A Study on Causal Relationship Between Spot Price and Futures Price of Crude Oil and Agricultural Products
: Focusing on Soybean Market and Wheat Market of the United States

Authors

Abstract

This paper studies the relationship among agricultural market, energy market, and agricultural derivatives market. Many previous studies empirically analyzed causal relationship between oil price and spot price of agricultural products. This study empirically analyzes how the analysis results of previous studies are shown in futures market. The empirical analysis method of this study uses Toda-Yamamoto Granger Causality methodology to test causal relationship between different prices. As a result of empirical analysis, futures price of crude oil (WTI) was verified as a Granger cause of spot price and futures price of soybean and wheat. Also, spot price of oil was found as a Granger cause of futures price of soybean and both futures and spot prices of wheat. Additionally, bidirectional causality was discovered between spot price and futures price of wheat, and the same relationship was also found in spot price and futures price of crude oil. While existing studies on prices of agricultural products and energies focused on spot prices, the results of this study show additional relationship between agricultural futures market and energy market.

Key words: Granger Causality, agricultural derivatives, agricultural products, oil price

Ⅰ. Introduction

High energy consumption of agriculture and the relationship between agricultural price and energy price from development of biofuel (Chang and Su, 2010; Zhang et al., 2010, etc.) are receiving the spotlight as important topics in both agricultural market and energy market. Also, many previous studies were conducted on agricultural price because of drastic inflation of agricultural price from 2006 to 2008. In regards to agricultural price, Michell (2008) reported that increase of agricultural production cost from increased production of biofuel, weakened dollars, and increased energy price greatly affected inflation of agricultural products. Furthermore, Baffes (2007) and Chang and Su (2010) examined the effect of change of oil price on agricultural price. There are studies supporting the effect of oil price on agricultural price (Busse et al., 2010; Hanson et al., 1993; etc.) and other studies supporting neutrality of agricultural price (Campiche et al., 2007; Nazlioglu and Soytas, 2011; etc.), and they have not reached an agreement yet. Accordingly, this study discusses the relationship between agricultural price and oil price as done by previous studies. This paper expands the focus of previous studies on spot price. It examines the relationship between spot price and futures price of agricultural commodities based on spot price and futures price of oil.

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

This study makes the following contributions by empirically analyzing the relevance of futures price between oil and agricultural products. First, it expands the scope of previous studies focused on spot price to futures price. The empirical analysis of the effect of the relevance between agricultural market and energy market (Baffes, 2007; Busse et al., 2010, etc.) on futures price can contribute to efficiency of information in the global agricultural futures market. This empirical analysis result can set an important mark about the relationship among the markets, making an academic contribution of expanding the field of future study. Second, the empirical analysis result showed that oil price not only affects spot price[1] of soybean and wheat but

1) There are studies that showed the relationship between oil spot price and spot price of soybean and wheat (Harri et al, 2009, etc.) and studies that showed no relationship (Yu et al, 2006, etc.).

also affects futures price. This supported previous studies arguing that oil price is related to agricultural price. Also, the result of this paper implies that fluctuation of spot and futures prices of oil can help predict rate of return for agricultural futures price. It would contribute to efficiency of information in futures markets based on the effect of spot and futures prices of oil on agricultural futures price.

The primary analysis of this study is about the causality between agricultural futures price and oil futures price. Toda−Yamamoto Causality methodology that supplemented limitations of Granger Causality, the method most widely used to analyze causality, is used. The results of empirically analyzing the causality among the commodities are as follows. First, except for the fact that there was no causality between spot price of oil and spot price of soybean, spot and futures prices of oil were found to form causality with spot and futures prices of soybean and wheat. This supported the results of previous studies that argued statistically significant relationship between agricultural price and oil price.

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

Ⅱ. Previous Studies

Previous studies explain and analyze the relationship between oil price and agricultural price because of 3 major reasons.

ⅰ) Change of agricultural production cost caused from change of oil price (Baffes, 2007; Chang and Su, 2010, etc.)

ⅱ) Expansion of biofuel industry (Busse et al., 2010; Zhang et al., 2010, etc.)

ⅲ) Indirect effect of oil price on agricultural price based on change of currency value (Harri et al., 2009, etc.)

Some studies support the causality between energy price and agricultural price (Hanson et al, 1993; Harri et al, 2009; Mitchell, 2008, etc.) and others argue that agricultural price is neutral from oil price (Zhang and Reed, 2006; Campiche et al., 2007; Nazlioglu and Soytas, 2011, etc.).

Kwon and Koo (2009) empirically analyzed the relationship between energy price and agricultural price including exchange rate using Toda−Yamamoto Granger Causality. According to their study, exchange rate shows causality with PPI indexes of crude energy at 10% significance level, and PPI indexes of crude energy have causality with crude foodstuffs and feedstuffs. In this way, they examined the effect of exchange rate and oil price on overall process of agricultural products. The results of their study are presented in [Appendix 1].

