International Journal for Innovation Education and Research

ISSN: 2411-2933

A Study on the Causal Relationship between Spot Price and Futures Price of Crude Oil and Agricultural Products

Seon Hyeon Kim;Dong-Hoon Shin

Abstract

This paper studies the relationship between the agricultural, energy, and derivatives markets. This study empirically analyzes how the results of previous studies on the Granger causality between oil price and the spot price of agricultural products appear in the futures market by using the Toda and Yamamoto (1995)' causality test. There are two main findings. First, 7 bidirectional causalities and 27 causalities between oil and 6 agricultural products are found, providing strong evidence of a causal relationship. Second, causality is found between oil prices and grain and oilseed type agricultural products, and the spot price of oil has relatively more causalities on agricultural product prices than the futures price of oil. Lastly, testing each period shows that a financial crisis can strengthen the relationship between the agriculture markets and the energy markets

Keyword: Granger Causality, Toda-Yamamoto causality test, agricultural derivatives, agricultural products, oil price

Published Date: 5/1/2020 **Page.296-315** **Vol 8 No 05 2020**

DOI: https://doi.org/10.31686/ijier.vol8.iss5.2345

A Study on the Causal Relationship between Spot Price and Futures Price of Crude Oil and Agricultural Products

Seon Hyeon Kim
Department of Business Administration, Korea Universe, Seoul, South Korea.
ejejfl3@naver.com

Dong-Hoon Shin (Corresponding Author)
Associate Professor in the Department of Global Finance and Banking, Inha University, Incheon, South Korea.
dhshin@inha.ac.kr

Abstract

This paper studies the relationship between the agricultural, energy, and derivatives markets. This study empirically analyzes how the results of previous studies on the Granger causality between oil price and the spot price of agricultural products appear in the futures market by using the Toda and Yamamoto (1995)' causality test. There are two main findings. First, 7 bidirectional causalities and 27 causalities between oil and 6 agricultural products are found, providing strong evidence of a causal relationship. Second, causality is found between oil prices and grain and oilseed type agricultural products, and the spot price of oil has relatively more causalities on agricultural product prices than the futures price of oil. Lastly, testing each period shows that a financial crisis can strengthen the relationship between the agriculture markets and the energy markets

Key words: Granger Causality, Toda-Yamamoto causality test, agricultural derivatives, agricultural products, oil price

1. Introduction

The high-energy consumption of agriculture, and the relationship between agricultural price and energy price since the development of biofuel (Chang and Su, 2010; Zhang et al., 2010) are in the spotlight as important topics in both the agricultural and energy markets. Further, many previous studies have been conducted on agricultural price because of its drastic inflation from 2006 to 2008. Michell (2008) reported that the increase in agricultural production cost caused by the increased production of biofuel, the weakened dollar, and the increased energy price, greatly affected the inflation of agricultural products. Furthermore, Baffes (2007) and Chang and Su (2010) examined the effect of the change in oil price on agricultural price. Some studies support this effect (Busse et al., 2010; Hanson et al., 1993), while others support the neutrality of the agricultural price (Campiche et al., 2007; Nazlioglu and Soytas, 2011), and no agreement has been reached yet. Accordingly, this study discusses the relationship between agricultural price and oil price as done by previous studies, but expands the focus on spot price. It examines the relationship between the spot and futures prices of agricultural commodities based on the spot and futures price of oil.

Agricultural products and oil clearly have different regions of production and consumption. The futures market for these commodities has been developed because they are produced in large scale in specific regions. The futures market is one in which profit can be made or hedging can be done by predicting the price of commodities, and price data is the most important part of this market. Despite this, it is surprising that previous studies directly analyzing the results of such relationship are rarely found. Thus, this study empirically analyzes the relationship between the spot and futures prices of several agricultural products and crude oil. The focus of the analysis is testing the causality between the price data of those markets by using the Toda-Yamamoto causality methodology.

This study makes the following contributions by empirically analyzing the relevance of the futures price between oil and agricultural products. First, it expands the scope of previous studies focused on spot price to the futures price. The empirical analysis of the effect of the relevance between agricultural and energy markets (Baffes, 2007; Busse et al., 2010) on futures price can contribute to efficiency of information in the global agricultural futures market. This result can set an important mark on the relationship among the markets, making an academic contribution by expanding the field for future study. Second, the result shows that oil price affects not only spot prices (Harris et al., 2009) but also futures prices of soybean, wheat, sugar, coffee, corn, cotton, and live cattle. This finding supports previous studies by arguing that oil price is related to agricultural price. It also implies that the fluctuation of spot and futures prices of oil can help predict the rate of return for the agricultural futures price. It would contribute to efficiency of information in the futures markets. Third, this result can help the economy of many developing nations where production of agricultural products takes up a large portion of GDP and is the central economic activity. The causality between prices of agricultural products and oil can increase the efficiency of market information and help improve the economic status of developing nations through futures market hedging. Notably, since Korea imports a lot of agricultural products and oil, it needs research to prepare for the price risk.

The primary analysis of this study is about the causality between agricultural and oil futures prices. The Toda-Yamamoto Causality methodology, which supplements the limitations of the Granger Causality, the most widely used method of analyzing causality, is used. The results are as follows. First, bidirectional causality is found between oil spot price and oil futures price. Also, according to AIC and FPE, 7 bidirectional causalities are found, including the spot price of soybean and futures price of oil, the spot prices of soybean and oil, and the spot prices of corn and oil. This is a strong evidence for the relationship between prices of agricultural products and energy. Second, as a result of the Toda-Yamamoto causality test conducted on 72 relationships, oil price has more causalities with grain and oilseed type agricultural products than with food and fiber type agricultural products. Further, spot price of oil is found to have more causalities with agricultural products than futures price of oil does. Lastly, the Toda-Yamamoto causality test is performed on 4 periods: before global financial crisis, during financial crisis, after financial crisis, and during biofuel policy introduction. The largest number of causalities is found during financial crisis, and there is little evidence that the causality between prices of agricultural products and oil is strengthened by the introduction of biofuel policy.

