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**VOLATILITY LINKAGES BETWEEN
ENERGY AND FOOD PRICES:
CASE OF SELECTED ASIAN
COUNTRIES**

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Abstract

This study examines the linkages between energy price and food prices over the period 2000–2016 by using a Panel-VAR model in the case of eight Asian economies, namely Bangladesh, the PRC, Indonesia, India, Japan, Sri Lanka, Thailand, and Viet Nam. Our results confirm that energy price (oil price) has a significant impact on food prices. According to the results of impulse response functions, agricultural food prices respond positively to any shock from oil prices. Furthermore, the findings from variance decomposition reveal that shares of oil prices in agricultural food price volatilities are the largest. In the second period 4.81%, and in the 20th period 62.49%, of food price variance is explained by oil price movements. The paper opens up new policy insight. Since inflation in oil price is harmful for food security, particularly in vulnerable economies, it would be necessary to diversify the energy consumption in this sector, from too much reliance on fossil fuels to an optimal combination of renewable and nonrenewable energy resources. In addition, the paper found that the impact of biofuel prices on food prices is statistically significant but explains less than 2% of the food price variance. However, by increasing the demand for biofuel, especially in advanced countries, there should be more concern about the global increase in agricultural commodities prices and endangering food security, especially in vulnerable economies.

Keywords: oil price, food price, agricultural commodities prices, Panel-VAR model