As this paper deals with spot price and futures price together, it is important not only to discuss the relationship between agricultural price and oil price but also to find the relationship between spot price and futures price. The primary focus of the relationship between spot price and futures price is in which price precedes to lead the other. Garbade and Silver (1983) discovered that spot price of agricultural products including wheat move towards futures price. Later on, studies were consistently conducted on this relationship (Oellermann et al., 1989; Silvapulle and Moosa, 1999; Schwarz and Szakmary, 1994, etc.). Whereas futures price leads spot price in some study results (Newberry, 1992; Silvapulle and Moosa, 1999, etc.), the opposite is shown by other studies (Moosa, 1996, etc.). It is not awkward to see the result of Kawaller et al. (2001) that the two prices affect one another.

In regards to the relationship between spot price and futures price of oil, Bekiros and Diks (2008) found out that the rates of return of spot and futures prices in oil market (WTI) are asymmetric, showing statistically significant higher order moment. They argue that bidirectional relationship between lead and lag can change with time.

There is a study that reviewed the relationship between spot price and futures price of agricultural products. Baldi et al. (2011) showed that the relationship between spot and futures prices tends to break up when an event occurs to affect demand or supply of energy or agricultural products. The direction of two relationships differs according to sub-period.

Therefore, the causality between futures price and spot price of oil and agricultural products cannot be seen as to reach a general agreement, and different results can be obtained from same samples depending on the period. The results of such previous studies suggest that the causality between futures price and spot price of agricultural products can be changed by various factors.

Ⅲ. Methodology

Granger Causality analysis created by Granger (1969) is one of the most general methods of testing causality between two variables. However, Toda-Yamamoto Causality methodology has recently been used as a method improved by criticism of previous studies on Granger Causality. Many previous studies (Baldi et al., 2011; Kwon and Koo, 2009, etc.) on agricultural price used this methodology, including this study. Also, Toda-Yamamoto Causality methodology follows the procedure used by Alimi and Ofonyelu (2013)[2].

2) They did not conduct their study on the topic of agricultural price and energy price, but this study referred to their explanation of Toda-Yamamoto methodology.

3.1 Granger Causality

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

$$\textit{If } y \textit{ is a Granger cause of } x,$$

$$MSE[\hat{E}(x_{t+s}|x_t, x_{t-1}, \ldots) = MSE[\hat{E}(x_{t+s}|x_t, x_{t-1}, \ldots, y_y, y_{t-1}, \ldots). \qquad (3.1)$$

$$Here, s > 0.$$

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

$$x_t = c + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + u_t \qquad (3.2)$$

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

3.2 Toda-Yamamoto Granger Causality

The method of Toda and Yamamoto 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.

i) Causality analysis model is formed using Toda-Yamamoto methodology.

ii) Order of integration and optimum time difference are found for Toda-Yamamoto causality analysis.

iii) Significance of the Toda-Yamamoto model is tested by Wald test.

In addition, primary model used in empirical analysis of this study is shown in Eq. (3.3) below. Eq. (3.3) shows whether individual agricultural futures price at time t can be explained by oil prices before time t. The null hypothesis (H_0) is that all $\delta_{i,j}$ are equal to 0 and agricultural futures price at time t cannot be explained by past data of oil price. 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 order of integration ($d_{\max}$) and optimum time difference (m). Unit root test and information criterion are used for this.

$$X_{t,c} = \omega_c + \sum_{i=1}^{m} \theta_{t-i,c} X_{t-i,c} + \sum_{i=m+1}^{m+d_{\max}} \theta_{i,c} X_{t-i,c} + \sum_{i=1}^{m} \delta_{i,j} Y_{t,j} + \sum_{i=m+1}^{m+d_{\max}} \delta_{i,j} Y_{t-i,j} + v_c \quad (3.3)$$

$$Here, j = 1,\ 2 \quad \begin{cases} 1 = crude\,oil\,spot\,price \\ 2 = crude\,oil\,futures\,price \end{cases}$$

$$c = 1,2,3,4 \quad \begin{cases} 1 = soybean\,spot\,price,\ 2 = soybean\,futures\,price \\ 3 = wheat\,spot\,price,\quad 4 = wheat\,futures\,price \end{cases}$$

$$\omega = constant$$

$$v = error$$

$$X_j = agriculture\,commodities\,futures$$

$$Y_j = oil\,prices$$

Variables used in (3.3) become VAR model in vector form.

3.2.1 Stationary test in time series

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

Many previous studies used unit test to test stationarity of time series data, and this study also use unit test. 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 reject, it can be seen as to mean that unit root of 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 such joint test as "confirmatory analysis".