The composition of this paper is as follows. Section 2 (Previous Studies) introduces previous studies on the relationship between agricultural and energy markets, and on detailed price data. Section 3 (Methodology) describes the methodology of Toda and Yamamoto (1995) used for empirical analysis in this study. Section 4 (Empirical Analysis) summarizes the results of the empirical analysis. Lastly, Section 5 (Conclusion) explains the achievements of this study and records its effect on the actual market and on future studies.

2. Previous Studies

Previous studies explain and analyze the relationship between oil price and agricultural price caused by three major factors.

energy or agricultural products. The direction of the two relationships differs according to sub-period. Therefore, the causality between the futures price and spot price of oil and agricultural products cannot be seen as reaching a general agreement, and different results can be obtained from the same samples depending on the period. The results of such previous studies suggest that the causality between the futures price and spot price of agricultural products can be changed by various factors.

3. Methodology

The Granger Causality analysis, created by Granger (1969), is one of the most general methods of testing causality between two variables. However, the Toda-Yamamoto Causality methodology, which follows the procedure used by Alimi and Ofonyelu (2013), has recently been used as a method improved through criticism of previous studies on Granger Causality. Many studies (Baldi et al., 2012; Kwon and Koo, 2009) on agricultural price, including this one, use this methodology.

Granger (1969) created the Granger cause by analyzing causality between two variables. If variable y helps predict another variable x, then y is a Granger cause of x. In his writing, Hamilton (1994) expresses the Granger cause as below:

If Y is not a Granger cause of X,

(3.1)

This can be expressed by VAR (Vector Auto Regression) as below:

(3.2)

Here, if Y is not a Granger cause of X, all β_i must be 0. In other words, the null hypothesis (H_0) is that all β_i are equal to 0. When H_0 is rejected, Y becomes a Granger cause of X. This means that past values of Y help explain the current value of X, and Y helps predict X. Such a relationship is referred to as a Granger cause. However, the Granger Causality test has been criticized (Christiano and Ljungqvist, 1988; Feige and Pearce, 1979; Stock and Watson, 1990) by methodologies involving past time difference (Gujarati, 1995) and non-stationary time series data (Maddala, 2001) for high sensitivity.

Toda and Yamamoto (1995)'s method can draw a useful prediction value even if the VAR system is not cointegrated. Toda and Yamamoto (1995) proposed an interesting yet simple procedure requiring the estimation of an augmented VAR, which guarantees the asymptotic distribution of the Wald statistic, since the testing procedure is robust to the integration and cointegration properties of the process. (Alimi and Ofonyelu, 2013, pp.131)

The analytical procedure of this paper, based on Alimi and Ofonyelu (2013), is as follows:

) The causality analysis model is formed using the Toda-Yamamoto methodology.

) The order of integration and the optimum time difference are found for the Toda-Yamamoto causality analysis.

) The significance of the Toda-Yamamoto model is verified by the Wald test.

In addition, the primary model used in the empirical analysis of this study is expressed in Eq. (3.3) below, which shows whether individual agricultural futures price at time t can be explained by oil prices before time t. The null hypothesis ( ) is that all $\delta_{i,j}$ are equal to 0, and agricultural futures price at time t cannot be explained by past oil price data. However, if this null hypothesis is rejected, oil price, or oil futures price, can be regarded as a Granger cause of agricultural price samples selected in this study. In order to analyze the model of Eq. (3.3), it is necessary to find the order of integration ( ) and the optimum time difference (m), and the unit root test and information criteria are used to do so. Variables used in (3.3) become the VAR model in vector form.

(3.3)

where X = agriculture commodities price return, c = soybean futures price, soybean spot price, wheat futures price, wheat spot price, sugar futures price, sugar spot price, coffee futures price, coffee spot price, corn futures price, corn spot price, cotton futures price, cotton spot price, live cattle futures price, and live cattle spot price return, w = constant, Y = oil price, j = crude oil spot price return, crude oil futures price return, = error

3.2.1 Stationary test in time series

The causality methodology of Toda-Yamamoto must first determine whether the time series data is stationary in order to avoid the criticism that Ganger Causality is sensitive to the stationarity of time series. When the time series data cannot satisfy stationarity, the order of integration ( ) is used to resolve this problem. Here, refers to the minimum difference required for non-stationary time series data to become stationary.

Many previous studies used the unit test to stationarity, and this study does the same. As done by Alimi and Ofonyelu (2013), Augmented dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) are used as detailed test methods. ADF tests unit root, and KPSS tests stationary hypothesis. Therefore, if the null hypothesis of ADF is rejected, it means that the unit root of the time series data is larger than 1. This data is statistically non-stationary. On the contrary, if the null hypothesis of KPSS is rejected, the time series data is statistically non-stationary. Alimi and Ofonyelu (2013) introduced this joint test as the "confirmatory analysis."

If the analysis shows that the time series data is non-stationary with statistical significance, it can be differentiated to find the time difference at which it first becomes stationary. The stationarity of the differentiated time series data is also tested using ADF and KPSS.

3.2.2 Optimum time difference test

The Granger Causality test was criticized (Gujarati, 1995) for its sensitivity to time difference (p) and, using information criteria, Alimi and Ofonyelu (2013) found the optimum time difference ( ) that can best reflect samples used in the model. This study uses 4 criteria called AIC (Akaike Information Criterion), SC(Schwarz Information Criterion), FPE(Final Prediction Error), and HQ(Hannan-Quinn). There are differences in each information criterion, but no specific one can be regarded as superior to others. All 4 criteria are used in our study. An information criterion based on the information theory is used to find an appropriate model by relatively evaluating statistical models from given data. This study uses the information criterion to find the most appropriate time difference for each commodity group. Models used in this study can have 8 models, as expressed in Eq. (3.3) above, with spot and futures prices of oil, and spot and futures prices of 7 agricultural products. However, since the causality between spot and futures prices of the same commodity is also analyzed, there are 36 models for the relationship between two price data. Since 36 relationships have directions of causality, we try to find 72 causalities. Our study involves causality analysis on the overall period, as well as before global financial crisis, during financial crisis, after financial crisis, and upon biofuel policy introduction. The same Toda-Yamamoto causality test is used for each period. Detailed analysis is provided for the overall period, and only causality results are presented for the sub-periods.