JEL Classification: O13; Q41; Q11; Q18

Contents

1. INTRODUCTION AND LITERATURE SURVEY

Energy, especially oil and derivatives, is considered a key factor of production in an economy. It is widely used to supply different sectors including transportation, agriculture, industry, and households, and as a raw material in the production of petrochemical products; this is why it has great value and affects other commodities prices. Since the first oil price shock of 1973, examining the effects of energy prices, especially oil, on macro- and microeconomic levels has become one of the most fundamental issues of energy economics (Taghizadeh-Hesary et al. 2013). Several papers have found that higher oil prices could account for a decline in the growth of GDP and an increase in the inflation rate. For example, Hamilton (1983) concluded that almost all the economic downturns in the US have occurred following oil price increases. Cunado and Gracia (2003) found that oil price shocks have a significant effect on economic growth for a sample of European economies, while a more recent finding by Du, Yanan, and Wei (2010) showed that the world oil price affects Chinese economic growth and inflation significantly. Their result was found through an investigation of the relationship between the world oil price and the People's Republic of China's (PRC) macroeconomy based on a monthly time series from 1995:1 to 2008:12, using the method of multivariate vector auto regression (VAR). In a more recent study, Taghizadeh-Hesary and Yoshino (2015) assessed the impact of crude oil price movements on two macro variables, the gross domestic product (GDP) growth rate and consumer price index inflation rate, in the developed economies of the United States and Japan, and an emerging economy, the PRC. Their results suggest that the impact of oil price fluctuations on developed oil importers' GDP growth is much lower than on the GDP growth of an emerging economy. On the other hand, the impact of oil price movements on the PRC's inflation rate was found to be milder than in the two developed countries that were examined. Also, several studies have been carried out to assess the impact of oil and other energy prices on other commodity prices, including agricultural commodity prices and food prices. Al-Maadid et al. (2017) attempted to examine the relationships between food and energy prices by using a bivariate VAR_GARCH (1,1) model. Their findings revealed that there are significant linkages between food and both oil and ethanol prices. Furthermore, the 2006 food crisis and 2008 financial crisis led to the most significant shifts in the volatility in the price series (food, oil, and ethanol prices). Bergmann, O'Connor, and Thummel (2016) analyzed price volatility transmission in butter, palm oil, and crude oil markets by using the VAR model. The findings revealed evidence that oil prices spill over into world butter prices and volatility. Mawejje (2016) tried to discover the effects of energy and climate shocks on Uganda's food prices. The empirical results proved that there was a long-run cointegrating relationship between food prices and energy prices. McFarlane (2016) investigated the linkages between agricultural commodity prices and oil prices in the US. The findings showed strong evidence of cointegration between prices in two consecutive seven-year periods: 1999–2005 and 2006–2012. Cabrera and Schulz (2016) investigated price and volatility risk originating in linkages between energy and agricultural commodity prices in Germany using a GARCH model as well as a multivariate multiplicative volatility model. Their results revealed that in the long run, prices move together and preserve an equilibrium, while correlations are mostly positive with persistent market shocks. Nwoko, Aye, and Asogwa (2016) concentrated on the effect of oil price on the volatility of food prices in Nigeria from 2000 to 2013. The estimation results from the VAR model showed a positive and significant short-run linkage between oil price and food price volatility. Furthermore, Granger causality test results revealed a unidirectional causality from oil price to maize, soya bean, and sorghum price volatilities. Rezitis (2015) examined the linkage between crude oil
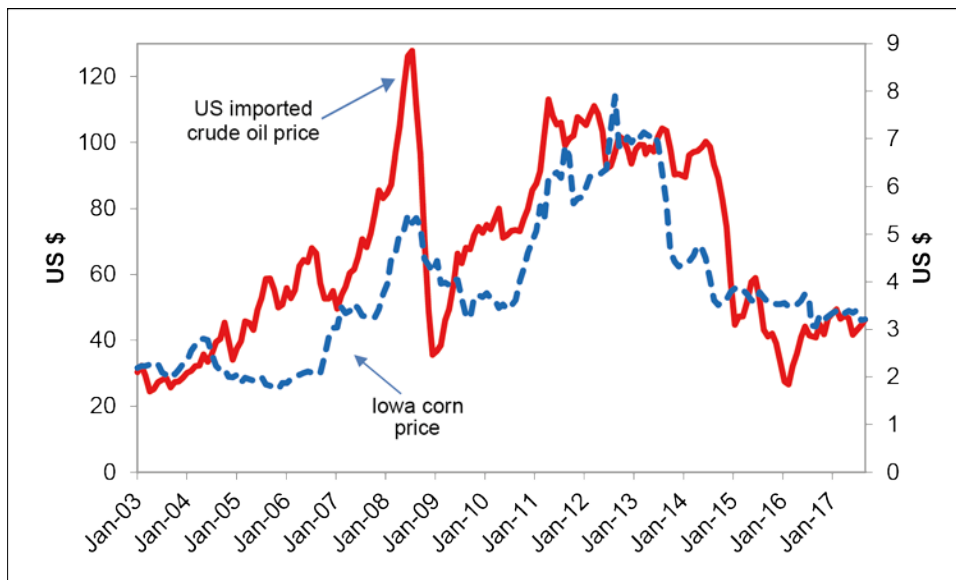
prices, US dollar exchange rates, and 30 selected international agricultural prices in a panel data model. Using Panel-VAR estimation, the findings indicated that both crude oil prices and US dollar exchange rates affect international agricultural commodities. Moreover, the results demonstrated a bidirectional panel causality effect between crude oil prices and international agricultural prices. Zhang and Qu (2015) studied the effect of global oil price shocks on agricultural foods in the PRC. They found that the oil price shocks in most agricultural commodities, such as wheat, corn, soya bean, bean pulp, cotton, and natural rubber, were asymmetric. Koirala and Mehlhorn (2015) investigated the correlation between energy prices and agricultural commodity prices. The results revealed that agricultural commodity and future energy prices are highly correlated and exhibit a positive and significant relationship. This study highlighted the fact that an increase in energy price increases the price of agricultural commodities. Ibrahim (2015) analyzed the linkages between food and oil prices for Malaysia through a nonlinear autoregressive distributed lag (NARDL) model. The results revealed that there is no long-run relationship between oil price reduction and food prices. In the short run, only fluctuations in the positive oil price exert significant influences on food price inflation. Wang, Wu, and Yang (2014) used a structural VAR model to discover the impacts of oil price changes on agricultural commodity markets. The main findings showed that the responses of agricultural commodity prices to oil price changes depend on whether they are caused by oil supply shocks and aggregate demand shocks. Nazlioglu, Erdem, and Soytas (2013) examined volatility transmission between oil and selected agricultural commodity prices (wheat, corn, soybeans, and sugar). They developed a causality in variance test and impulse response functions for daily data from 1 January 1986 to 21 March 2011. Their variance causality test showed that while there is no risk transmission between oil and agricultural commodity markets in the pre-crisis period, oil market volatility spills over into the agricultural markets—with the exception of sugar—in the post-crisis period. Their impulse response analysis also indicates that a shock to oil price volatility is transmitted to agricultural markets only in the post-crisis period. Natanelov et al. (2011) tried to discover whether there is co-movement of future agricultural commodities prices and crude oil. The results revealed that biofuel policy buffers the co-movement of crude oil and corn prices until the crude oil prices surpass a certain threshold. Balcombe and Rapsomanikis (2008) investigated nonlinear adjustment towards long-run equilibria between crude oil, ethanol, and sugar in Brazil using Bayesian techniques. They find a long-run equilibrium between each price pair. Further, their analysis reveals a causal hierarchy from oil to sugar to ethanol. Uri (1996) investigated the oil price inflation impacts on agricultural employment in the US over the period 1947–1995. He found a negative relationship between oil price increase and agricultural employment in the US.

