Zeszyty Naukowe Uniwersytet Ekonomiczny w Krakowie

4 (940)

ISSN 1898-6447
Zesz. Nauk. UEK, 2015; 4 (940): 101–116
DOI: 10.15678/ZNUEK.2015.0940.0408

Monika Papież
Department of Statistics
Cracow University of Economics

The Application of a Rolling Causality Test for Analysing Dependencies between the Prices of Corn, Crude Oil and Ethanol*

Abstract

The objective of the paper is to analyse causality between the prices of corn, crude oil and ethanol. The analysis conducted for the 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 the prices of corn, crude oil and ethanol is carried out with the use of rolling regression applied to the augmented-VAR framework proposed by Toda and Yamamoto in 1995. The application of the rolling regression procedures in the modified Wald (MWALD) causality test allows for the investigation of the persistence of stability in causal relations between the prices analysed. The results obtained indicate that the linkages between energy prices and agricultural commodity prices changed 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, ethanol prices were not observed to influence crude oil prices or corn prices.

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

* Supported by the grant No. 2012/07/B/HS4/00700 of the Polish National Science Centre.

1. Introduction

Limited fossil fuel resources and the fact that demand for them is growing continuously coupled with the economic development and excessive pollution of the environment have thrust renewable energy sources to a position of greater importance. Additionally, the European Commission has set an overall binding target to satisfy 20% of the EU's energy needs using renewable sources including 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). These factors caused ethanol production to grow by about 70% in the period 2007–2013. However, such increased demand for ethanol fuel translates into greater demand for corn, which, in turn, increases the price 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 fuels, including crude oil prices. L. Kilian and C. Park (2009) claim that the price of crude oil has the greatest influence on food prices because when it goes up so too do transport and food production costs through the growth of fuel costs for mechanised farming. Additionally, growing prices of crude oil increase the economic motivation to produce 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 food prices, crude oil prices representing fossil fuel prices, and ethanol prices representing biofuel prices.

The investigation of related issues can be seen in numerous recent studies, although their conclusions have been inconclusive. Some researchers analyse only the relations between food and fossil fuel prices while generally ignoring biofuel prices. Some studies confirm the linkages between food prices and crude oil prices (e.g. Chen, Kuo & Chen 2010, Ciaian & Kancs 2011a, 2011b, Harii, Nalley & Hudson 2009, Natanelov *et al*. 2011, Nazlioglu & Soytas 2011, Nazlioglu 2011, Papież & Śmiech 2012). Other empirical studies report no evidence regarding the oil-food price nexus, thereby supporting the neutrality hypothesis. S. Nazlioglu and U. Soytas (2012) and Z. Zhang *et al*. (2010) both find agricultural commodity prices to be unaffected by oil price changes in the long run.

The subject literature contains a large number of studies on the linkages between the prices of energy sources (fossil fuel and biofuels) and food prices. Many of these studies use time-series econometric techniques to quantify the relations between oil, ethanol, and food prices in levels (e.g., Kristoufek, Janda & Zilberman 2012, McPhail 2011, Natanelov, McKenzie & Van Huylenbroeck 2013, Qiu *et al*. 2012, Saghaian 2010, Serra *et al*. 2011, Wixson & Katchova 2012, Zhang *et al*. 2009; Zhang *et al*. 2010) or their volatility interactions (e.g., Gardebroek & Hernandez 2013, Haixia & Shiping 2013, Trujillo-Barrera, Mallory & Garcia 2012). However, to the best of my knowledge, dynamic causality in the crude oil-corn-ethanol nexus analysed with the use of the rolling regression procedures applied in the modified Wald causality test has not yet been addressed in any of them.

The objective of this study is to investigate dependencies between the prices of corn, crude oil and ethanol, using weekly futures data spanning the period 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 the augmented-VAR framework proposed by H. Y. Toda and T. Yamamoto (1995). The application of the rolling regression procedures in the modified Wald (MWALD) causality test allows for the investigation of the persistence of stability in causal relations between the prices analysed.

This allows us to address the following questions:

– Are the dependencies between the prices of energy sources and the food prices stable in time?

– Do the prices of biofuels or fossil fuels affect food prices in the short run?

– Do food prices affect the prices of biofuels or fossil fuels in the short run?

– Do the prices of biofuels affect the prices of fossil fuels in the short run?