Therefore, 36 relational expressions are observed in this study, and it is necessary to find the most appropriate time difference for data given by each of the 36 models. The model of Eq. (3.3) is tested under AIC, SC, FPE, HQ, and order of integration. And the causality is examined using the Wald test. If the null hypothesis is rejected in the Wald test, and of Eq. (3.3) is found to be not equal to 0 with statistical significance, it can be said that Y is a Granger causality of X, or X is a Granger causality of Y. Thus, the final result of this study seeks to determine whether the relationships show Granger causality.

4. Empirical Analysis

Among various agricultural products, 7 of them are selected as sample products in our study. The samples for our study were selected to include soybean, wheat, sugar, coffee, corn, cotton, and live cattle. Price data consists of the futures price and spot price ofoil(OIF, OIS), soybean(SBF, SBS), wheat(WEF, WES), sugar(SGF, SGS), coffee(CFF, CFS), corn(CRF, CRS), cotton(CTF, CTS), and live cattle (CLF, CLS),provided by Bloomberg. Daily closing prices of each commodity, transacted at each exchange from January 2, 2003 to March 10, 2015, are adopted. However, there is a difficulty in historically tracing the futures price of a commodity because there are many futures commodities with different expiration dates for the same commodity. Bloomberg offers generic tickers as a solution to this. Generic tickers combine futures prices that cling according to each monthly expiration date. Crude oil and agricultural futures prices used in this study can cling to different periods because each commodity has a different expiration date, but this does not present a serious problem in the selection of samples, because the aim of our study is to analyze whether there is a causality between changing prices of oil and agricultural products. In addition, dates of different price data do not accurately agree, but omission of less than 50 data for each commodity is not a serious issue since time series data are selected from a long sampling period of over 12 years. Table 1 summarizes basic statistics for each price data.

Table 1. Basic statistics on each commodity price

	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
OIF	25.2	145	73.9	24.95	-0.061	-0.749
OIS	24.7	147	74.8	24.79	-0.22	-0.518
SBF	499.5	1771	1017	332.4	0.08	-1.24
SBS	426	3850	1065.9	618.77	1.192	0.779
WEF	275.5	1280	556.48	186.79	0.42	-0.45
WES	1080	2640	1877.6	443.23	0.173	-1.023
SGF	5.36	35.31	15.31	6.56	0.62	-0.33
SGS	2.1	8.97	5.186	1.68	0.201	-1.044
CFF	55.5	304.9	135.7	51.58	0.87	0.5
CFS	40.5	294.75	126.06	51.12	0.907	0.698
CRF	186.25	831.25	418.78	173.83	0.55	-0.87
CRS	1.0	8.0	4.11	1.751	0.44	0.953
CTF	39.14	215.15	72.06	28.17	2.36	6.91
CTS	104.25	401.78	163.1	49.75	2.033	6.124
CLF	44.53	133.88	74.51	16.35	0.86	0.99
CLS	72.84	171.76	99.93	22.73	1.346	0.953

Table 1 summarizes basic statistics for each commodity price, and the price of each commodity refers to the daily closing price announced by each exchange. Moreover, the sampling period is from January 2, 2003 to March 13, 2013. Price data are oil futures price (OIF), oil spot price (OIS), soybean futures price(SBF), soybean spot price(SBS), wheat futures price(WEF), wheat spot price(WES), sugar futures price(SGF), sugar spot price(SGS), coffee futures price(CFF), coffee spot price(CFS), corn futures price(CRF), corn spot price(CRS), cotton futures price(CTF), cotton spot price(CTS), live cattle futures price(CLF), and live cattle spot price(CLS).

The basic statistics for each price data can be found in Table 1. A large difference between the mean spot price and futures price is seen because the basic units of the two prices are different, and the Bloomberg generic tickers for futures prices are provided by combining the various subordinate transactions of a commodity. Moreover, in the standard deviation and absolute values of kurtosis and skewness, the spot price of cotton is highest.

This study aims to empirically analyze whether the spot price and futures price of crude oil have Granger Causality with those of 7 agricultural commodities. Granger (1969) proposed that a variable is a Granger cause of another variable if its change explains the change in the other variable. This relationship is one of the most widely used methodologies to analyze causality among time series data. However, Granger's methodology has been receiving various criticisms, and Toda and Yamamoto (1995) reported that the problem can be overcome by using order of integration ( ) and optimum time difference (m). Therefore, this study uses the Toda-Yamamoto Granger Causality methodology in order to analyze causality among the commodities of the two markets. This requires order of integration ( ) and optimum time difference (m).

To find order of integration ( ) with the Toda-Yamamoto Granger Causality methodology, Alimi and Ofonyelu (2013) used Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). These analysis methods test the stationarity of the time series data, which can be found by the minimum difference that satisfies it. The results of this empirical analysis are summarized in Appendix 1. In the results, all daily returns are stationary. Therefore, it is not necessary to find the minimum difference that satisfies stationarity to find the order of integration ( ). Since all variables satisfy stationarity, the of all variables used in the test becomes 0. The results showing time serial stationarity of daily returns for all samples of our study are excessively good. However, Baldi et al. (2012), who studied the relationship between agricultural spot price and futures price, also analyzed the stationarity of time series using the ADF-GLS and ZA (Zivot and Andrews, 1992) methods. All of their results satisfied stationarity after the first differentiation. Unlike Baldi et al. (2012), rate of return data is used in this study, but the prices of the samples in this paper satisfy stationarity after the first difference when the ADF and KPSS tests are completed. Such time serial characteristics can be another topic of study.

For the Toda-Yamamoto Granger Causality, the optimum time difference (m) needs to be found in addition to , usingthe information criterion. As done by Alimi and Ofonyelu (2013), this paper uses 4 criteria: AIC, SC, FPE, and HQ. The information criterion based on information theory is used to find the most appropriate model by relatively evaluating statistical models in the given data. Accordingly, time differences of models for each commodity are configured, up to 10, and the most appropriate time difference for the given data is found based on the 4 criteria. The empirical analysis results are presented in Appendix 2. In the test results, the same time difference is shown by AIC and HQ for each relationship. On the contrary, SC and FPE show the same time difference for some relationships, but not for others. The appropriate time difference presented by each test method is used to perform the Granger causality analysis. Therefore, the VAR() model that combines the appropriate time difference for each relationship and order of integration ( ) is shown in Table 2 below.

