Modeling the Relationship between the Oil Price and Global Food Prices

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Abstract

The growth of corn-based ethanol production and soybean-based bio-diesel production following the increase in the oil prices have significantly affect the world agricultural grain productions and its prices. The main purpose of this paper is to investigate the relationships between the crude oil price and the global grain prices for corn, soybean, and wheat. The empirical results show that the change in each grain price is significantly influenced by the changes in the crude oil price and other grain prices during the period extending from the 3rd week in 2005 to the 20th week in 2008 which implies that grain commodities are competing with the derived demand for bio-fuels by using soybean or corn to produce ethanol or biodiesel during the period of higher crude oil prices in these recent years. The subsidy policies in relation to the bio-fuel industries in some nations engaging in bio-fuel production should be considered to avoid the consequences resulting from high oil prices.

Key Words: Grain Prices, Crude Oil Price, Autoregressive Distributed Lag Model, Global Cropland Allocation Model.

JEL: Q11, C22.
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1. Introduction

The recently increasing oil price has changed our lives in various ways. One remarkable result has been the changes in commodity prices that have led to inflation especially in relation to the food prices that support our basic living needs. The substantial increases in grain prices have perhaps been due to a variety of factors and the crude oil price no doubt has also played important role in raising prices in general. The other factors that have caused prices to increase include increased demand and climate change. Figure 1 displays the global grain and crude oil prices during the period from 1983 to 2010 and shows that there has been a significant relationship between global grain prices and the crude oil price.

The trend in the oil price as depicted in Figure 1 remained steady at about 30 dollars a barrel before 1985 but sharply decreased to 15 dollars per barrel after 1985. Then, the oil price also experienced a spike in 1990 because of the Gulf War. In addition, the increased demand for oil from the U.S. and China, the weakening of the U.S. dollar, and the stagnation of oil production due to the U.S. occupation of Iraq from 2003 caused the oil price to begin to experience a sharp increase and this upward trend continued until the middle of 2008. Ellobeid et al. [1] pointed out that the ongoing growth of corn-based ethanol production following the increase in the oil price would have a significant impact on both U.S. and world agriculture. In addition, Yang et al. [2] investigated the land and water requirements of biofuel in China given government biofuel development plans from year 2010 to 2020. They found that the 3.5-4% of maize production will be used for biofuel production while 5-10% of cultivated land in China will be devoted to produce biofuel crops which imply that the current biofuel development paths will impose significant impacts on
China’s food supply and trade. Additionally, Lunnan [3] discussed agriculture-based biomass energy supply and concluded that the major problem of the development in agriculture-based biomass energy supply is due to the higher costs as compared with corresponding fossil fuels. These provide some examples of the variations in the relationship between grain prices and the oil price from period to period.

The price of a single grain commodity may be affected by the prices of oil and other grain commodities in a number of ways. On the supply side, increases in the crude oil price push crop production costs and, therefore, shifts the supply curve of a grain commodity to the left, resulting in a price increase. Baffes [4] indicated that the crude oil price should be included in the aggregate production function for most primary agricultural commodities through the use of various energy-intensive inputs. For instance, the prices of fertilizer, fuel, and transportation were found to be affected by the crude oil price directly, and subsequently influenced the production of grain commodities.

On the demand side, grain commodities are competing with the derived demand for bio-fuels. Since bio-fuels have very significantly impacts on environment and economy [5], governments from major agricultural production countries have implemented production subsidy to encourage farmers planting energy crops. For instance, as Runge and Senauer [6] observed, “a combination of high oil prices and even more generous government subsidies, corn based ethanol has become the rage. The ethanol industry’s growth has meant that a larger and larger share of corn production is being used to feed the huge mills that produce ethanol.” Bio-fuel firms may thus have an incentive to produce ethanol or bio-diesel if the crude oil price remains at a higher level. Therefore, the higher crude oil price has induced a higher derived demand for corn or soybeans and has resulted in higher
prices of corn and soybeans. The increase in the crude oil price has not only affected corn and soybean prices but also other agricultural commodities such as wheat and rice. Since the global cropland endowment is limited, the increase in the derived demand for corn or soybeans due to the increase in the oil price will expand their planted acreages and result a decrease in the planted acreage for wheat and rice.