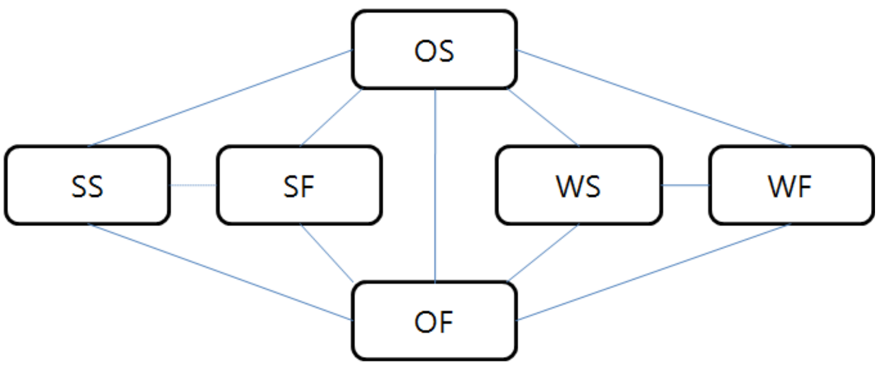
If the analysis shows with statistical significance that time series data is non-stationary, we can differentiate the time series data to find the time difference at which the differentiated time series data first becomes stationary. Stationarity of the differentiated time series data is also tested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

3.2.2 Optimum time difference test

Granger Causality test was criticized (Gujarati, 1995) for its sensitivity to time difference (p), and Alimi and Ofonyelu (2013) found optimum time difference (m) among past time differences that can best reflect samples used in the model using information criterion. This study uses 4 criteria called AIC, SC, FPE, and HQ. 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 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 two agricultural prices. However, since the causality between spot and futures prices of same commodity is additionally analyzed, there are 11 models on the relationship between two price data. [Figure 1] below illustrates the relationship used in this study.

[Figure 1] Relationship between different commodity prices

[Figure 1] expresses the causality between prices of commodities to be confirmed in this study. Samples of this study are 6 price data, and 11 relationships indicated by dotted lines are to be tested in this study. 6 commodity prices include crude oil spot price (OS), crude oil futures price (OF), soybean spot price (SS), soybean futures price (SF), wheat spot price (WS), and wheat futures price (WF). The relationship between prices is examined while focusing on spot and futures prices. Therefore, the models introduced in Eq. (3.3) are applied to each dotted line.



[Figure 1] shows the effect or relationship of crude oil spot price (OS) and crude oil futures price (OF) with soybean spot price (SS), soybean futures price (SF), wheat spot price (WS), and wheat futures price (WF).

Therefore, 11 relational expressions are observed in this study, and it is necessary to find the most appropriate time difference for data given by each of 11 models. The models of Eq. (3.3) are found using time difference suggested by AIC, SC, FPE, and HQ and order of integration, and the causality is examined using Wald test. If the null hypothesis is reject in Wald test and δ of Eq. (3.3) is found to be not equal to 0 with statistical significance, we can say that Y is a Granger causality of X. Thus, the final result of this study aims to find out whether the relationships in [Figure 1] show Granger causality.

Ⅳ. Empirical Analysis

4.1 Samples

Price data used in this study are spot price and futures price of crude oil (WTI), soybean, and wheat provided by Bloomberg. For prices of each commodity, daily closing prices of the commodity transacted the Chicago Board of Trade in the United States from January 2, 2003 to March 11, 2015 were used. However, there is a difficulty in historically tracing 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, soybean, and wheat futures prices used in this study can cling to different periods because each commodity has different expiration date, but this does not present a serious problem in selection of samples because this study examines the effect of change of crude oil price on agricultural futures price instead of finding the causality among agricultural futures prices. In addition, dates of different price data did not accurately agree, but omission of less than 50 data for each commodity is not a serious issue since time series data were selected from long sampling period of over 12 years. [Table 1] summarizes basic statistics on each price data, and [Figure 2] expresses historical trend of each price data.

[Table 1] Basic statistics on each commodity price

[Table 1] summarizes basic statistics of each commodity price, and price of each commodity refers to daily closing price announced by Chicago Board of Trade in the United States. Also, sampling period is from January 2, 2003 to March 11, 2015. Price data are oil spot price (OSPIUC), oil futures price (OFPIUC), wheat spot price (WSPIUC), wheat futures price (WFPIUC), soybean spot price (SSPIUC), and soybean futures price (SFPIUC).