Table 2. Values of and determined for each relationship

		d_{max}	m	$d_{max}+m$
OIF	OIS	0	10	10
OIF	SBS	0	1,7	1,7
OIF	SBF	0	1,2	1,2
OIF	WES	0	1	1
OIF	WEF	0	1	1
OIF	SGS	0	5,8,10	5,8,10
OIF	SGF	0	1	1

OIF	CFS	0	1,	1,2
OIF	CFF	0	1	1
OIF	CRS	0	1	1
OIF	CRF	0	1	1
OIS	CTS	0	3,6,8	3,6,8
OIS	CTF	0	1	1
OIS	CLS	0	1,7	1,7
OIS	CLF	0	1	1
OIS	SBS	0	1,8	1,8
OIS	SBF	0	1,5,8	1,5,8
OIS	WES	0	1	1
OIS	WEF	0	1,7,9	1,7,9
OIS	SGS	0	6,7,10	6,7,10
OIS	SGF	0	1,6,7	1,6,7
OIS	CFS	0	1,6	1,6
OIS	CFF	0	1,7	1,7
OIS	CRS	0	1,6	1,6
OIS	CRF	0	1,5,7	1,5,7
OIS	CTS	0	3,7,10	3,7,10
OIS	CTF	0	1,9	1,9
OIS	CLS	0	1,4,8	1,4,8
OIS	CLF	0	1,7	1,7
SBS	SBF	0	1	1
WES	WEF	0	1,7	1,7
SGS	SGF	0	5,7,10	5,7,10
CFS	CFF	0	2,3	2,3
CRS	CRF	0	1,3	1,3
CTS	CTF	0	4,8	4,8
CLS	CLF	0	1,6	1,6

Table 2 shows the final time difference needed for the Toda-Yamamoto causality test. Since rates of return for the two products have different time differences, the final time difference is different for each relationship. Moreover, the final time difference represents the sum of the order of integration and optimal time difference according to the method of Alimi and Ofonyelu(2013).

The results above present and $m$for the Toda-Yamamoto Granger Causality analysis based on Alimi and Ofonyelu's (2013) procedure. In the table, the final VAR models to be used for oil futures price and oil spot price are VAR(10). Likewise, the VAR models for soybean spot price and soybean futures price are VAR(1) and VAR(7), respectively. The results of this study can become more robust if appropriate time differences under the 4 criteria yield similar analysis results in regards to causality.

In this paper, the Wald test is performed to test the Toda-Yamamoto Granger Causality based on the results above. The results are presented in Table III. From the Wald test, bidirectional causality is found between oil spot price return and oil futures price return at a significance level of 1%. This relationship is also observed between soybean spot price and oil futures price, soybean spot price and oil spot price, soybean futures price and oil spot price, wheat futures price and oil spot price, corn spot price and oil spot price, corn futures price and oil spot price, and cotton futures price and oil futures price, according to the appropriate time difference presented by AIC and HPE. Moreover, the oil price return is verified as a Granger cause of futures price return and of spot price return of agricultural products. The results from the 4 information criteria (AIC, SC, HQ and FPE) are relatively consistent. AIC and FPE show the same results at a 5% significance level, returning 27 causalities, while HQ and SC show 18 and 17 causalities, respectively. The difference becomes smaller at the 10% significance level. The results can be described as below based on AIC, the most widely used method, and FPE, which shows the same results as AIC. Mostly, oil has greater influence on agricultural products than agricultural products do on oil. Among 27 causalities, 18 causalities involve rates of return for oil futures price and spot price. This supports the argument that fluctuation in energy price can explain the price fluctuation of agricultural products. In the detailed results, there is no causality that shows significance at the 5% level among the 10 relationships related to live cattle. Moreover, oil is a much clear causality of agricultural products of grain and oilseed types (soybean, wheat, and corn) compared to food and fiber types (coffee, cotton, and sugar). The overall test results are briefly shown in Figure 4, where the matters described above can be easily observed.

Table 3. Results of Toda-Yamamoto Granger Causality

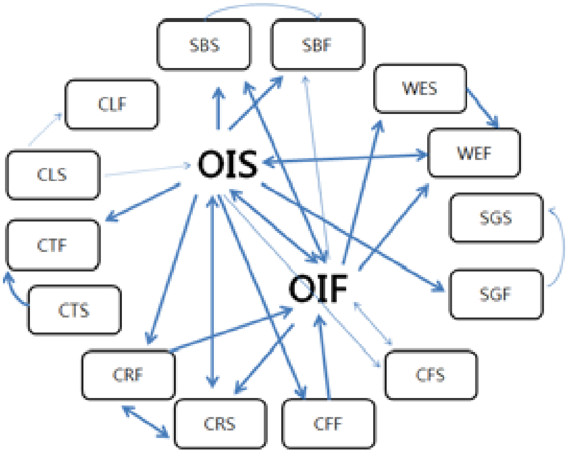
Cause relationship	HQ	AIC, FPE	SC
	1011.7***	1011.7***	1011.7***
	32.0***	32.0***	32.0***
	1.2	20.4***	1.2
	7.7***	17.8***	7.7***
	0.0012	0.73	0.0012
	1.6	5.9**	1.6
	1.2	20.3***	1.2
	7.7***	17.8***	7.7***
	5.3	10.9	0.85
	32.0***	63.5***	0.65