Tables 1 and 2 provide the US annual price and global planted acreage and production for soybeans, corn and wheat during the period from 1997 to 2008. Because commercially viable ethanol or bio-diesel facilities require vast amounts of corn or soybeans, high corn or soybean prices will provide an incentive to plant more corn or soybean areas, and will create competition for the planted areas and prices of other grains. For instance, by comparing grain prices between 2005 and 2006, it is seen that the larger range of increase in the corn price of 60% induced an expansion in the planted acreage for corn and a decrease in the planted acreage for wheat in 2006. However, any decrease in planted acreage will result in an increase in price. The huge increase in the price of soybeans and the huge increase in their value in 2007 due to the decrease in their planted acreage in 2007 is one example.

In the field of investigating the relationships between agricultural grain productions and energy development, two methodologies including mathematical programming and econometric approaches could be applied. The applications of the partial and general equilibrium model were the widely used models in recent empirical studies. For instance, Saunders et al. [7] applied Lincoln Trade and Environment Model which is a non-spatial, partial equilibrium model of international agricultural trade to analyze the impact of the renewable fuel standard (RSF) of United States on agricultural sector in New Zealand. They find that the RSF policy has a significant impact on corn prices, but a small effect on livestock
prices and production. In addition, Elobeid and Tokgoz [8] developed a multi-market international ethanol model comprised the US, Brazil, and the rest of the world. The model endogenizes the prices of crops used in ethanol production. They applied the model to discuss the impact of trade liberalization and removal of the federal tax credit in the US on US and Brazilian ethanol markets and find that ethanol policies leads to higher US domestic ethanol prices and increase the production of ethanol and the price of corn feedstock. Ignaciuk and Dellink [9] used general equilibrium model to assess the impact of multi-product crops in the response to climate policies and found that the competition between agriculture and biomass for scarce land will result in production of agricultural goods decreases at most with 5% and the price of agricultural goods increase to amount about 5%. However, such mathematical programming model only apply for a particular year data set and could not catch the time trend and variation of energy price change on food prices.

For the econometric approach regarding with the effects of biofuel and oil price on food prices have been investigated by Urbanchuk [10], Imai et al.[11], Kind et al. [12], and Baek and Koo [13]. Urbanchuk found that rising oil and energy prices had twice the impact on food prices as measured by the Consumer Price Index (CPI) than did ethanol production and the price of corn. Kind et al. have similarly finding. They found that the growing use of corn for ethanol accounted for about 10 percent to 15 percent of the increase in the food prices over the period of April-2007 to April-2008. However, Baek and Koo have pointed out that the methodology of recent studies on the assessments of rising foods prices are on the basis of descriptive statistics and graphical methods and only a few studies have relied on an econometric technique in investigating factors affecting fast-rising food prices in the United States. Baek and Koo applied ARDL approach to analyze the effects of
market factors on U.S. food prices. They concluded that agricultural commodity
prices play an important role in affecting the short- and long-run behavior of U.S. food
prices and found that energy prices and exchange rate have been significant factors
influencing U.S. food prices in recent years in both short- and long-run. However, as
they consider the price change effect from 1989 to 2008, the samples were separate
subjectively (or exogenously) into two parts for the structural break.

Although the investigations relating to the relationships between agricultural
grain productions and energy received some attention in recent years, the
applications of the econometric technique in the time-series context were relatively
rare. The purpose of this paper is to estimate the relationships between the prices of
corn, soybean, and wheat, and the crude oil price during different periods, weekly
time series data for the future prices of the oil and the three grain commodities were
collected and investigated. The time period covered in this study extends from the
12th week in 1983 to the 5th week in 2010.