This paper contributes to the existing literature mostly due to its application of dynamic analysis, which makes it possible 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 organised as follows. Section 2 briefly reviews the relevant literature. Section 3 presents the methodology applied. Section 4 illustrates the data, while Section 5 contains the empirical results. Finally, the last section presents the main conclusions.

2. Literature Review

Dynamic price relationships between commodity and energy markets have been widely discussed in the literature. Table 1 presents an overview of studies devoted to the linkages between commodity (corn prices) and energy markets (crude oil prices and ethanol prices) in recent years. The table contains a summary of the papers reviewed, their modelling approach, data used and the main research conclusions as concern the relationship between crude oil, corn and ethanol prices. The analysis of the results of previous studies indicates different relationships between crude oil, corn and ethanol prices, which are attributable to the period and the frequency of data chosen in a given study.

L. Kristoufek, K. Janda & D. Zilberman (2012) use weekly price data for the period between November 2003 and February 2011 to analyse the relationships between biofuels, their production factors (corn, wheat, soybeans and sugarcane) and fossil fuels. Their analyses are based on autoregressive models (VAR and autoregressive distributed lag models — ARDL), which only allow for short-term causality inferences to be drawn. They find that corn causes changes in ethanol prices, while both elasticity and causality are price-dependent. They also discover that biodiesel is caused and elastic to the changes in German diesel prices and the effects are again price-dependent.

L. L. McPhail (2011) uses the monthly price data for the period between January 1994 and February 2010. He employs a structural VAR model to analyse the relationship between US ethanol, crude oil and gasoline and shows that a policy-driven increase in demand for ethanol leads to lower crude oil and gasoline prices. McPhail (2011) supports bidirectional causality links between crude oil and ethanol prices.

In their empirical analysis, V. Natanelov, A. M. McKenzie & G. Van Huylenbroeck (2013) use daily futures prices of crude oil, corn, and ethanol from March 23, 2005 to December 15, 2011. Their results indicate that crude oil Granger causes corn and ethanol. They find that corn precedes ethanol in the corn–ethanol relationship.

C. Qiu *et al*. (2012) use monthly time series data from January 1994 to October 2010 to estimate the structural VAR model and determine the directed acyclic graph (DAG) causality among the variables. Their results for contemporaneous causality relationships between the food and fuel markets show that corn prices are not directly caused by any other prices or quantities. Qiu *et al*. (2012) uncover no spillover effects on corn prices from the oil, gasoline, or ethanol markets. Thus, this indicates no direct or indirect causes of corn prices, which contradicts the popular food-versus-fuel assumption. They also find that the price of corn is a direct cause of the price of ethanol.

S. H. Saghaian (2010) analyses pairwise Granger-causality relations by looking at monthly data on oil, ethanol, corn, soybean, and wheat prices for the period from January 1996 to December 2008. Saghaian (2010) shows that corn prices Granger-cause ethanol prices with statistical significance at all conventional levels, but the reversed direction of Granger causality is statistically significant only at the 10% significance level. The results also show the existence of unidirectional

Table 1. Summary of the Literature on Biofuel Markets

Reference	Time Series Modelling Approach	Data Frequency	Period of Study	Short-run Granger Causality		
				Crude oil prices (CO) – corn prices (C)	Crude oil prices (CO) – ethanol prices (E)	Corn prices (C) – ethanol prices (E)
Kristoufek, Janda & Zilberman (2012)	VAR	Weekly	November 2003–February 2011	CO – C	CO – E	C → E
McPhail (2011)	Structural VAR	Monthly	January 1994–February 2010	×	CO ↔ E	×
Natanelov, McKenzie & Van Huylenbroeck (2013)	VECM	Daily	March 23, 2005–December 15, 2011	CO → C	CO → E	C → E
Qiu *et al.* (2012)	Structural VAR	Monthly	January 1994–October 2010	CO – C	CO – E	C → E
Saghaian (2010)	VECM	Monthly	January 1996–December 2008	CO → C	CO → E	C ↔ E
Wixson & Katchova (2012)	TVECM	Monthly	January 1995–December 2010	CO ← C	CO → E	C → E
Zhang *et al.* (2009)	VECM	Weekly	March 1989–December 1999	CO ← C	CO ← E	C – E
			January 2000–December 2007	CO – C	CO – E	C – E

Note: $X \rightarrow Y$ denotes Granger causality running from variable X to variable Y, $X \leftarrow Y$ denotes Granger causality running from variable Y to variable X, $X \leftrightarrow Y$ denotes bidirectional Granger causality between variable X and variable Y, $X – Y$ denotes no Granger causality between variable X and variable Y. Variable X and Y denotes CO – crude oil prices, C – corn prices and E – ethanol prices.