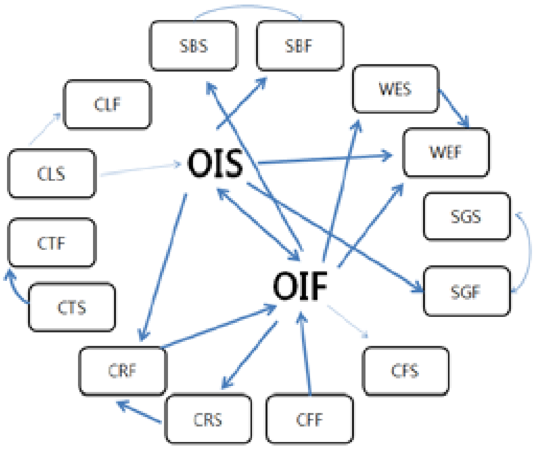
3.7**	3.7**	3.7**
2.2	2.2	2.2
0.029	0.029	0.029
6.3***	6.3***	6.3***
0.026	0.026	0.026
10.8***	10.8***	10.8***
0.57	0.57	0.57
0.18	0.18	0.18
3.5	14.9*	0.031
50.1***	51.3***	0.32
0.33	10.2	0.33
32.9***	41.1***	32.9***
3.7	4.6	1,9
7	7.5	2,7
1.1	1.1	1.1
1.3	1.3	1.3
1.8	3.7	1.4
3.9	8.2	2.2
4.2	5.2	0.021
51.4***	57.2***	3.6*
10.7*	13.1	6.9
16.1**	19.1**	7.8*
3.3	3.2*	3.3
3.6*	4.8**	3.6*
8.5***	8.5***	8.5***
0.0032	0.0032	0.0032
0.59	3.9	0.59
0.016	14.6**	0.016
0.18	4.3	0.18
0.002	32.1***	0.002
2.3	2.3	3.2*
3.9	3.9	4.8**
1.3	1.3	1.3
9.5***	9.5***	9.5***
8.5***	8.5***	8.5***
0.0032	0.0032	0.0032
0.58	18.6***	0.58
0.69	18.5***	0.69
2.6	5.7	0.046
28.4***	65.6***	0.094

	6.4***	6.8**	6.4***
	0.12	5.7*	0.12
	5.9	6.8	3.8
	2.3	3.1	553.3***
	1.1	1.1	1.1
	1.2	1.2	1.2
	1.8	3.3	0.94
	4.3	6.2	553.6***
	0.12	6.7	0.12
	0.65	37.9***	0.65
	10.2	10.2	8.5**
	36.9***	36.9***	25.6***
	0.14	4.8	0.14
	0.17	7.8	0.17
	0.031	0.87	0.87
	0.96	0.97	0.97

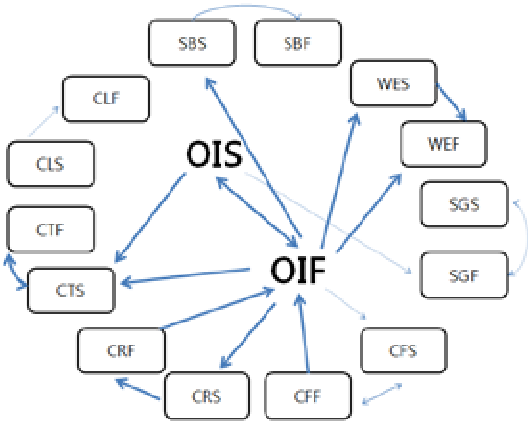
Table 3 shows the results of the Wald test on the models used in this paper, and the significance of these results represents Granger causality according to the methodology of Toda-Yamamoto. The numbers below each information criterion refer to chi-squared values and significance levels. Also, AIC and FPE are combined into a single category, as they show the same time difference. All causal relationships are tested. *** means the null hypothesis is rejected at a significance level of 1%, ** at 5%, and * at 10%. The null hypothesis states that fluctuation of the explanatory variable does not explain fluctuation of the dependent variable, and is introduced in Eq. (3.3). In addition, daily return data are indicated as follows: oil futures return (OIF), oil spot return (OIS), soybean futures return(SBF), soybean spot return(SBS), wheat futures return(WEF), wheat spot return(WES), sugar futures return(SGF), sugar spot return(SGS), coffee futures return(CFF), coffee spot return(CFS), corn futures return(CRF), corn spot return(CRS), cotton futures return(CTF), cotton spot return(CTS), live cattle futures return(CLF), and live cattle spot return(CLS).

Figure 1 expresses the results of analyzing Granger causality according to the Toda-Yamamoto methodology. Dark arrows in the figure represent Granger causality, and bidirectional arrows refer to bidirectional Granger causality. Bold arrows show statistical significance at the 1% significance level, thin arrows at 5%, and dotted line arrows at 10%.