To investigate the relationships between the prices of corn, soybeans, and wheat,
and the crude oil price during different time periods, two important methodologies
are adopted in this study. First, we estimate the structural breakpoints of the crude
oil price using the two-break minimum Lagrange Multiplier (LM) unit root test of
Lee and Strazicich [14] to verify whether the time period should be separated into
different periods when the relationships between the grain prices and the crude oil
price are estimated. Secondly, the autoregressive distributed lag (ARDL) model,
which is a popular dynamic model, is implemented to estimate the relationships
between alternative grain prices and the oil price. In the ARDL model, the price of a
specific grain is explained by lags of its own price and the current and lagged values
of a number of explanatory variables, including the oil price and other grain prices.
The empirical results derived from using the unit root test with structural breaks show that the time period may be separated into three periods to investigate the relationships between the oil price and grain prices. The estimated results with regard to the relationships between alternative grain prices and the oil price in different periods are obtained through the use of ARDL models for these three grain prices, respectively. The remainder of this paper is organized as follows. Section 2 presents the theoretical model which illustrates how the relationship between global grain prices and the crude oil price are linked based on a Global Cropland Allocation Model. Section 3 introduces the data set and the econometric approaches adopted. The results of the empirical estimation are analyzed in Section 4. Finally, concluding remarks and policy implications are presented in Section 5.

2. Theoretical Model

The theoretical model is based on McConnell [15] cropland allocation model but we extend it to a Global Cropland Allocation Model to illustrate the relationship between global grain prices and the crude oil price. Suppose the global cropland endowment is defined as \( \bar{L} \), which will be allocated as either producing food crops \( (L_A) \) or energy crops \( (L_E) \). We assume there are three major crops including corn, soybeans, and wheat in this model where corn and soybeans could be either defined as food crops or energy crops while wheat is only used for food purposes. Therefore, the acreage for wheat is denoted as \( X_w \) while the acreages for corn and soybeans for energy purposes are denoted as \( X^E_C, X^E_S \) and the acreages for food purposes in the case of corn and soybeans are denoted as \( X^F_C, X^F_S \), respectively.

Suppose the inverse demand function for the \( i^{th} \) food crop is denoted as \( P_i^d(Q_i^d) \) where \( Q_i^d \) and \( P_i^d \) represent the demand quantity and price. The inverse
demand function for the \( j \)-th bio-fuel is denoted as \( P_{j}^{d}(Q_{j}^{d}) \) where \( Q_{j}^{d} \) and \( P_{j}^{d} \) are the demand quantity and price for \( j \)-th bio-fuel product. The production cost per hectare for planting the \( i \)-th food crop is \( TC_{i}^{F} \) while it is \( TC_{i}^{E} \) for the \( i \)-th energy crop used to produce bio-fuel. The total production cost for producing the \( j \)-th bio-fuel is \( C_{j}(Q_{j}^{d}) \).

The global cropland allocation model may be expressed as follows,

\[
\begin{align*}
\text{Max:} & \sum_{i=1}^{m} \left[ \int P_{i}^{d}(Q_{i}^{d})dQ_{i}^{d} - TC_{i}^{F} X_{i}^{F} \right] + \sum_{j=1}^{m} \left[ \int P_{j}^{d}(Q_{j}^{d})dQ_{j}^{d} - C_{j}(Q_{j}^{d}) \right] - \sum_{i=1}^{n} TC_{i}^{E} X_{i}^{E} \\
\text{s.t.} & \quad -Y_{i} X_{i}^{F} + Q_{i}^{d} \leq 0 \quad \forall \ i \\
& \quad -\sum_{i=1}^{n} BY_{i} X_{i}^{E} + Q_{j}^{d} \leq 0 \quad \forall \ j \\
& \quad \sum_{i=1}^{n} (X_{i}^{F} + X_{i}^{E}) \leq \bar{L}
\end{align*}
\]

where \( Y_{i} \) is the crop yield for the \( i \)-th food crop,

\( BY_{ij} \) is the transformation rate from the \( i \)-th crop to the \( j \)-th bio-fuel.

Equation (1) is the objective function that could be referred to as the global social welfare. The first term is the area under the food crop demand curve minus the total cost of food crops which is defined as the social welfare for the food crops. Similarly, the second and the third terms are included in the social welfare for bio-fuel products. Equations (2) and (3) are the demand and supply balance constraints for the food crops and bio-fuel products and equation (4) is the global land constraint.