The rising food prices[1] during the period 2002–2011 raised the question of whether oil markets have any explanatory power in the recent upward movements in agricultural food prices. The statistics for imported crude oil prices and corn prices, shown in Figure 1, prove that there is a positive correlation between these two variables.

It can be seen that from 2003 to the end of 2017, due to an increase in the prices of crude oil imported into the US, the corn prices in this country go up. Moreover, such a correlation can be seen between the prices of crude oil imported into the US and soybean prices in this country. Figure 2 provides evidence that there is a positive relationship between these two variables in the US.

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[1] Between 2002 and 2011 the FAO food index rose from 89.6 to 229.9 (average for each year).

**Figure 1: Linkage between Imported Oil Prices and Corn Prices in US,
January 2003–October 2017**

Constant line is the , $/ barrel,(left-hand side axis) dashed line is: Iowa corn price $/bu (right hand side axis).

Source: US imported crude oil price is from Energy Information Administration database. Iowa corn price is from United States Department of Agriculture, National Agricultural Statistics Service database.

**Figure 2: Linkage between Imported Oil Prices and Soybean Prices in US,
January 2003–October 2017**
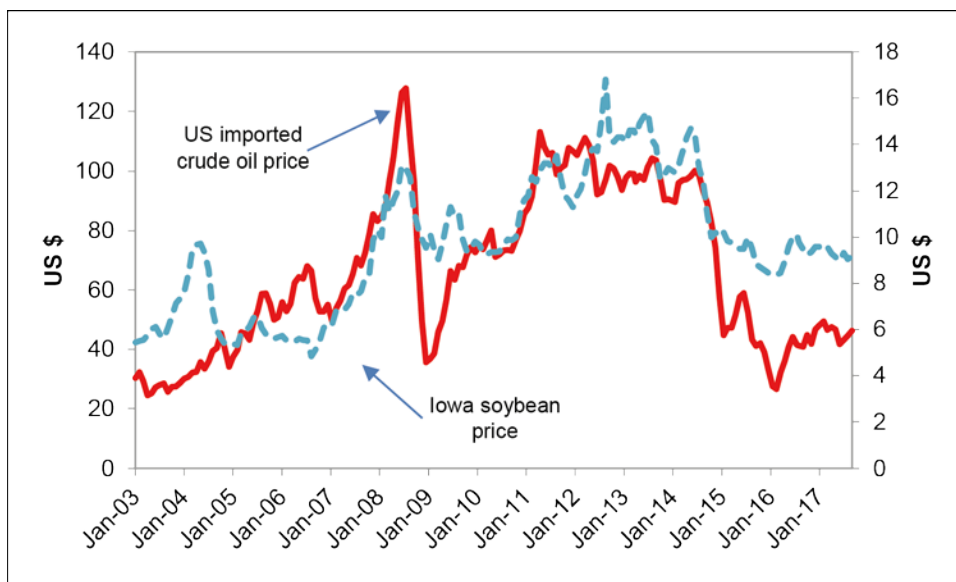
Note: Constant line is the US imported crude oil price, $/ barrel (left-hand side axis), dashed line is: Iowa soybean price $/bu (right hand side axis).

Source: US imported crude oil price is from Energy Information Administration database. Iowa soybean price is from United States Department of Agriculture, National Agricultural Statistics Service database.

The food-energy nexus has become a controversial issue. Many researchers indicate that increasing oil prices was the main factor behind the major shocks experienced by agricultural markets (e.g., Abbott, Hurt, and Tyner 2008; Baffes 2007; Balcombe and Rapsomanikis 2008; Chang and Su 2010; Mitchell 2008; Rosegrant et al. 2008;

Yang et al. 2008). In contrast, some researches indicate that there is no direct relationship between oil and agricultural commodity prices. For example, Zhang et al. (2010) argued that oil price increases do not have direct impacts on agricultural commodity prices. Pindyck and Rotemberg (1990) examined the co-movement of wheat, cotton, copper, gold, crude oil, lumber, and cocoa prices and found that the cross-price elasticities of demand and supply are zero. Gilbert (2010) stated that there is no direct causal relationship between oil and agricultural prices and that the correlation between oil and agricultural prices is due to demand growth and monetary and financial developments. His findings do not offer support for restrictions on the use of food commodities as biofuel production. According to the Council of Economic Advisors, only around a 3% retail food price increase can be attributed to the ethanol production in 2007 (Lazear 2008).