[Panel A] Information criterion: AIC, FPE [Panel B] Information criterion: HQ



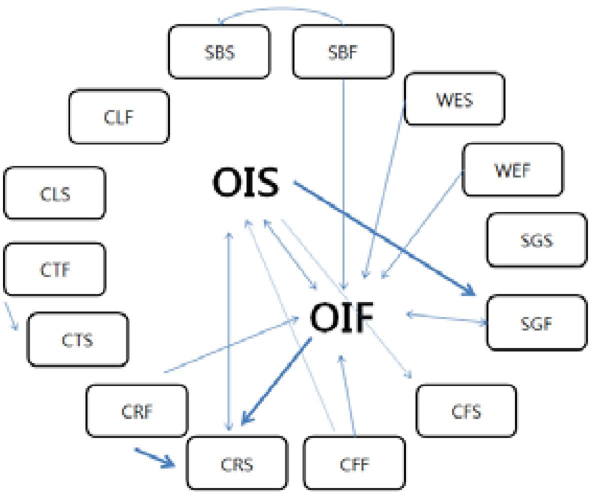
[Panel C] Information criterion: SC

Figure 1. Results of causality test

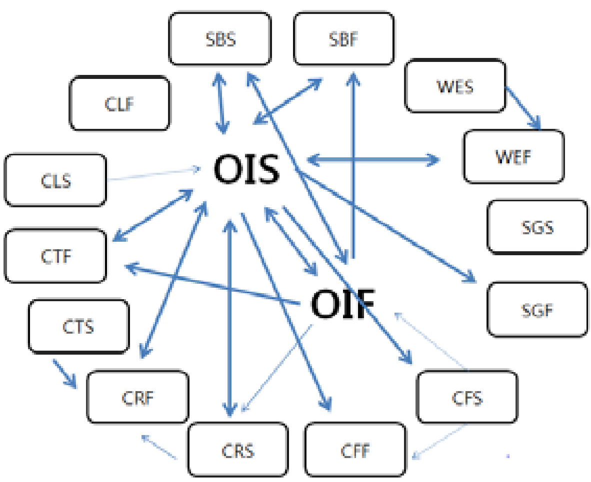
Figure 1 shows the results of the causality test performed using the Toda-Yamamoto methodology. Based on these results, the spot price and futures price of crude oil show bidirectional Granger causality for all criteria. This means that the two prices cause fluctuation of each other equally. Similarly, soybean and corn spot prices and wheat futures price show bidirectional Granger causality for AIC and FPE criteria. The causality test on futures and spot price returns of agricultural products shows bidirectional causality between futures and spot prices of cotton according to the SC criterion. Based on AIC and FPE, bidirectional causality is shown in corn. None of the criteria shows bidirectional causality between any other agricultural products. In regards to the relationship between spot price and futures price in the agricultural market, Hernandez and Torero (2010) found through the causality test that the change in spot price lead by futures price is stronger than the opposite. On the other hand, Baldi et al. (2012) found that this relationship tends to break when there is an event that affects demand or supply of energy or agricultural product, and the direction of the two relationships differs according to sub-period. Therefore, causality between spot price and futures price of agricultural products cannot be seen as reaching an agreement. Summarizing the results of previous studies and this study, there is no unilateral relationship between spot price and futures price of agricultural products, and the relationship can differ for different commodities. In fact, such discordance also appeared in a study on the oil futures market. Bekiros and Diks (2008) found that the rates of return for spot and futures prices of oil are asymmetric and statistically significant higher

order moment. They argued that the bidirectional relationship of lead and lag could change with time.
Except for live cattle, causality between oil and agricultural products is found in almost all relationships, though with different significance. This means that the spot and futures prices of oil affect the spot and futures prices of agricultural products. Moreover, in the significance and causality results of the test on the VAR models for the 4 criteria, both spot and futures price returns of oil show many causalities with spot and futures price returns of grain and oilseed type agricultural products. For food and fiber types, spot price of oil has more causalities. Further, in Panel A of Figure 4, the spot price of oil has many arrows pointed at agricultural products, but the futures price has relatively more arrows pointed from agricultural products to oil. Therefore, it is probable that the prices of agricultural products respond more sensitively to the spot price of oil. This can be further experimented in a future study.
Lastly, causality is analyzed during 4 sub-periods using the Toda-Yamamoto method. Silvennoinen and Thorp(2016) tested conditional correlation during the period in which price levels of agricultural products changed, the period of change in energy policy, and the time of financial crisis. As a result, they reported an increase of correlation according to the energy policy and price level of agricultural products. In our study, sample periods are divided into the following: before financial crisis (2003-2006), during financial crisis (2007-2008), after financial crisis (2009-2015), and during biofuel policy introduction (2005-2007). Figure 2 illustrates the causality relation.

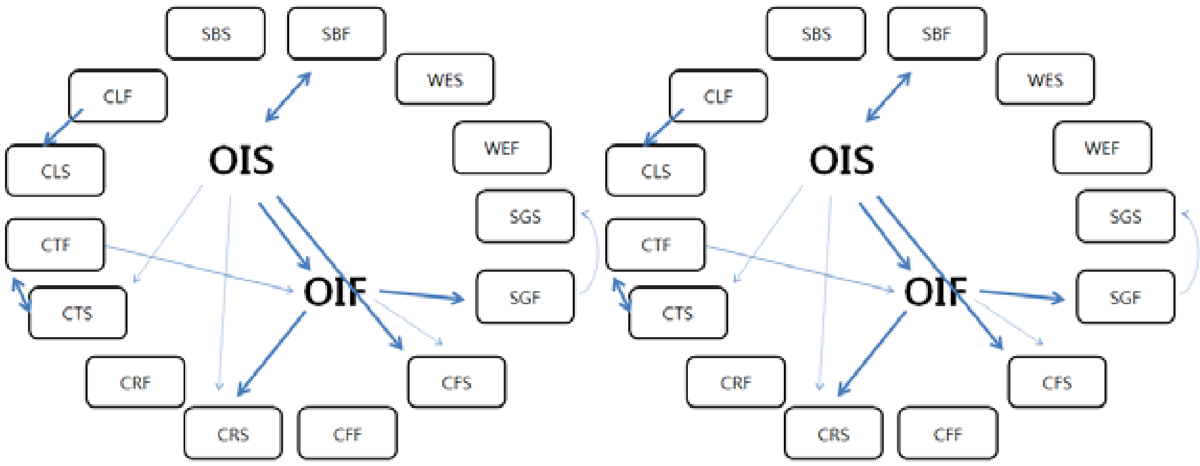
Figure 2 expresses the results of analyzing Granger causality according to the Toda-Yamamoto methodology (for each sub-period). Bold arrows represent Granger causality, and bidirectional arrows refer to bidirectional Granger causality. Bold arrows show statistical significance at the 1% significance level, thin arrows at 5%, and dotted line arrows at 10%.



[Panel A] Before financial crisis(2003-2006)



[Panel B] financial crisis(2007-2008)



[Panel C] After financial crisis(2003-2006) [Panel D] Biofuel policy introduction (2005-2007)

Figure 2. Results of causality test

The Toda-Yamamoto causality test results for each sub-period can be found in Figure 2. Since relationships between different products are described in detail in the section about the overall period, differences between periods can be described as follows. Thirteen causalities are found before the financial crisis, 25 during the financial crisis, 10 after the financial crisis, and 15 during the change of biofuel policy. Thus, the clearest causality between agricultural products and oil is shown during the financial crisis. At 5% significance level, no bidirectional causality is found, except between corn spot price and corn futures price during the change of biofuel policy. However, bidirectional causality is shown during the financial crisis between oil futures price and spot price, soybean spot price and oil futures price, soybean spot price and oil spot price, wheat futures price and oil spot price, corn spot price and oil spot price, corn futures price and oil spot price, and cotton futures price and oil futures price. This means that correlation between agricultural products and oil has been greatly increased. Centered on the financial crisis, causalities are rarely found with a specific period. Likewise for the overall sampling period, the number of causalities is shown in the order of grain and oilseed types, food and fiber types, and live cattle. Soybean and wheat only show relationships before the financial crisis (soybean futures to soybean spot, wheat futures to oil futures, wheat spot to oil futures), and no significance is found afterwards. Contrary to the results of Silvennoinen and Thorp(2016), our results show that the financial crisis stands out in the relationship between agricultural products and oil, compared to the change of biofuel policy. Of course, Silvennoinen and Thorp(2016) only presented a gradual increase of correlation with the change of biofuel policy in 2005-2007, and did not specify the years. Our results show a decrease of causality since 2009, after the financial crisis. Our study is also limited in that it fails to clearly control the inflation period of agricultural products mentioned in many previous studies (2006-2008), the change of biofuel policy (2005 and on) and the financial crisis (2007-2008). Nonetheless, as noted by previous studies, relevant causality between markets increases with increasing market fluctuation. This fact can be easily verified through Figure 2 below.