The Lagrange function is written as follows:
The first-order conditions, given the positive solutions assumption, are as follows:

\[
\frac{\partial L}{\partial Q^d_i} = P^d_i - \mu_i = 0, \quad \frac{\partial L}{\partial Q^d_j} = P^d_j - MC_j - \lambda_j = 0,
\]

\[
\frac{\partial L}{\partial X^E_i} = -TC^E_i + \mu_i Y_i - \gamma = 0, \quad \frac{\partial L}{\partial X^E_j} = -TC^E_j + \lambda_j BY_{ij} - \gamma = 0
\]

Therefore, the equilibrium conditions could be written as

\[ P^d_i Y_i = TC^E_i + \gamma \] (5)

\[ P^d_j BY_{ij} = TC^E_j + MC_j BY_{ij} + \gamma \] (6)

The left-hand side of equation (5) is the marginal revenue from producing the \(i^{th}\) food crop while the right-hand side is the marginal cost that includes the production cost per hectare plus the land rent cost per hectare. Similarly, the marginal revenue for producing the \(j^{th}\) bio-fuel is shown as the left-hand side of equation (6) and the right-hand side is the marginal cost. Equations (5) and (6) indicate that the quantity of food crops and bio-fuel demanded depends on the prices of food crops \((P^d_i)\), bio-fuel prices \((P^d_j)\), the production technology of bio-fuel \((BY_{ij})\), as well as its production cost. These equilibrium conditions illustrate the higher linkage between grain prices and energy prices. Therefore, the main advantage of this theoretical model is to incorporate both food crop and energy crop...
production activities as well as the demand of these two products are taken into the
consideration in this Global Cropland Allocation model. The equilibrium condition
could display the crop production activities and bio-fuel demand will depend on the
food prices, bio-fuel prices, the production technology and cost of bio-fuel which
build the linkage of grain prices and bio-fuel prices.

3. Data Description and Econometric Models

3.1 Data

To estimate the relationships between the prices of corn, soybean, and wheat,
and the crude oil price during different periods, weekly time series data for the
future prices of the oil and the three grain commodities need to be collected. The
weekly price data for soybeans, corn and wheat are obtained from the average
setting price of futures contracts in the nearest month traded on the Chicago Board
of Trade (CBOT) and the crude oil price is the average setting price of future light
crude oil contracts in the nearest month traded on the New York Mercantile
Exchange (NYMEX). The above weekly time series data are collected by Thomson
Datastream which is the world’s largest and most respected financial statistical
database. The time period covered in this study extends from the 12th week in 1983
to the 5th week in 2010 because the data set for the futures contracts in the case of
light crude oil becomes available from the 12th week in 1983.

3.2 The unit root test with structural breaks

Since the main explanatory variable used to explain the grain prices is the crude
oil price, the two-break minimum Lagrange Multiplier (LM) unit root test of Lee and
Strazicich [14] will be implemented to find the breakpoints of the crude oil price and
to also provide the stationarity of this series. Lee and Strazicich [14] proposed a
two-break minimum Lagrange Multiplier (LM) unit root test in which the alternative hypothesis unambiguously implies that the series is trend stationary. We accept that the model allows for a change in both the level and trend and consider the model as follows:

\[ y_t^* = \delta'Z_t + e_t, \quad e_t = \beta e_{t-1} + \varepsilon_t \]  \hspace{1cm} (7)

where \( y_t^* \) is the crude oil price at time \( t \) and \( Z_t \) is a vector of exogenous variables. \( \delta' \) is the inverse coefficient vector of \( Z_t \) while \( \beta \) describes whether exists breaking points in the model. Breaking points will occur under the null hypothesis of \( \beta = 1 \) and no break when the alternative hypothesis of \( \beta < 1 \) is accepted. The model, which includes two changes in level and trend, is described by

\[ Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]' \] and \( \varepsilon_t \sim iid N(0, \sigma^2) \), where \( D_{jt} = 1 \) and \( DT_{jt} = t - T_{Bj} \) for \( t \geq T_{Bj} + 1, j = 1, 2, \) and 0 otherwise. \( T_{Bj} \) is the time period when a break occurs.

