results indicate that there are no causal relations between fossil fuel prices (represented by crude oil prices) and biofuel prices (represented by ethanol prices). Zhang et al. [26] find a similar lack of relationship between ethanol prices and crude oil prices in the period of the ethanol boom (2000-2007), although McPhail [10], who uses monthly data from the period of 1994:01–2010:02, shows that real ethanol prices Granger cause real oil prices and vice versa.

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