Source: the author's own calculation.

relationships running from crude oil price series to ethanol and corn prices. Additionally, Saghaian (2010) uncovers cointegration relationships between crude oil and corn, soybean and wheat prices with causality running from oil prices to the prices of these agricultural commodities.

T. Serra *et al*. (2011) use an exponential smooth transition VECM for monthly data of ethanol, corn, oil, and gasoline prices from 1990 to 2008. They show that an increase in ethanol prices causes an increase in corn prices. However, they also illustrate that corn price hikes lead to increases in the price of ethanol. Their results indicate the existence of a long-term relationship among the prices analysed. They also identify strong links between energy and food prices.

S. E. Wixson and A. E. Katchova (2012) show on monthly US data from 1995 to 2010 that prices of corn Granger-cause prices of ethanol and prices of crude oil. They find evidence of unidirectional Granger causality running from oil to ethanol.

Zhang *et al*. (2009) estimate a vector error correction model (VECM) using weekly data for fuel prices and prices of agricultural commodities over the period from March 1989 to December 2007. Their results of Granger causality tests for the pre-ethanol boom period from 1989 to 1999 show the existence of unidirectional Granger causality running from ethanol and corn prices to crude oil prices. However, short-run causality between crude oil, ethanol and corn prices is not observed in the ethanol boom period from 2000 to 2007.

3. Methodology

The assessment of causal dependencies between the prices of corn, crude oil and ethanol is done by applying rolling regression to the augmented-VAR framework proposed by Toda and Yamamoto (1995) and further developed by A. N. Rambaldi and H. E. Doran (1996) and H. O. Zapata and A. N. Rambaldi (1997). This procedure avoids the problems involved with testing for Granger causality with respect to the power and size properties of unit root and co-integration tests (Zapata & Rambaldi 1997). The approach suggested by Toda and Yamamoto (1995) 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.

The Toda and Yamamoto methodology involves the following stages. Firstly, the lag length (k) of the system VAR and the maximal order of integration (d_{max}) are established. To determine whether each series is stationary or not (that is, whether it contains a unit root) the following unit root tests are traditionally used: the Augmented Dickey-Fuller test (ADF) (Dickey & Fuller 1979), DF-GLS test of Elliott, Rothenber & Stock (1996), and the KPSS (Kwiatkowski *et al*. 1992) unit root test. However, in recent years structural changes have proved to be a key factor in various economic and financial analyses. Unfortunately, the above tests do not assume structural breaks in the series, so it is advisable to use tests which take structural changes into account – for example, the E. Zivot and D. Andrews (1992) sequential test procedure for unit roots, in which the structural breakpoint is estimated endogenously. Zivot and Andrews (1992) considered three different models: model A, which allows for one break in the intercept; model B, which allows for a break in the slope of the trend function; and model C, which allows for a single break in the intercept and in the slope of the trend function. The Zivot and Andrews (1992) test analyses the null hypothesis of a unit root in a series with no break against the alternative of a trend stationary process which combines one-time changes in the level and in the slope of the trend function of the series.

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 (1995) 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 the case under consideration in this paper, the Toda and Yamamoto version of $VAR(k + d_{max})$ can be written as:

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

$$\begin{aligned} CORN_t = \alpha_{02} + \sum_{i=1}^{k} \alpha_{3i} OIL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \alpha_{3j} OIL_{t-j} + \sum_{i=1}^{k} \beta_{3i} CORN_{t-i} + \\ + \sum_{j=k+1}^{k+d_{\max}} \beta_{4j} CORN_{t-j} + \sum_{i=1}^{k} \gamma_{3i} ETHANOL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{4j} ETHANOL_{t-j} + \varepsilon_{2t}. \end{aligned} \tag{2}$$

$$\begin{aligned} ETHANOL_t = \alpha_{03} + \sum_{i=1}^{k} \alpha_{5i} OIL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \alpha_{6j} OIL_{t-j} + \sum_{i=1}^{k} \beta_{5i} CORN_{t-i} + \\ + \sum_{j=k+1}^{k+d_{\max}} \beta_{6j} CORN_{t-j} + \sum_{i=1}^{k} \gamma_{5i} ETHANOL_{t-i} + \sum_{j=k+1}^{k+d_{\max}} \gamma_{6j} ETHANOL_{t-j} + \varepsilon_{3t}. \end{aligned} \tag{3}$$