5. Conclusion

There are three main empirical analysis results of this study. First, bidirectional Granger causality is found between oil spot price and oil futures price. Based on AIC and FPE criteria, bidirectional causality is also observed between soybean spot price and oil futures price, soybean spot price and oil spot price, soybean futures price and oil spot price, wheat futures price and oil spot price, corn spot price and oil spot price, corn futures price and oil spot price, and cotton futures price and oil futures price. This presents strong evidence about the relationship between prices of agricultural products and energy. In addition, this result is similarly shown for wheat spot price and wheat futures price. Such results imply that, unlike the theory, in reality, futures price can lead or lag spot price, or vice versa. This is the primary topic of studies on spot price and futures price. As argued by Bekiros and Diks (2008), the direction of influence can differ according to time. Next, oil spot price and oil futures price were verified as Granger causes of the futures prices of wheat and soybean. Although many previous studies, like Campiche et al. (2007), reported that agricultural price is not affected by oil price, causality between agricultural and oil prices found in the futures market is evidence that strongly supports the argument that the price fluctuation of agricultural and oil markets can be affected.

Second, the Toda-Yamamoto causality test shows causality in 27 out of 72 relationships tested, or 27 out of 62 relationships, if live cattle is excluded. The oil price return shows causality with agricultural products of grain and oilseed types (soybean, wheat, and corn) in more cases than food and fiber types (sugar, coffee, and cotton). Among oil price returns, spot price shows a greater number of causalities than futures price.

Lastly, a causality test is conducted on the 4 sub-periods. As a result, an especially large number of causalities is found during the financial crisis(2007-2008) compared to before and after it. The years 2005-2007, when biofuel policy started to change, are separately analyzed by referring to Silvennoinen and Thorp(2016). No significant difference is shown from other sub-periods, except for the period during financial crisis.

6. References

[1] Alimi, S, R., and C. C. Ofonyelu, “Toda-Yamamoto Causality test between money market interest rate and expected inflation: the fisher hypothesis revisited,” European Scientific Journal, 9(7), 125-142, 2013.

[2] Baffes, J., “Oil spills on other commodities,” Resources Policy, 32, 126–134, 2007.

[3] Baldi, P., S. Forouzan, and Z. Lu, “Complex-Valued Auto encoders,” Neural Networks, 33, 136-147, 2012.

[4] Beiros, D. S., and C. G.H. Diks, “The relationship between crude oil spot and futures prices: Cointegration, linear and nonlinear causality,” Energy Economics, 30(5), 2673-2685, 2008.

[5] Busse, S., B. Brummer, and R. Ihle, “Interdependencies between fossil fuel and renewable energy markets: The German biodiesel market,” DARE Discussion Paper 1010, 2010.

[6] Campiche, J.L., H.L. Bryant, J.W. Richardson, and J.L. Outlaw, “Examining the evolving correspondence between petroleum prices and agricultural commodity prices,” The American Agricultural Economics Association Annual Meeting, Portland, OR. July 29-August 1, 2007.

[7] Chang, T., and H. Su. “The substitutive effect of biofuels on fossil fuels in the lower and higher crude oil price periods. Energy,” 35 (7), 2807–2813, 2010.

[8] Christiano, L. J., and L. Ljungqvist, “Money does granger-cause output in the bivariate money-output

relation. Journal of monetary economics," 22, 217-32, 1988.

[9] Dickey, D.A., and W.A. Fuller, "Distribution of the estimators for autoregressive time series with a unit root," Journal of the American Statistical Society, 75, 427–431, 1979.

[10] Edgar, E. L., and D. K. Pearce, "The casual causal relationship between money and income: some caveats for time series analysis," Review of economics and statistics, 61, 251-33, 1979.

[11] Garbade, K. D., and W. L. Silver, "Price movements and price discovery in futures and cash markets," Review of Economics and Statistics, 65, 289–297, 1983.

[12] Granger, C. W. J., "Investigating causal relations by econometric models and cross spectral methods," Econometrica, 37, 424- 38, 1969.

[13] Hamilton, J. D., "Time series analysis. Princeton," NJ: Princeton University Press, 1994.

[14] Hanson, K., Robinson, S., and Schluter, G., "Sectoral effects of a world oil price shock: economywide linkages to the agricultural sector," Journal of Agricultural and Resource Economics. 18 (1), 96–116, 1993.

[15] Harri, A., L. Nalley, and D. Hudson, "The relationship between oil, exchange rates, and commodity prices," Journal of Agricultural and Applied Economics, 41(2), 501–510, 2009.

[16] Hernandez, M., and M. Torero, "Examining the dynamic relationship between spot and future prices of agricultural commodities," Markets, Trade and Institutions Division. IFPRI Discussion Paper 00988, 2010.

[17] Kwiatkowski, D., P.C.B. Phillips, P. Schmidt, and Y. Shin, "Testing the null hypothesis of stationary against the alternative of a unit root," Journal of Econometrics, 54, 159–178, 1992.

[18] Kwon, D., and W.W. Koo, "Price transmission channels of energy and exchange rate on food sector: a disaggregated approach based on stage of process," The Agricultural and Applied Economics Association 2009 AAEA and ACCI Joint Annual Meeting, Milwaukee, Wisconsin. July 26-29, 2009.

[19] Maddala, G.S., "Introduction to Econometrics, 3rd Edition," Wiley and Sons, Inc., 2001.