In recent years, both the sharp increase in oil prices that began in 2001 and the sharp decline that followed in 2008 following the subprime mortgage crisis have renewed interest in the effects of oil prices on the macroeconomy. Recently, the price of oil more than halved in a period of less than five months from September 2014. After nearly 5 years of stability, the price of a barrel of Brent crude oil in Europe fell from more than $100 per barrel in September 2014 to less than $46 per barrel in January 2015. Several studies have evaluated these impacts (see, for example, Angelidis, Degiannakis, and Filis 2015; Basnet and Upadhyaya 2015; Du, Yanan, and Wei 2010; Kang, Ratti, and Vespignani 2016; Taghizadeh-Hesary et al. 2013; Taghizadeh-Hesary and Yoshino 2014, 2015, 2016; Zhang and Qu 2008). In addition, more recently in January 2018, Brent crude oil prices broke through the $70 a barrel barrier for the first time since December 2014. Oil prices have been supported by a stronger-than-expected demand fueled by worldwide economic growth, ongoing output limits set by OPEC and the Russian Federation, and a series of global events that have stoked geopolitical tension. The most recent movements of oil prices have renewed the attention toward the impact of oil prices on commodities prices.

2. ENERGY CONSUMPTION AND AGRICULTURAL PRODUCTION

2.1 Agricultural Sector in Asian Economies

Generally, Asian agriculture contributes to around two thirds of global agricultural GDP (Mendelsohn 2014). It can almost be said that Asian nations have the most favorable agricultural conditions in the world. Figure 3 shows the share of land area that is arable in selected Asian economies. It can be seen that a remarkable percentage of countries' land in Asia comprises agricultural land. For instance, over 60% of the land in Bangladesh and India is agricultural. Moreover, a number of Asian economies, such |as Sri Lanka, Viet Nam, and Indonesia, experienced an increased in the share of agricultural land over the period 2000–2015. In a few Asian nations such as Japan, where, due to geographical circumstances, the agriculture sector cannot be developed as much as in other Asian nations, there is evidence of various attempts to build agricultural land through new technologies (Tamaki et al. 2013; Nasu and Momohara 2016) or by employing various policies to develop agricultural land in urban areas. Yeung (1988) points out that in the PRC; Hong Kong, China; and Singapore there has been large-scale and systematic planning for food production within urban areas.

Figure 3: Agricultural Land (%) **in Selected Asian Economies, 2000–2015**
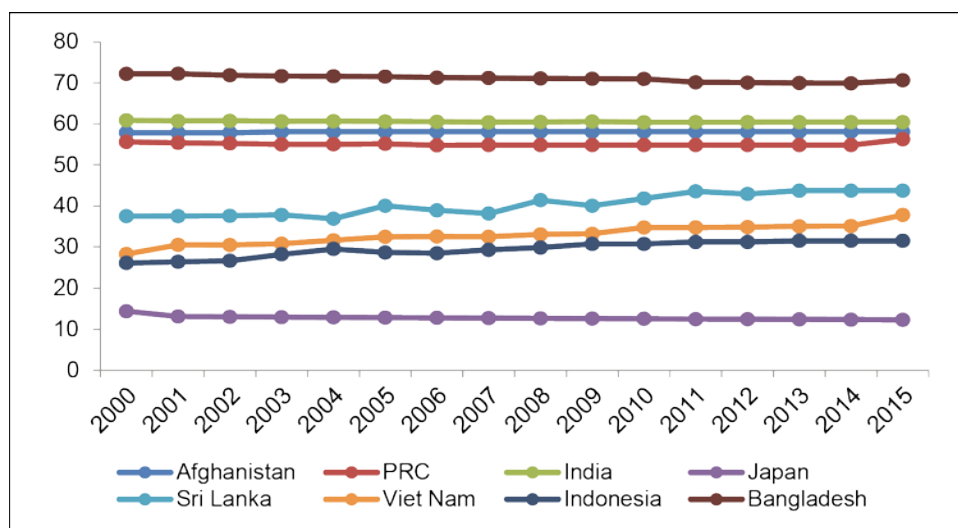
Source: Authors' compilation from the World Bank data set.