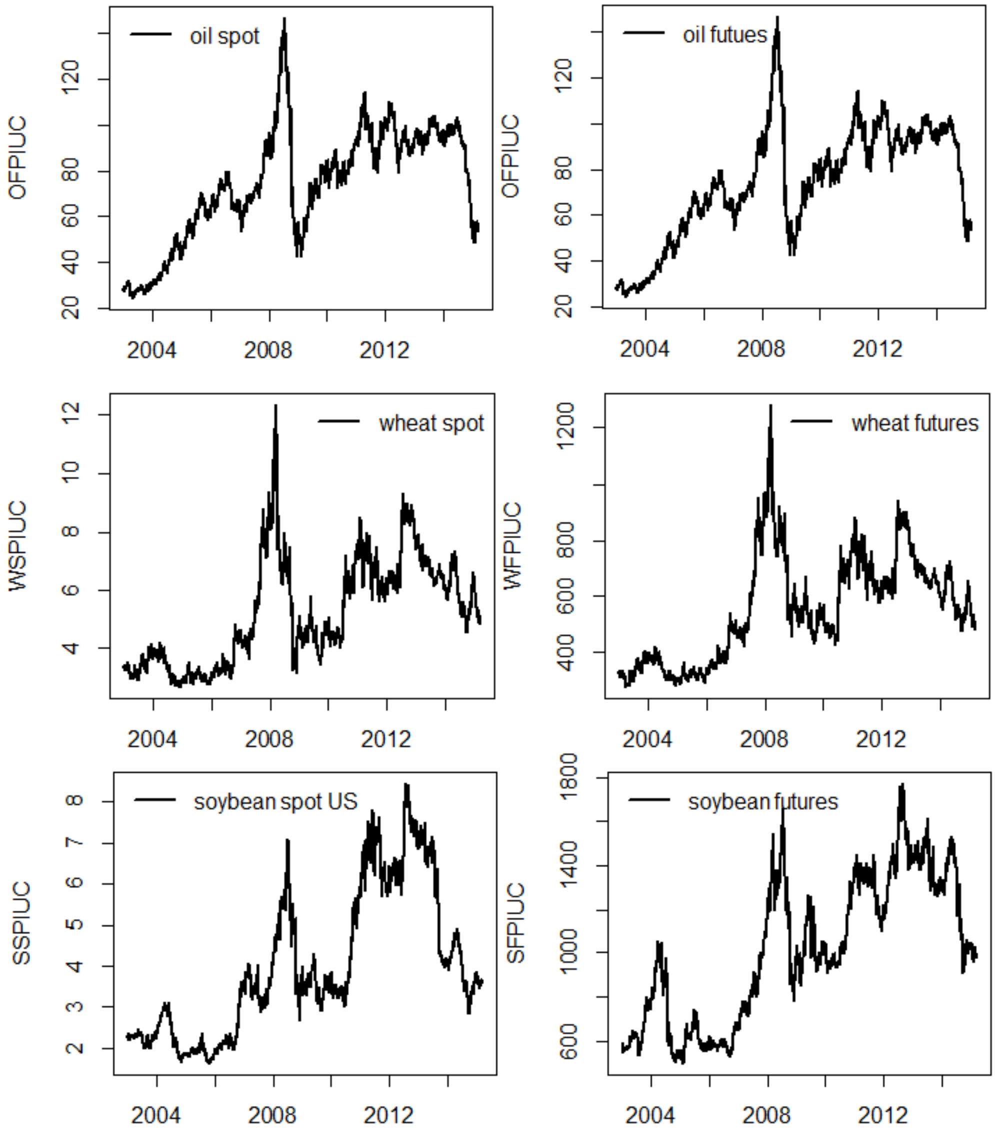
	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
OSPIUC	25.2	145	73.9	24.95	−.061	−.749
OFPIUC	24.7	147	74.8	24.79	−.220	−.518
WSPIUC	2.7	12	5.2	1.82	.510	−.517
WFPIUC	279.3	1280	556.6	187.07	.430	−.442
SSPIUC	1.6	8	4.0	1.79	.639	−.789
SFPIUC	499.5	1771	1013.0	334.09	.110	−1.237

Basic statistics of each price data can be found by looking at [Table 1]. Large difference between mean spot price and futures price is shown because basic units of the two prices are different and generic tickers for futures prices of Bloomberg are provided by combining various subordinate transactions of a commodity. Also looking at standard deviation and absolute values of kurtosis and skewness, futures price of soybean is highest. This implies that fluctuation of soybean futures price is relatively large, as shown in [Figure 2]. [Figure 2] illustrates historical trend of each price data.

[Figure 2] shows that spot price has similar trend as futures price. Historical trend of soybean spot price and futures price has relatively large fluctuation compared to wheat and oil. Also, spot price and futures price of oil move with the most similar trend. This is because fluctuation of oil price is more stable than agricultural price. Historical trend of rates of return for each commodity price can be found by looking at [Figure 3].