Therefore, the empirical model is established as follows:

\[ y_t^* = \sum_{l=1}^{p} \delta_y y_{t-l}^* + \beta_1 t + \beta_2 D_{1t} + \beta_3 D_{2t} + \beta_4 DT_{1t} + \beta_5 DT_{2t} + \varepsilon_t \]  \hspace{1cm} (8)

where \( l \) denotes the lags.

The two breakpoints \( (T_{Bj}) \) are determined endogenously by utilizing a grid search through the two-break minimum LM unit root test.\(^1\) The breakpoints are determined to be where the LM statistic is minimized. An LM score principle is used to figure the unit root test statistic based on the following regression model:

\(^1\) The LM statistics can be found in Lee and Strazicich (2003) where they are explained in detail.
\[ \Delta y_t^* = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + u_t \]  \hspace{1cm} (9)

where \( \tilde{S}_t = y_t - \tilde{\psi}_t Z_t \delta \); \( t = 2, ..., T \). \( \tilde{\delta} \) are coefficients in the regression of \( \Delta y_t^* \) on \( \Delta Z_t \); \( \tilde{\psi}_t = y_t - Z_t \tilde{\delta} \). The unit root hypothesis with two structural breaks can be tested by examining the t-statistic associated with \( \phi = 0 \), and the critical value can be found in Lee and Strazicich [14].

### 3.3 The Empirical Model Setting

The prices of grain commodities will be affected by the crude oil price and global grain prices due to various factors as mentioned above. In addition, Westcott and Hoffman [16] indicated that corn and wheat are major feed grains and play important roles in the linkages within the agricultural sector between grains and livestock. Finally, grain prices could be affected by each other based on the illustration of the theoretical model. Therefore, it seems reasonable to conclude that several correlations exist between the crude oil price and the prices of corn, soybeans and wheat and such relationships are determined by using the autoregressive distributed lag (ARDL) model. The ARDL model where the data are allowed to determine the particular short-run dynamics is probably one of the widely used models for estimating energy demand relationships in a time-series context. For instance, Jones [17] and Benten and Engsted [18] had used the ARDL model to investigate a demand relationship for U.S. petroleum consumption and Danish residential energy consumption. Furthermore, Dimitropoulos et al. [19], Hunt et al. [20], and Hunt and Ninomiya [21] had employed a combination of the ARDL model to examine the energy demand models.

The ARDL model is a popular dynamic model which combines dynamics and
interdependence with different interpretations based on linear equations [22]. In this model, the price of a specific grain is explained by lags of its own price and the current and lagged values of a number of explanatory variables, including the oil price and other grain prices. A general ARDL model for the global corn price can be written as

\[ CornP_t = \alpha_0 + \sum_{i=1}^{T} \alpha_i CornP_{t-i} + \beta_0 OilP_t + \sum_{i=1}^{T} \beta_i OilP_{t-i} + \gamma_0 SoyP_t + \sum_{i=1}^{T} \gamma_i SoyP_{t-i} \]

\[ + \eta_0 WheatP_t + \sum_{i=1}^{T} \eta_i WheatP_{t-i} + u_t \]

where \( CornP_t, SoyP_t, WheatP_t \) denote the global price of corn, soybeans, and wheat, respectively, at time \( t \), and \( OilP_t \) is the price of crude oil at time \( t \).

The meaning of the estimated coefficients of \( \beta \) could be interpreted as the change of crude oil price in different periods on corn price which implies that the corn price is affected by crude oil price either from the increasing of production cost or increasing derive demand on corn production through biofuel demand. Similarly, the meanings of the estimated coefficients of \( \gamma \) and \( \eta \) represent the effects of changing soybean price and wheat price in different periods on corn price which imply how corn product compete with soybean and wheat products. The estimated coefficients of \( \alpha \) represent the effects of own price change in the past periods on the current price which explain how the current corn price being affected by its own lag.