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): $H_0: \beta_{11} = = \beta_{12} = \ldots = \beta_{1k} = 0$ implies that corn prices (CORN) do not Granger cause crude oil prices (OIL), and $H_0: \gamma_{11} = \gamma_{12} = \ldots = \gamma_{1k} = 0$ 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 (Śmiech & Papież 2013). The fixed window rolling regression is applied to the level VAR model. The first model is built using the data covering observations from 1 to n, while the second model covers observations from 2 to $n + 1$, etc. AIC is used to fix the number of lags of the VAR model each time. The parameters of VAR models are then estimated, and, finally, the MWALD test statistic is used to test Granger causality. This makes it possible to observe whether the dependencies between the variables change for consecutive rolling windows, and if so, how.

4. Data

The data used in this study consist of weekly prices of crude oil (OIL), corn (CORN), and ethanol (ETHANOL) from the period between January 5, 2007 and April 11, 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 a weekly consumer price index is unavailable. The detailed description of variables and descriptive statistics for weekly time series data are presented in Table 2. Fig. 1 presents the weekly prices of the commodities. Next, for the purpose of the study, all the variables are converted to their natural logarithm form.

Table 2. Summary Statistics for Weekly Time Series

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

Source: the author's own calculation.

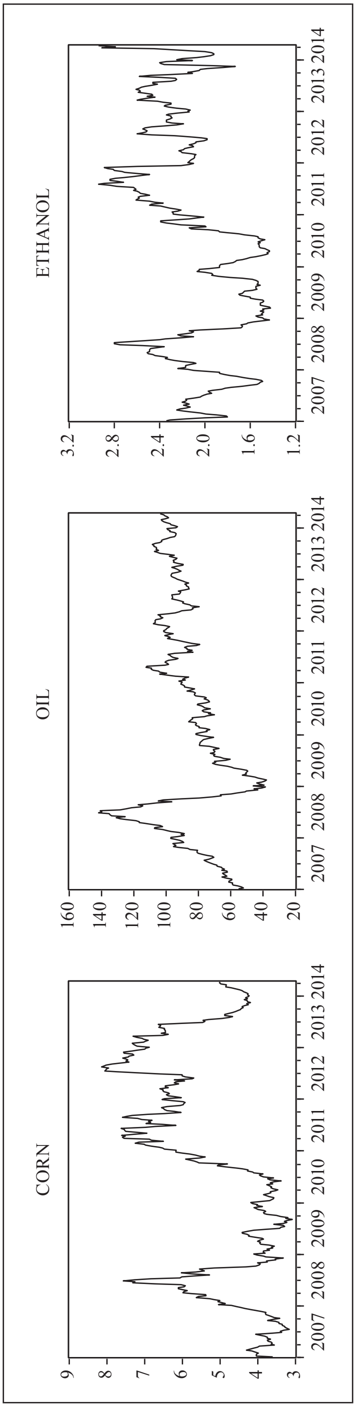

Fig. 1. Weekly Prices of Crude Oil (OIL), Corn (CORN), and Ethanol (ETHANOL) between January 5, 2007 and April 11, 2014

Source: the author's own calculations.

5. Empirical Results

To investigate the stationarity issue and the possible presence of unit roots in the series, univariate analysis of each of the time series is carried out. We initially investigate the issue of unit root in all time series data by applying the Zivot and Andrews (1992) unit root test. Table 3 shows the results of the test for three alternative models (one break in the level of the series, a one-time change in the slope of the trend function, one break in the level and the slope of the trend function of the series). The test statistics indicate that all series are I (1).