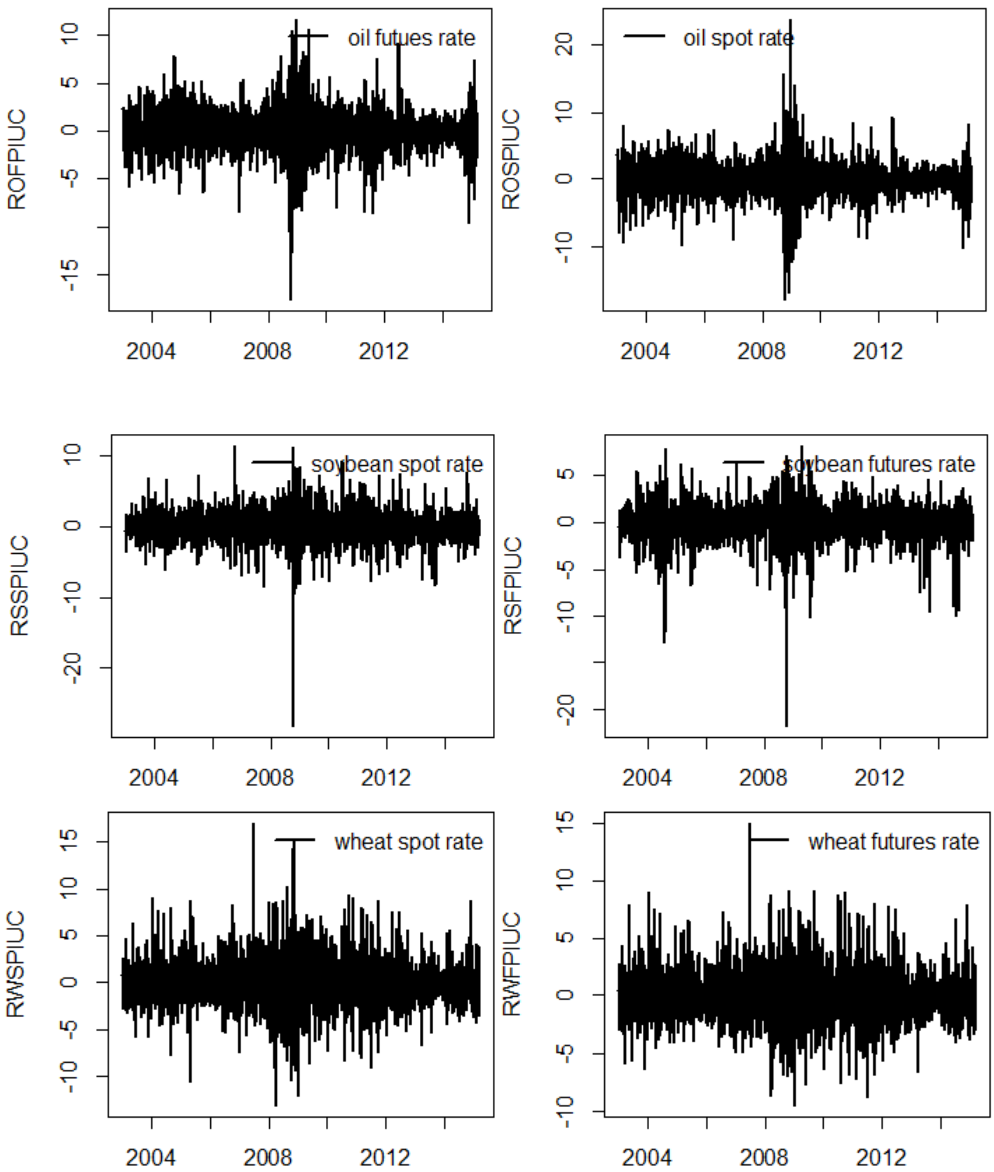
[Figure 2] Histocial trend of each commodity price

[Figure 2] shows historical trend of each commodity price. Samples are spot price and futures price of oil (OSPIUC, OFPIUC), spot price and futures price of soybean (WSPIUC, WFPIUC), and spot price and futures price of wheat (WSPIUC, WFPIUC) traded at Chicago Board of Trade in the United States.



[Figure 3] Historical trend of rates of return for each commodity

[Figure 3] shows historical trend of rates of return for each commodity. Samples are returns for spot price and futures price of oil (ROSPIUC, ROFPIUC), returns for spot price and futures price of soybean (RSSPIUC, RSFPIUC), and returns for spot price and futures price of wheat (RWSPIUC, RWFPIUC) traded at Chicago Board of Trade in the United States.



[Figure 3] historically traces rates of return for each commodity price. Rate of return for soybean shows relatively wide thickness with largest extreme value. This was not examined using statistical analysis because variability of commodity price is not the purpose of this study, but all three commodities cannot be seen as to have maintained stable price for about 10 years.

4.2 Time series test

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

Order of integration

To find order of integration ($d_{\max}$) with Toda−Yamamoto Granger Causality methodology, Alimi and Ofonyelu (2013) used Augmented Dickey−Fuller (ADF) and Kwiatkowski−Phillips−Schmidt−Shin (KPSS). These analysis methods test stationarity of time series data, and $d_{\max}$ can be found by minimum difference that satisfies stationarity of time series data. The results of this empirical analysis are summarized in [Appendix 3]. Looking at the results, all prices including oil spot price (OSPIUC), oil futures price (OFPIUC), soybean spot price (SSPIUC), soybean futures price (SFPIUC), wheat spot price (WSPIUC), and wheat futures price (WFPIUC) were non−stationary. Therefore, it is necessary to find the minimum difference that satisfies stationarity to find order of integration ($d_{\max}$). Since all variables satisfies stationarity after the first differentiation, $d_{\max}$ of all variables used in the test becomes 1. The fact that all variables consistently turned out to be too good after the first differentiation (I(1)) can actually make the data seem suspicious. However, Baldi el al. (2011) who studied the relationship between agricultural spot price and futures price also analyzed stationarity of time series using ADF−GLS and ZA (Zivot and Andrews, 1992) methods. All of their time series results satisfied stationarity after the first differentiation as well.