[20] Mishkin, F.S., and J. Simon. "An empirical examination of the Fisher effect in Australia," Economic Record. 71, 214:217-229, 1995.

[21] Mitchell, D., "A note on rising food prices," World Bank Policy Research Working Paper Series, No. 4682. Available at SSRN: http://ssrn.com/abstract=1233058, 2008.

[22] Moosa, I.A., "An econometric model of price determination in the crude oil futures markets. In: McAleer, M., Miller, P., and Leong, K. (Eds.) Proceedings of the Econometric Society Australasian meeting 3, 373–402, Perth: University of Western Australia, 1996.

[23] Nazlioglu, S., and U. Soytas, "World oil prices and agricultural commodity prices: Evidence from an emerging market," Energy Economics, 33(3), 488-496, 2011.

[24] Oellermann, C. M., B. W. Brorsen, and P. L. Farris, "Price discovery for feeder cattle," The Journal of Futures Markets, 9, 113–121, 1989.

[25] Scheinkman, J., and B. LeBaron, "Nonlinear dynamics and stock returns," The Journal of Business, 62(3), 311-337, 1989.

[26] Silvapulle, P., and I.A. Moosa, "The relationship between spot and futures prices: Evidence from the crude oil market," The Journal of Futures Markets, 19, 175-193, 1999.

[27] Silvennoinen, A., and S. Thorp, "Crude oil and agricultural futures: an analysis of correlation dynamics," The journal of Futures Markets, 36(6), 522-544, 2016.

[28] Sims, C.A., J.H. Stock, and M.W. Watson, "Inference in linear time series models with some unit roots," Econometrica, 58, 133–144, 1990.
[29] Toda, H. Y., and T. Yamamoto, "Statistical inference in vector auto-regression with possibly integrated processes," Journal of Econometrics, 66, 225–250, 1995.
[30] Zhang, Q. and M. Reed, "Examining the impact of the world crude oil price on China's agricultural commodity prices: The case of corn, soybean, and pork," The Southern Agricultural Economics Association Annual Meetings, Dallas, TX. February 2-5, 2008.
[31] Zhang, Z., L. Lohr, C. Escalante, and M. Wetzstein, "Food versus fuel: what do prices tell us?," Energy Policy, 38, 445–451, 2010.

APPENDIX 1. ADF and KPSS test results

Table 4. ADF and KPSS test results

	ADF	KPSS
	Dickey-Fuller Statistic	KPSS Level
OIS	-13.5941***	0.4372*
OIF	-13.678***	0.3563*
SBS	-12.9148***	0.1179
SBF	-13.6049***	0.1261
WES	-13.5354***	0.1128
WEF	-13.7822***	0.1053
SGS	-9.1213***	0.1766
SGF	-13.5736***	0.1955
CFS	-14.0956***	0.1265
CFF	-13.8463***	0.1379
CRS	-13.355***	0.1594
CRF	-13.4163***	0.1399
CTS	-11.5728***	0.1078
CTF	-14.4827***	0.0962
CLS	-13.3867***	0.0647
CLF	-14.2932***	0.0885

Table 4 summarizes the results of the ADF and KPSS tests on the stationarity of time series data. The null hypothesis (H_0) of the ADF test is that time series data satisfies stationarity, and the null hypothesis (H_0) of KPSS is that time series data does satisfy stationarity. Daily return data are indicated as follows: oil futures return (OIF), oil spot return (OIS), soybean futures return(SBF), soybean spot return(SBS), wheat futures return(WEF), wheat spot return(WES), sugar futures return(SGF), sugar spot return(SGS), coffee futures return(CFF), coffee spot return(CFS), corn futures return(CRF), corn spot return(CRS), cotton futures return(CTF), cotton spot return(CTS), live cattle futures return(CLF), and live cattle spot return(CLS). indicates that the significance level is less than 1%, and results showing only numbers imply that the null hypothesis is not rejected.

APPENDIX 2. Information criterion test results

Table 5. Information criterion test results

		AIC	SC	FPE	HQ
OIF	OIS	10	10	10	10
OIF	SBS	7	1	1	7
OIF	SBF	2	1	1	2
OIF	WES	1	1	1	1
OIF	WEF	1	1	1	1
OIF	SGS	10	8	5	10
OIF	SGF	1	1	1	1
OIF	CFS	2	1	1	2
OIF	CFF	1	1	1	1
OIF	CRS	1	1	1	1
OIF	CRF	1	1	1	1
OIF	CTS	8	6	3	8
OIF	CTF	1	1	1	1
OIF	CLS	7	1	1	7
OIF	CLF	1	1	1	1
OIS	SBS	8	1	1	8
OIS	SBF	8	5	1	8
OIS	WES	1	1	1	1

OIS	WEF	9	7	1	9
OIS	SGS	10	7	6	10
OIS	SGF	7	6	1	7
OIS	CFS	6	1	1	6
OIS	CFF	7	1	1	7
OIS	CRS	6	1	1	6
OIS	CRF	7	5	1	7
OIS	CTS	10	7	3	10
OIS	CTF	9	1	1	9
OIS	CLS	8	4	1	8
OIS	CLF	7	1	1	7
SBS	SBF	1	1	1	1
WES	WEF	7	1	1	7
SGS	SGF	10	7	5	10
CFS	CFF	3	3	2	3
CRS	CRF	3	1	1	3
CTS	CTF	8	8	4	8
CLS	CLF	6	1	1	6

Table 5 summarizes the results of AIC, SC, FPE, and HQ criteria about the 11 relationships tested in this study. The study aims to test 36 causalities formed by relationships among oil futures return (OIF), oil spot return (OIS), soybean futures return(SBF), soybean spot return(SBS), wheat futures return(WEF), wheat spot return (WES), sugar futures return(SGF), sugar spot return(SGS), coffee futures return(CFF), coffee spot return(CFS), corn futures return(CRF), corn spot return(CRS), cotton futures return(CTF), cotton spot return(CTS), live cattle futures return(CLF), and live cattle spot return(CLS), and find the optimum time difference (m) for the 72 causalities. Values in the table represent the optimum time difference for each criterion.