Table 3. Zivot-Andrews Unit Root Tests

Specification	Statistics (Level)			Statistics (First Differences)		
	A	*B*	*C*	*A*	*B*	*C*
Corn	–3.31 7/02/2010	–2.49 7/20/2012	–3.35 7/30/2010	–16.33*** 9/11/2009	–16.17*** 10/15/2010	–16.47*** 7/04/2008
Oil	–4.33 9/26/2008	–2.90 1/16/2009	–4.74 7/18/2008	–9.49*** 2/20/2009	–9.28*** 9/19/2008	–10.45*** 1/02/2009
Ethanol	–3.90 8/06/2010	–3.14 1/30/2009	–4.12 8/06/2010	–11.84*** 8/12/2011	–11.75*** 3/01/2013	–11.88*** 7/04/2008

Note: *A*, *B*, *C* denote model types and correspond to the three models in Zivot and Andrews (1992). The 1%, 5% and 10% critical values are –5.34 / –4.93 / –4.58; –4.80/–4.42/–4.11 and –5.57/–5.08/–4.82 for models *A*, *B* and *C*, respectively. The numbers in brackets are the estimated structural break dates (mm/dd/year). *** Rejection of the null hypothesis at the 1% level. The null hypothesis states that a series has a unit root with drift and an exogenous structural break.

Source: the author's own calculation.

As a large number of structural changes has been identified (cf. Table 3), a traditional analysis of causal relations may be distorted. To avoid this problem, rolling regression applied to the augmented-VAR framework proposed by Toda and Yamamoto (1995) is used in further analysis. 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 observation time frame (approximately 2 calendar years) by adding one observation to the end and removing the first one, and so on. That is, starting with observations 1–104, the first VAR model is calculated. The VAR model for observations 2–105, 3–106, etc. are then calculated. Using AIC, we determine k – the number of lags in VAR models for each window.

Granger causality tests can be applied using an MWALD test statistic on the first k coefficients. Fig. 2 presents the p-value for Granger causality tests. The horizontal axis indicates the ending point of the window of analysis. (The test statistics are reported 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 January 5, 2007 to December 26, 2008. The last one represents the p-value for the Granger causality tests in the VAR estimated for the window April 20, 2012–April 11, 2014. The horizontal line in the chart indicates a significance level of 5%. The values below this line mean that for a given sub-period variable A Granger causes variable B ($A \rightarrow B$).