In this model for estimating the relationships between grain prices and the oil price, the grain price will be influenced by the crude oil price directly. Therefore, current and lagged values of the oil price should be included to explain the specific grain price. However, since the competition between alternative grain commodities might result from the derived demand for bio-fuels and substitutable grain commodities and the limited cropland endowment, the price of a specific grain may
be influenced by lags of its own price and other grain prices. Consequently, this
study sets $\gamma_0 = \eta_0 = 0$. The estimation is thus modified to become the following
specification:

$$Corn_P_t = \alpha_0 + \sum_{i=1}^{T} \alpha_i Corn_{P_{t-i}} + \beta_0 Oil_{P_t} + \sum_{i=1}^{T} \beta_i Oil_{P_{t-i}} + \sum_{i=1}^{T} \gamma_i Soy_{P_{t-i}} + \sum_{i=1}^{T} \eta_i Wheat_{P_{t-i}} + u_t$$ (10)

Similarly, if the global soybean price becomes the dependent variable in this
ARDL model, then the lag of global corn and wheat prices will be the independent
variables. In addition, all variables included in the price models must be stationary
series to avoid spurious results. Therefore, if a series is an $I(0)$ series, the variable
included in the price model will be in the level form. On the contrary, if a series is an
$I(1)$ series, the variable will be included in the first-difference form. Later, the
structural breakpoints of the crude oil price are estimated using the two-break

Once structural breakpoints are found, grain price equations will be estimated for
different periods.

4. Empirical Results

The results of the unit root tests for series of the oil price and the prices of
soybeans, corn, and wheat using the Augmented Dickey Fuller (henceforth ADF)
test [23] and the Phillips and Perron (henceforth PP) test [24] are reported in Table 3.
The ADF test indicates that the two series are $I(1)$ for all four variables in both the
model with no time effect and the model with a fixed time effect. The empirical
results of the PP test indicate that the four series are all $I(1)$ processes at the 5%
significance level regardless of whether the model has a time effect or does not have
a fixed time effect. Therefore, the unit root can be rejected for the first differences
of the four time series at the 5% level of significance. The combined results of the
PP tests for the different models based on 5% critical values suggest that all series are $I(1)$. These tests allow us to conclude that the four series are all non-stationary data and thus stationarity with a first difference can be obtained.

The structural breakpoints of the crude oil price during the period of 12th week in 1983 to 20th week in 2008 are estimated using the two-break minimum Lagrange Multiplier (LM) unit root test of Lee and Strazicich [14] and the estimation results are shown in Table 4. The reason to select this time period is because the crude oil price reaches higher peak in the middle of year 2008. The null hypothesis that the crude oil price has a unit root even with two structural breaks can not be rejected since the absolute value of the t-statistic associated with $\phi = 0$ is smaller than the critical value at the 5% level of significance obtained by Lee and Strazicich [14]. Therefore, two structural breaks actually exist and these two breakpoints are found in the 49th week in 1985 and the 3rd week in 2005. These test results indicate that the time period will be separated into three periods when the relationship between the grain prices and the crude oil price are estimated.

The estimation results in equation (10) for the soybean, corn, and wheat price equations are shown in the first three columns of Tables 5 to 7. Table 5 reports the estimated effects of the crude oil price, corn, and wheat prices on the soybean price in different periods while the coefficients of the price variables represent the absolute change in the soybean price due to the absolute change in the crude oil price and other grain prices. Similarly, the estimation outcomes of the price change for corn and wheat are reported in Tables 6 and 7.

Several findings are illustrated as follows. The first finding shows that the change of the crude oil price has significant positive effects on the changes in soybean, corn, and wheat prices during the period 1983w12-1985w48 (first period)
and 2005w03-2008w20 (third period). During the first and third periods the crude oil prices are maintained at higher levels as shown in Figure 1. These empirical findings indicate that the crude oil price and grain prices are more highly linked when the crude oil price is at a higher level, which is consistent with the previous theoretical findings and the observations regarding data sets.

The second finding shows that the price changes in relation to each grain price are significantly influenced by the changes in the prices of other grains and the sign varies in different periods. For instance, the impacts of the change in the wheat price on the change in the soybean price during the second and third periods are negative while the relationship between the changes in the corn and soybean prices is positive in the second period. One possible explanation for the significant estimates might be that grain commodities are competing with the derived demand for bio-fuels by using soybeans or corn to produce ethanol or bio-diesel.