Figure 4: Typical Employment Structures by Type of Economy
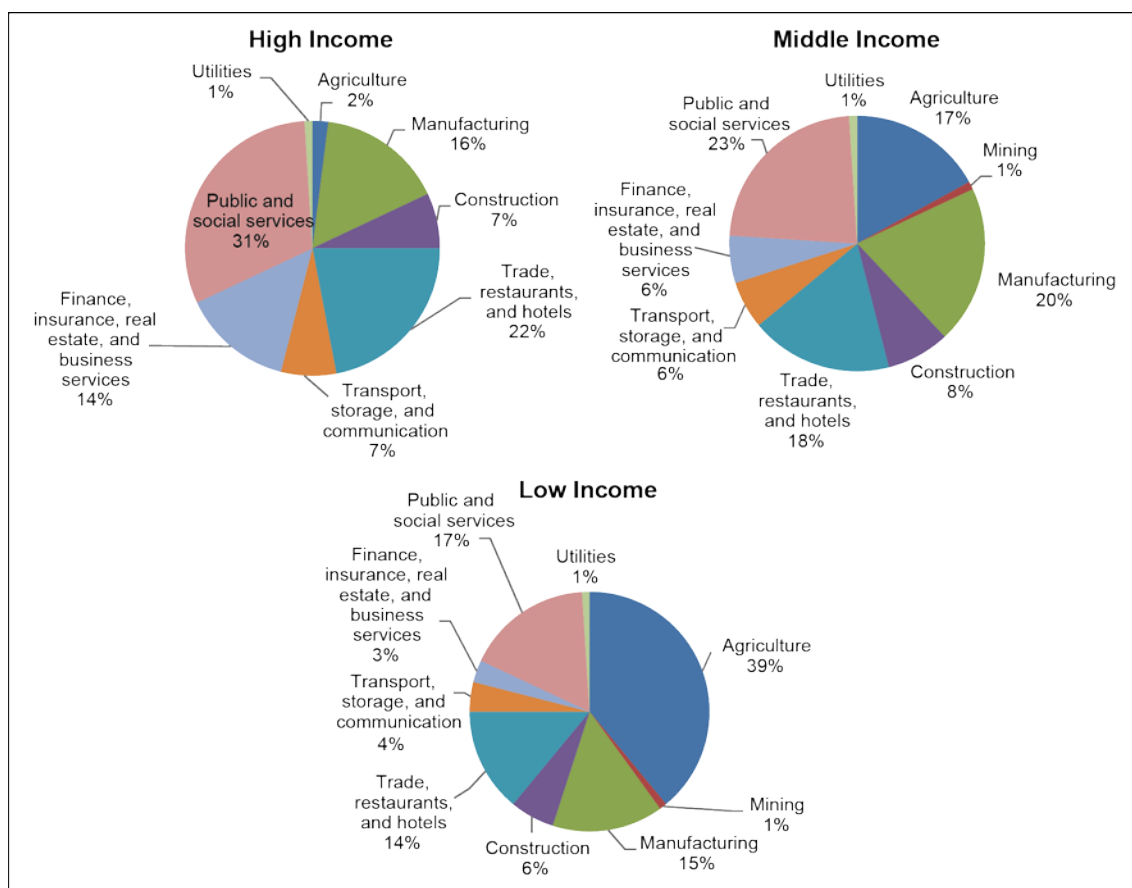
Notes: These are derived from Lowess regressions (Foster-McGregor and Verspagen 2016). The shares in the three charts are the predicted values of these regressions at three distinct values of GDP per capita: $24,189 (the 2011 value for Taipei,China as the high-income reference), $8,737 (the 2011 value for the PRC as the middle-income reference), and $3,372 (the 2010 value for India as the low-income reference). To be precise, the employment structure of these three economies is not used, but rather the predicted values of the employment structure derived from the Lowess regression at these levels of GDP per capita.

Source: ADB (2016).

However, the lack of developed industrialized sectors is another reason for focusing more on Asian nations in the agriculture sector. According to Hamidov, Helming, and Balla (2016), agriculture is the main sector in the economy of Central Asia because of the absence of developed industrial and service sectors. The importance and huge magnitude of the agricultural sector in this region of the world makes the share of employment in this sector significant. Asia, India, Pakistan, Thailand, Viet Nam, and many other economies still have very high agricultural employment shares making a significant contribution to the GDP. Figure 4 shows the employment structure of typical low-, middle-, and high-income countries. Probably the most salient feature is the different shares of agriculture: 39% of total employment in low-income economies, 17% in middle-income economies, and 2% in high-income economies.