Optimum time difference (m)

For Toda−Yamamoto Granger Causality, optimum time difference (m) needs to be found in addition to $d_{\max}$. Information criterion is the general method used to find time difference. As done by Alimi and Ofonyelu (2013), this paper uses 4 criteria such as AIC, SC, FPE, and HQ. Information criterion based on the information theory is used to find the most appropriate model by relatively evaluating statistical models in given data. Accordingly in this study, time differences of models for each commodity are configured up to 10, and the time difference most appropriate for given data between 10 models is found based on the 4 criteria (AIC, SC, FPE, and HQ). The empirical analysis results are presented in [Appendix 3]. Looking at the test results, same time difference is shown by AIC and HQ for each relationship. On the contrary, SC and FPE show same time difference for some relationships and not for others. Accordingly, appropriate time difference presented by each test method is used to perform Granger causality analysis. Therefore, the VAR($p+m$) model that combines time difference appropriate for each relationship and order of integration ($d_{\max}$) is as shown in [Table 2] below.

[Table 2] Values of $d_{\max}$ and m determined for each relationship

	$d_{\max}$	m	$d_{\max}+m$
OF ↔ OS	1	3,4,10	4,5,11
OF ↔ SS	1	8,2,1,	2,3,9
OF ↔ SF	1	4,2,1	2,3,5
OF ↔ WS	1	6,1	2,7
OF ↔ WF	1	6,1	2,7
OS ↔ SS	1	8,2,1	2,3,9
OS ↔ SF	1	4,2,1	2,3,5
OS ↔ WS	1	6,1	2,7
OS ↔ WF	1	6,1	2,7
SS ↔ SF	1	2,1	2,3
WS ↔ WF	1	8,3,2	3,4,9

The results above present $d_{\max}$ and m for Toda-Yamamoto Granger Causality analysis based on the procedure of Alimi and Ofonyelu (2013). Looking at the table, the final VAR models to be used for oil futures price and oil spot price are VAR(4), VAR(5), and VAR(11). Likewise, the VAR models for soybean spot price and soybean futures price are VAR(2) and VAR(3). The results of this study can become more robust if appropriate time differences found using the 4 criteria yield similar analysis results in regards to causality.

4.3 Toda−Yamamoto Granger Causality test

In this paper, Wald test was performed to test Toda−Yamamoto Granger Causality based on the results above. The results of Wald test are presented in [Table 3].

[Table 3] Results of Toda−Yamamoto Granger Causality

[Table 3] shows the results of Wald test on the models used in this paper, and significance of the results represents Granger causality according to the methodology of Toda−Yamamoto. Numbers below each information criterion refer to chi−squared values and significance levels. Also, AIC and HQ were combined into a single category as they showed same time difference. 22 causal relationships were tested. *** means the null hypothesis is rejected at significance level of 1%, ** at 5%, and * at 10%. The null hypothesis states that fluctuation of explanatory variable does not explain fluctuation of dependent variable. The equation for this is introduced in Eq. (3.3). In addition in this table, prices are indicated as follows: Oil spot price and futures price (OS, OF); soybean spot price and futures price (SS, SF); and wheat spot price and futures price (WS, WF).

Cause relationship	FPE	AIC, HQ	SC
OS → OF	42.8***	77.2***	44.9***
OF → OS	19.3***	50.3***	20.2***
SS → OF	0.38	24.4***	0.5
OF → SS	3.5 **	32.5***	4.6
SF → OF	0.39	5.8	1.7
OF → SF	5.4**	17.2***	15.9***
SS → OS	0.07	24.2***	0.37
OS → SS	1.7	26.9***	7.2**
SF → OS	0.39	5.8	1.7
OS → SF	5.4**	16.8***	15.9***
SS → SF	0.15	0.63	0.63
SF → SS	2.4	2.5	2.5
WS → OF	0.81	8.4	0.81
OF → WS	5.3**	15.6**	5.3**
WF → OF	0.27	9.7	0.27
OF → WF	10.1***	16.3**	10.1***
WS → OS	0.43	8.1	0.43
OS → WS	5.3**	15.6**	5.3**
WF → OS	0.00076	10.2	0.00076
OS → WF	7.0***	13.4**	7.0***
WF → WS	48.6***	66.7***	46.3***