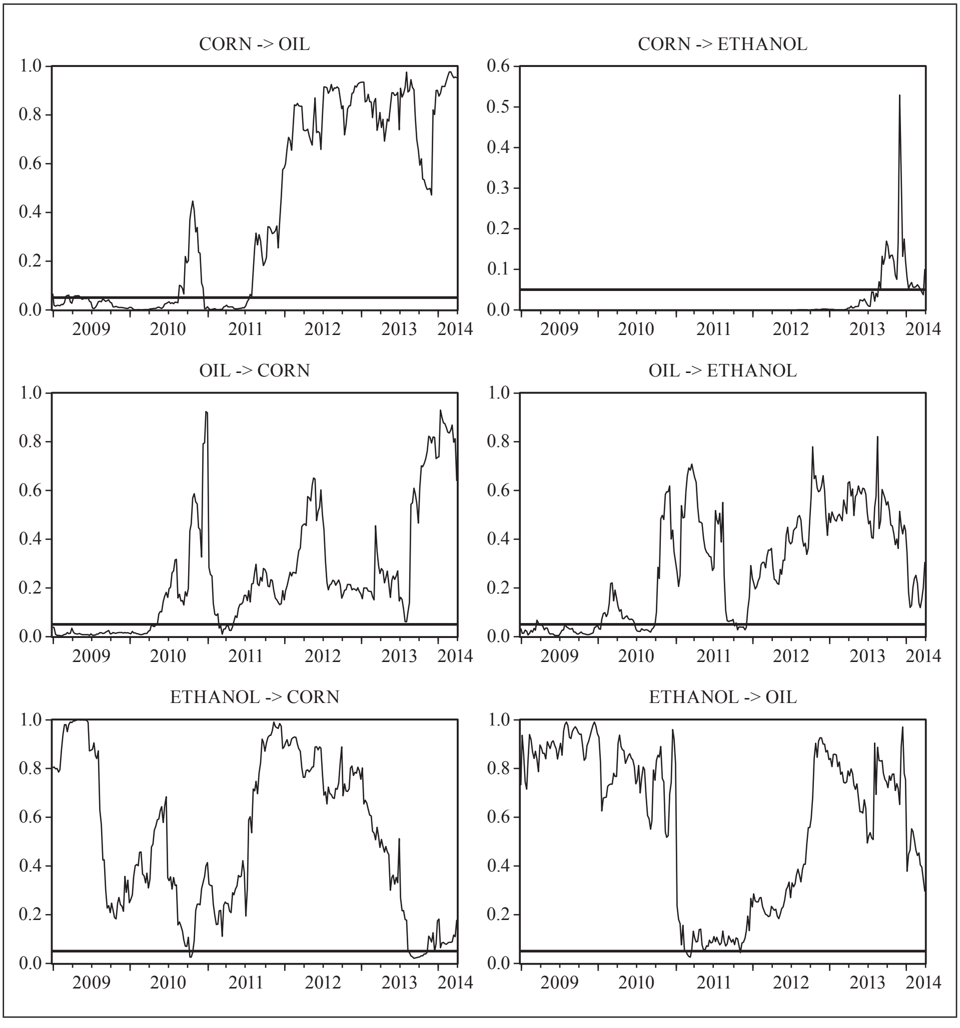

Fig. 2. Rolling Granger Causality Test – p-value of MWALD Test

Source: the author's own calculation, using econometric software EViews 8.0 and R Cran programme.

The results presented in Fig. 2 reveal that, in the period analysed, the variables influencing other variables change. The analysis of the results presented in Fig. 2 indicates that crude oil prices influence corn prices in the sub-periods which started at the beginning of the analysis, January 2007 (that is, the sub-period from January 2007 till December 2008), up to the sub-period beginning in April 2008 (the last dependence sub-period lasted from April 2008 till March 2010). This period witnesses considerable volatility in oil prices connected with the global financial crisis after the collapse of Lehman Brothers. In the sub-periods beginning after April 2008, crude oil prices do not influence corn prices. Similarly, corn prices influence crude oil prices in the sub-periods beginning in January 2007. Their influence is longer, however, and the last sub-period for which past values of corn prices improve the forecasts of crude oil prices is 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 sub-periods beginning in the second half of 2011.

Similarly, the results of the analysis presented in Fig. 2 indicate that crude oil prices influence ethanol prices for the sub-periods beginning in January 2007 up to the sub-periods beginning in October 2008 (that is, the last dependence period lasted from October 2008 to September 2010). However, the impact of ethanol prices on crude oil prices is not observed in the whole period analysed, 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 observed that past values of corn prices improve the forecasts of ethanol prices from the beginning of the analysis up to the sub-periods beginning in the third quarter of 2011 and which last up to the third quarter of 2013. Corn prices do not influence ethanol prices in the sub-periods which end from the fourth quarter of 2013 on, whereas in the whole period analysed significant causal relationships between ethanol prices and corn prices do not exist.

6. Conclusion

The objective of the study is to do a dynamic assessment of dependencies between prices of corn, crude oil and ethanol using weekly data spanning the period January 2007 to April 2014. The analysis, which uses rolling regression in augmented VAR models, allows me to answer the questions posed at the beginning. The results obtained reveal that the dependencies between the prices of energy sources and food prices change with time.

The results of this analysis may indicate that food prices represented by corn prices influence the prices of energy sources. Corn prices seem to have affected crude oil prices (a fossil fuel) only up to the middle of 2010, while they continue to affect ethanol prices (biofuel prices) up to the third quarter of 2013. In the later period the impact of corn prices on energy source prices is not observed. Similarly, using monthly data from 1995:01 to 2010:12, Wixson and Katchova (2012) show that changes in the price of corn can be a leading indicator of changes in oil and ethanol prices.

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 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, there are no causal relations between fossil fuel prices (represented by crude oil prices) and biofuel prices (represented by ethanol prices). Zhang *et al*. (2009) find a similar lack of links between ethanol prices and crude oil prices during the ethanol boom (2000–2007), although McPhail (2011), who uses monthly data from the period January 1994–February 2010, shows that real ethanol prices Granger cause real oil prices and vice versa.

Bibliography

Chen S., Kuo H., Chen C. (2010), *Modeling the Relationship between the Oil Price and Global Food Prices*, "Applied Energy", vol. 87: 2517–2525, http://dx.doi.org/10.1016/j.apenergy.2010.02.020.

Ciaian P., Kancs A. (2011a), *Food, Energy and Environment: Is Bioenergy the Missing Link?* "Food Policy", vol. 36: 571–580, http://dx.doi.org/10.1016/j.foodpol.2011.06.008.

Ciaian P., Kancs A. (2011b), *Interdependencies in the Energy–Bioenergy–Food Price Systems: A Cointegration Analysis*, "Resource and Energy Economics", vol. 33: 326–348, http://dx.doi.org/10.1016/j.reseneeco.2010.07.004.