The most interesting topic in this study is to calculate the percentage change in each grain price due to a 1% change of the crude oil price and this may be calculated based on the estimation results from Tables 5 to 7 which are shown in Table 8. The values of the percentage change in the grain price due to a 1% change in the oil price provide a range of information concerning the sensitivity of each grain price to the oil price change. Firstly, with regard to the impact of the oil price on the soybean price, if the oil price increases by 1%, the price of soybeans will be increased by 155.50% in the first period and by 26.81% in the third period. Furthermore, if the oil price increases by 1%, the corn price will increase by 29.41% in the first period and by 3.33% in the third period. Finally, a 1% increase in the oil price increases the wheat price by 41.30% in the first period.

The magnitude of the percentage change in each grain price due to a 1% change
in the crude oil price are found to be significant and positive in the first and third periods but not in the second period because the crude oil prices have reached extremely high peaks both in the first and third periods. The oil price change is found to affect the price of agricultural commodities through the sharp increases in the prices of various energy-intensive inputs, including fertilizer and fuel, as well as transportation costs. Furthermore, Elobeid et al. [1] pointed out that the ongoing growth of corn-based ethanol production following the increase in the oil price would have a significant impact on both U.S. and world agriculture. Holt-Gimenez and Shattuck also indicated that world’s food and fuels systems have been transformed due to the recent critiques of agrofuels which issues an important argument of food sovereignty [25]. Therefore, the higher crude oil price has induced a higher derived demand for corn or soybeans and has resulted in higher prices of corn and soybeans. This marked increase in the oil price might have increased the production cost and changed the competition relationships between different grains. Consequently, the sensitivity of each grain price to the crude oil price increased and became statistically significant when the crude oil price keeps steady at a higher level.

However, it would be interesting to analyze the effects of crude oil price on grain prices after the last peak of oil price to see whether the food prices were also decreased following the dropping of crude oil price\(^2\). Figure 1 shows food prices decreasing when oil price decreases after the last peak of oil price in 2008. Crude oil price in July in 2008 was US$ 140 per barrel and dropped to US$ 40 per barrel at the

\(^2\) We do appreciate for reviewer’s helpful suggestion to update the data set from 21\(^{st}\) week in 2008 to 5\(^{th}\) week in 2010 in order to analyze the effects of oil price on grain prices after the last peak of oil price.
end of 2008. In the mean time, soybean price dropped from 1658 cents per bushel to 957 cents per bushel while corn and wheat prices are dropped from 746 and 872 cents per bushel to 412 and 600.

The relationship between the grain prices and crude oil price during the period of 21th week in 2008 to 5th week in 2010 (fourth period) are estimated using ARDL and the estimation outcome are shown in the last column from Tables 5 to 7. These estimation outcomes indicate that the decreasing of oil price after the last peak in 2008 will result in a decreasing in grain prices. There are two reasons to cause such phenomenon, the first one is that production cost of these grain products are decreasing due to the decreasing of crude oil price while the second reason is from the decreasing on derived demand of corn and soybean for producing biofuels.

However, it may be interesting to observe the change of rice price when oil price drops since rice is not used for biofuel production. Based on the statistic data observation on global rice planting acreage and production as shown in Table 2, both planted acreage and production in 2008 is slightly increased as compared with year 2007. However, global rice price is still increased in 2008 which indicates that the increasing of production cost due to oil price increasing, the increasing of input usage from fertilizers, and increasing on demand side due to population are the major reasons. For instance, global nitrogen price in 2008 is about US$ 570 per metric ton while the price in 2007 is about US$ 320. Global nitrogen price increased due to the increasing of oil price will cause the increasing of rice production cost and result in an increasing of rice price.