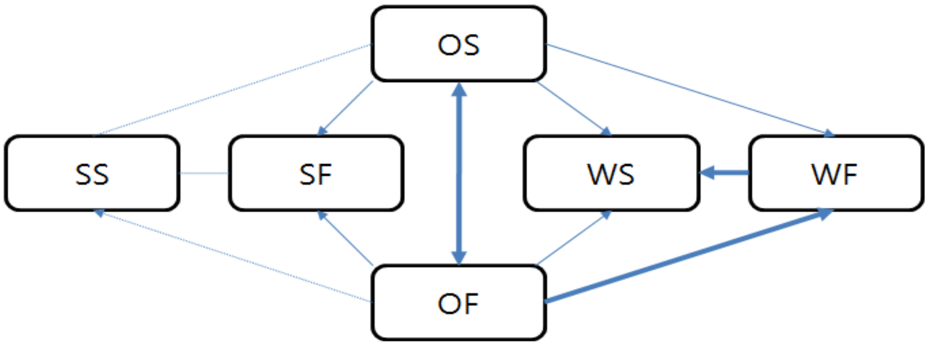
WS → WF	1.0	22.6***	1.9

As a result of Wald test, bidirectional causality was found between oil spot price and oil futures price at significance level of 1%. This relationship also occurred between wheat spot price and wheat futures price according to appropriate time difference presented by AIC and SC. Also in this paper, oil futures price was verified as a Granger cause of futures price and spot price of agricultural products (wheat and soybean). The overall test results are briefly shown in [Figure 4].

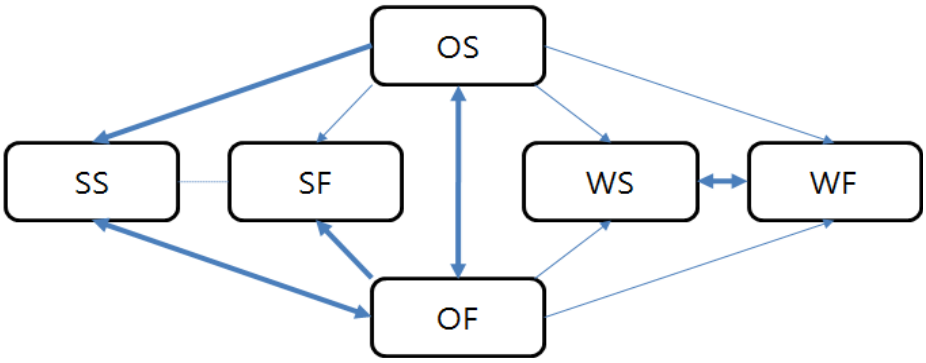
[Figure 4] Results of causality test

[Figure 4] expresses the results of analyzing Granger causality according to Toda-Yamamoto Granger Causality methodology. Dark arrows in the figure represent Granger causality, and bidirectional arrows refer to bidirectional Granger causality. Dotted lines mean that the causality was found to be statistically insignificant. Dark arrows show statistical significance at 1% significance level, thin arrows at 5%, and dotted line arrows at 10%.

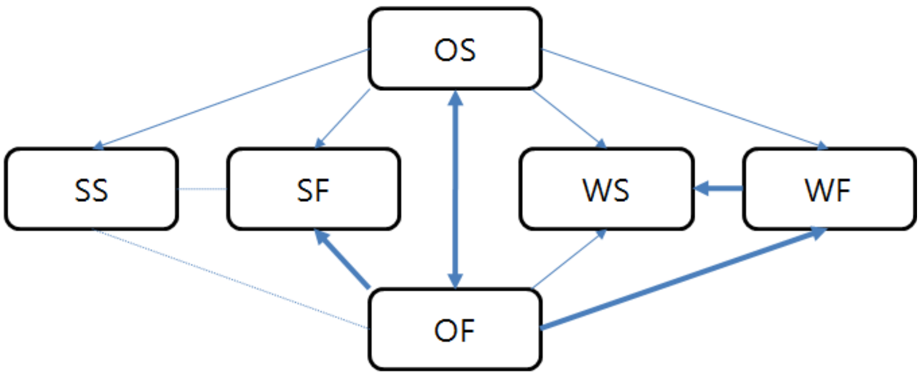
[Panel A] Information criterion : FPE



[Panel B] Information criterion : AIC, HQ



[Panel C] Information criterion : SC



[Figure 4] shows the results of causality test performed using Toda–Yamamoto methodology. Based on the results, spot price and futures price of crude oil showed bidirectional Granger causality for all criteria. This means that the two prices equally cause fluctuation of each other. This is similar to the results of Kawaller et al. (1998). Similarly, wheat spot price and wheat futures price showed bidirectional Granger causality for AIC and HQ criteria. In contrast, causality was not found in soybean spot price and soybean futures price for all criteria. In regards to the relationship between spot price and futures price in agricultural market, Hernandez and Torero (2010) discovered through causality test that leading of change of spot price by futures price is stronger than the opposite. On the other hand, Baldi et al. (2011) discovered that this relationship tends to break up when there is an event that affects demand or supply of energy or agricultural product, and the direction of two relationships differs according to sub–period. Therefore, causality between spot price and futures price of agricultural products cannot be seen as to reach a general 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 oil futures market. About such discordance, Bekiros and Diks (2008) found out that rates of return for spot and futures prices of oil are asymmetric and statistically significant higher order moment. They argued that bidirectional relationship of lead and lag can change with time.