Dickey D., Fuller W. (1979), *Distribution of the Estimators for Autoregressive Time Series with a Unit Root*, "Journal of the American Statistical Association", vol. 74: 427–431, http://dx.doi.org/10.1080/01621459.1979.10482531.

Elliott G., Rothenber T.J., Stock J.H. (1996), *Efficient Tests for an Autoregressive Unit Root*, "Econometrica", vol. 64: 813–836, http://dx.doi.org/10.2307/2171846.

Gardebroek C., Hernandez M. A. (2013), *Do Energy Prices Stimulate Food Price Volatility? Examining Volatility Transmission between US Oil, Ethanol and Corn Markets*, "Energy Economics", vol. 40: 119–129, http://dx.doi.org/10.1016/j.eneco.2013.06.013.

Haixia W., Shiping L. (2013), *Volatility Spillovers in China's Crude Oil, Corn and Fuel Ethanol Markets*, "Energy Policy", vol. 62: 878–886, http://dx.doi.org/10.1016/j.enpol.2013.07.026.

Harri A., Nalley L., Hudson D. (2009), *The Relationship between Oil, Exchange Rates, and Commodity Prices*, "Journal of Agricultural and Applied Economics", vol. 41: 501–510, http://dx.doi.org/10.1017/S1074070800002959.

Kilian L., Park C. (2009), *The Impact of Oil Price Shocks on The U.S. Stock Market*, "International Economic Review", vol. 50: 1267–1287, http://dx.doi.org/10.1111/j.1468-2354.2009.00568.x.

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, http://dx.doi.org/10.2139/ssrn.2294754.

Kwiatkowski D., Phillips P. C. B., Schmidt P., Shin Y. (1992), *Testing the Null Hypothesis of Stationary against the Alternative of a Unit Root*, "Journal of Econometrics", vol. 54: 159–178.

McPhail L. L. (2011), *Assessing the Impact of US Ethanol on Fossil Fuel Markets: A Structural VAR Approach*, "Energy Economics", vol. 33(6): 1177–1185, http://dx.doi.org/10.1016/j.eneco.2011.04.012.

Natanelov V., Alam M.J., McKenzie A.M., Van Huylenbroeck G. (2011), *Is There Co-movement of Agricultural Commodities Futures Prices and Crude Oil?* "Energy Policy", vol. 39: 4971–4984, http://dx.doi.org/10.1016/j.enpol.2011.06.016.

Natanelov V., McKenzie A. M., Van Huylenbroeck G. (2013), *Crude Oil–Corn–Ethanol–Nexus: A Contextual Approach*, "Energy Policy", vol. 63: 504–513, http://dx.doi.org/10.1016/j.enpol. 2013.08.026.

Nazlioglu, S. (2011), *World Oil and Agricultural Commodity Prices: Evidence from Nonlinear Causality*, "Energy Policy", vol. 39: 2935–2943, http://dx.doi.org/10.1016/j.enpol.2011.03.001.

Nazlioglu S., Soytas U. (2011), *World Oil Prices and Agricultural Commodity Prices: Evidence from an Emerging Market*, "Energy Economics", vol. 33: 488–496, http://dx.doi.org/10.1016/j.eneco.2010.11.012.

Nazlioglu S., Soytas, U. (2012), *Oil Price, Agricultural Commodity Prices, and the Dollar: A Panel Cointegration and Causality Analysis*, "Energy Economics", vol. 34: 1098–1104, http://dx.doi.org/10.1016/j.eneco.2011.09.008.

Papież M., Śmiech S. (2012), *Causality in Mean and Variance between Returns of Crude Oil and Metal Prices, Agricultural Prices and Financial Market Prices* (in:) J. Ramík, D. Stavárek (eds), *Proceedings of 30th International Conference Mathematical Methods in Economics*, Silesian University, School of Business Administration, Karviná: 675–680.

Qiu C., Colson G., Escalante C., Wetzstein M. (2012), *Considering Macroeconomic Indicators in the Food before Fuel Nexus*, "Energy Economics", vol. 34: 2021–2028, http://dx.doi.org/10.1016/j.eneco.2012.08.018.

Rambaldi A. N., Doran H. E. (1996), *Testing for Granger Non-causality in Cointegrated System Made Easy*, Working Papers in Econometrics and Applied Statistics, 88, Department of Econometrics, University of New England.