Based on the theoretical and empirical analysis of this study and compared with the literatures, the major contributions of this paper include three parts. The first one is that both the theoretical model and empirical model related with the relationship
between biofuel development and food prices are established and investigated. The second one is that a robust econometric estimation outcome. Based on the observation of oil price and food prices from last 25 years, there may exist structural break points. Previous studies treated such break points as exogenously while Lee and Strazicich’s approach is adopted in this study to get the endogenous break points.

The last one is that the effects of oil price and biofuel development on food prices could be distinguished through the estimation in different periods. The empirical results in this study show that two structural breaks are found in the 49th week in 1985 and the 3rd week in 2005. So the effects of oil price on food prices in the first two periods (i.e. 1983 to 1985 and 1985 to 2005) could be referred as the pure effects of oil price on food price without consideration of biofuel development. However, the increasing of food prices may come from the increasing of oil price or biofuel development in the third period (i.e. years 2005 to 2008). To clarify such effects of increasing oil price and biofuel development on food prices, the estimation outcomes of the effects of oil price on food prices in the first two periods and the last period could be compared. Therefore, the effects of oil price and biofuel development on food prices are investigated.

5. Conclusions and Policy Implications

The major purpose of this paper is to investigate the relationships among the prices of corn, soybeans and wheat, and the crude oil price. Several estimation results from the empirical procedures have been analyzed. First, because the crude oil price varies during different periods, the structural breaks in relation to the oil price were found to endogenously separate the time period into three sub-periods. Two breakpoints were found in the 49th week in 1985 and the 3rd week in 2005.
Therefore, the relationships between the three grain prices and the crude oil price for different time periods were considered.

Second, with regard to the relationships among the different grain prices, the empirical findings show that the change in one grain price was significantly influenced by the changes in other grain prices in the third and fourth periods, rather than in the first and second periods. This finding is consistent with the observation that grain commodities are competing with the derived demand for bio-fuels by using soybeans or corn to produce ethanol or bio-diesel in these recent years or in the third and fourth periods. However, the estimation outcomes of these elasticity of grain price with respect to crude oil price could only be interpreted as the percentage change of these grain prices when crude oil price change 1% but could not be distinguished from change of production cost due to oil price or change of derive demand due to the development of biofuel.

Runge and Senauer [6] indicated that the growth of ethanol industries involved the use of an increasingly large share of corn production to produce ethanol and induced the corn price to rise to its highest level in the last ten years. In addition, because there was a limited endowment of planted acreage and other grains were increasingly being used as substitutes for corn, the prices of wheat and other alternative grain prices also surged to decade-high levels [6]. In fact, the estimated results corresponded to the global price, planted acres and production for soybeans, corn and wheat over the past two years. As Tables 1 and 2 show, between 2005 and 2006, the larger the range of increase for the corn price which increased by 60% induced additional planted acreage for corn and fewer planted acres for soybeans in 2007. Because of the reduction in the planted acreage for soybeans in 2007, the soybean price subsequently increased by a wide margin.
Finally, the values of the percentage change in each grain price due to a 1% change in the oil price are relatively larger and statistically significant in the first (1983w12-1985w48), third (2005w03-2008w20), and fourth (2008w21-2010w05) periods. This implies that the high oil prices might then increase the production cost of grain commodities and intensify the competition relationships between alternative grains. In addition to the high oil prices, Runge and Senauer [6] pointed out that the hefty subsidies for corn-based ethanol industries in the United States would aggravate the impact of the oil price on grain prices. Consequently, the sensitivity of each grain price to the oil price increased and became statistically significant.

The increase in crude oil prices and grain prices may result in other social problems in different countries. For instance, Runge and Senauer [6] were of the opinion that the increase in the crude price of oil would starve the poor through the channel of bio-fuels. They found that bio-fuels may have even more devastating effects on the rest of the world, especially in terms of their effects on the prices of basic foods. If oil prices remain high, the bio-fuel boom will cause the poor countries to suffer not only food deficits but will also affect their imports of petroleum. As the effects of oil prices on grain prices have proved to be increasingly noticeable recently, the governments may consider dropping the subsidy policies that have given rise to bio-fuel industries which may increase the number of hungry and starve the poor countries, because it is not fair for the poor countries to suffer the consequences of the shortage of oil.
References