Causality was found in all relationships though with different significance, except for the fact that spot price of crude oil did not have causality with spot price of soybean. This means that spot and futures prices of oil affect spot and futures prices of agricultural products. Also, looking at significance and causality results of test on the VAR models for the 4 criteria, oil prices mostly had greater effect on futures price of agricultural products than spot price.

Ⅴ. Conclusion

There are two empirical analysis results of this study. First, bidirectional Granger causality was discovered between oil spot price and oil futures price. This result was similarly shown by wheat spot price and wheat futures price. Such results imply that futures price can lead or lag spot price or vice versa in reality, unlike the theory. 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 futures price 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 futures market is an evidence that strongly supports the argument that price fluctuation of agricultural and oil markets can be affected.

Lastly, whereas existing studies only focused on spot price in examining the relationship between agricultural price and energy price, this study made a noticeable achievement of finding Granger causality by expanding the scope to futures price. However, limitation of this study is that it did not account for exchange rate and time structure regarded as important in previous studies conducted recently. This remains to be the task for future studies.

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APPENDIX 1. Result of Kwon and Koo (2009)

[Figure 5] Result of Kwon and Koo (2009)3)

[Figure 5] shows the results of Kwon and Koo (2009), and abbreviations stand for the following: The PPI indexes of crude energy (CE), intermediate energy goods (IE), finished energy goods (FE), crude foodstuffs and feedstuffs (CF), intermediate foods and feeds (IF), finished consumer foods (FF), and Consumer Price Index of food at home (HF). Dotted line arrows refer to relationship at significance level of 10%, and dark arrows mean significance level of 5%.

As in the study results as shown in the figure above, exchange rate (ER) has causality with PPI indexes of crude energy (CE) at significance level of 10%, and CE shows causality with CF. CF has causality with FF. As such, they revealed causalities among exchange rate, energy price, and agricultural prices through Toda-Yamamoto Granger Causality methodology and further discovered various channels through which energy price affects final prices of foodstuffs.

APPENDIX 2. ADF and KPSS test results

[Table 4] ADF and KPSS test results

[Table 4] summarizes the results of ADF test and KPSS test on stationarity of time series data. The null hypothesis (H_0) of ADF test is that time series data satisfies stationarity, and the null hypothesis (H_0) of KPSS is that time series data does not satisfy stationarity. None of crude oil spot price (OSPIUC), crude oil futures price (OFPIUC), soybean spot price (SSPIUC), soybean futures price (SFPIUC), wheat spot price (WSPIUC), and wheat futures price (WFPIUC) satisfied stationarity, but the results have only been summarized for first differentiation because all variables satisfied stationarity after the first differentiation. *** indicates that significance is less than 1%, and results only showing numbers imply that the null hypothesis was not rejected.

	ADF	KPSS
	Dickey-Fuller Statistic	KPSS Level
OSPIUC	−1.6318	12.2218***
OFPIUC	−1.7012	12.8267***
SSPIUC	−1.8488	13.0056***
SFPIUC	−2.2492	15.5414***
WSPIUC	−2.7535	11.0969***

3) This is one of analysis results they presented at 2009 AAEA & ACCI Joint Annual Meeting of the Agricultural & Applied Economics Association.

SFPIUC	−2.4199	10.3472***
First differentiation		
OSPIUC	−13.0614***	0.2112
OFPIUC	−12.7061***	0.2429
SSPIUC	−12.7137***	0.2040
SFPIUC	−13.4245***	0.0970
WSPIUC	−12.9338***	0.0607
SFPIUC	−12.8533***	0.0852

APPENDIX 3. Information criterion test results

[Table 5] Information criterion test results

[Table 5] summarizes the results of AIC, SC, FPE, and HQ criteria about het 11 relationships to be tested in this study. This study aims to test 11 causalities formed by relationships among oil spot price (OSPIUC), oil futures price (OFPIUC), soybean spot price (SSPIUC), soybean futures price (SFPIUC), wheat spot price (WSPIUC), and wheat futures price (WFPIUC) and find the optimum time difference (m) for the 11 causalities. Values in the table represent the optimum time difference for each criterion.

	AIC	SC	FPE	HQ
OF ↔ OS	10	4	3	10
OF ↔ SS	8	2	1	8
OF ↔ SF	4	2	1	4
OF ↔ WS	6	1	1	6
OF ↔ WF	6	1	1	6
OS ↔ SS	8	2	1	8
OS ↔ SF	4	2	1	4
OS ↔ WS	6	1	1	6
OS ↔ WF	6	1	1	6
SS ↔ SF	2	1	1	2
WS ↔ WF	8	3	2	8