Saghaian S. H. (2010), *The Impact of the Oil Sector on Commodity Prices: Correlation or Causation?* "Journal of Agricultural and Applied Economics", vol. 42: 477–485, http://dx.doi.org/10.1017/S1074070800003667.

Serra T., Zilberman D., Gil J. M., Goodwin B. K. (2011), *Nonlinearities in the US Corn-ethanol-oil-gasoline Price System*, "Agricultural Economics", vol. 42(1): 35–45, http://dx.doi.org/10.1111/j.1574-0862.2010.00464.x.

Śmiech S., Papież M. (2013), *Fossil Fuel Prices, Exchange Rate, Stock Market: A Dynamic Causality Analysis on the European Market*, "Economics Letters", vol. 118: 199–202, http://dx.doi.org/10.1016/j.econlet.2012.10.010.

Toda H. Y., Yamamoto T. (1995), *Statistical Inference in Vector Autoregressions with Possibly Integrated Processes*, "Journal of Econometrics", vol. 66: 225–250, http://dx.doi.org/10.1016/0304-4076(94)01616-8.

Trujillo-Barrera A., Mallory M., Garcia P. (2012), *Volatility Spillovers in US Crude Oil, Ethanol, and Corn Futures Markets*, "Journal of Agricultural and Resource Economics", vol. 37(2): 247–262.

Wixson S. E., Katchova A. E. (2012), *Price Asymmetric Relationships in Commodity and Energy Markets*, Paper presented at the 123rd European Association of Agricultural Economists' Seminar, Price Volatility and Farm Income Stabilisation, Dublin, February 23–24.

Zapata H. O., Rambaldi A. N. (1997), *Monte Carlo Evidence on Cointegration and Causation*, "Oxford Bulletin of Economics and Statistics", vol. 59(2): 285–298, http://dx.doi.org/10.1111/1468-0084.00065.

Zhang Z., Lohr L., Escalante C., Wetzstei M. (2009), *Ethanol, Corn, and Soybean Price Relations in a Volatile Vehicle-fuels Market*, "Energies", vol. 2(2): 320–339, http://dx.doi.org/10.3390/en20200320.

Zhang Z., Lohr L., Escalante C., Wetzstein M. (2010), *Food versus Fuel: What Do Prices Tell Us?* "Energy Policy", vol. 38: 445–451, http://dx.doi.org/10.1016/ j.enpol.2009.09.034.

Zivot E., Andrews D. (1992), *Further Evidence of the Great Crash, the Oil-price Shock and the Unit-root Hypothesis*, "Journal of Business and Economic Statistics", vol. 10: 251–270, http://dx.doi.org/10.1080/07350015.1992.10509904, http://dx.doi.org/10.2307/1391541.

Zastosowanie rolowanego testu przyczynowości do analizy zależności między cenami kukurydzy, ropy naftowej i etanolu

(Streszczenie)

Celem artykułu jest analiza zależności przyczynowych pomiędzy cenami kukurydzy, ropy naftowej i etanolu. Badanie krótkookresowych zależności przyczynowych przeprowadzono w ramach analizy przyczynowości w sensie Grangera na danych tygodniowych z okresu 5 stycznia 2007–11 kwietnia 2014 r. z wykorzystaniem regresji ruchomych (*rolling regresion*) do modelu VAR, który zaproponowali H.Y. Toda i T. Yamamoto w 1995 r. Zastosowanie procedury ruchomych regresji do zmodyfikowanego testu przyczynowości (MWALD) pozwala na sprawdzenie, czy relacje przyczynowe pomiędzy analizowanymi cenami są stabilne w czasie. Uzyskane wyniki pozwalają stwierdzić, że związki między cenami surowców energetycznych i cenami towarów rolnych ulegają zmianie w analizowanym okresie. Wyniki badań wskazują, że ceny kukurydzy

są przyczyną w sensie Grangera cen surowców energetycznych (ropy naftowej i etanolu). Również ceny ropy naftowej są przyczyną w sensie Grangera cen kukurydzy i etanolu. Dodatkowo stwierdzono, że ceny etanolu nie są przyczyną w sensie Grangera cen ropy naftowej i kukurydzy.

Słowa kluczowe: ceny towarów, metoda Tody-Yamamoty, przyczynowość w sensie Grangera, regresje ruchome.