2.2 Food Insecurity in Asia

Achieving food security is of huge importance for human development and peace in any nation. However, food insecurity still prevails in many developing countries in Asia. According to the latest State of Food Insecurity in the World report, between 2014 and 2016, the number of chronically undernourished people in Asia's developing countries was still as high as 512 million (globally, 780 million chronically undernourished people are living in developing countries) (ADBI 2017) (Figure 5).

**Figure 5: Asia's Share of Undernourished People
in the World's Developing Regions, 2014–2016**
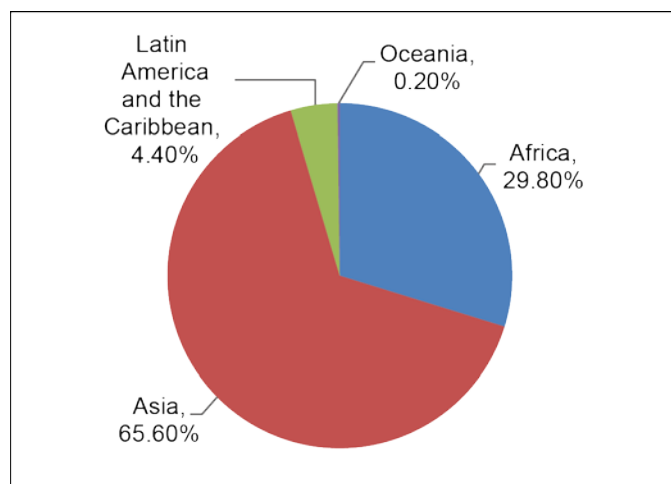
Sources: FAO, IFAD, and WFP (2015: 44–47).

On the whole, Asia has made remarkable progress in feeding its huge populations and improving its food security since World War II. However, the ongoing food insecurity status of over 500 million hungry people in today's Asia is disturbing and unacceptable. Strategies need to be developed and measures need to be taken to improve the food security of this large number of underprivileged people (ADBI 2017). More expensive agricultural commodities prices will endanger and increase food security and raise the number of undernourished people in Asia. As with other commodities, energy prices have a significant impact on food prices, and higher energy prices will increase food insecurity, especially in vulnerable economies. The following section will highlight how energy prices affect the primary and secondary production of agricultural commodities as well as the prices in the food market.

2.3 Energy Inputs in Primary and Secondary Production

Energy carriers, especially fossil fuels (oil, gasoline, diesel, natural gas, etc.), are widely used in the primary production of agricultural products, e.g., as a fuel for tractors and machinery, for irrigation, in the production of fertilizers, in protected cropping in greenhouses, and in fishing and aquaculture, livestock, and forestry. Ambitions to increase global food supplies in Asia through increased productivity of crops, animals, and fish resources may be partly constrained by the limited future availability of cheap and accessible fossil fuel. Small-scale agricultural and fishery production systems in low-income countries in Asia may not be able to emulate the past efforts of high-income countries in achieving desirable productivity increases if to do so will depend on increased reliance on fossil fuels (Sims and Flammini 2014).

Energy is widely consumed not only in primary production, but also in secondary production, such as in drying, cooling and storage, and transport and distribution.

The modernization of food supply chains has been associated with higher GHG emissions from both pre-chain inputs (fertilizers, machinery, pesticides, veterinary products, transport) and post-farm gate activities (transportation, processing, and retailing) (FAO 2016). It has been estimated, using previous calculations and data from Bellarby et al. (2008) and Lal (2004), that the production of fertilizers, herbicides, and pesticides, along with emissions from fossil fuels used in the field, represented in 2005 approximately 2% of global GHG emissions.

3. ENERGY PRICE VOLATILITY VERSUS AGRICULTURAL COMMODITY PRICES

In this paper, we look at the relationship between energy prices and food prices in selected Asian countries. Recently, in developing Asia, inflation was further subdued in 2015, falling to 2.2% from 3.0% in 2014. The deceleration partly tracked the slowing economic growth across the region and the consequent weakening of demand-side inflationary pressures. Supply-side factors, in particular weak global oil and food prices, also helped to tame inflation. Average Brent crude prices fell to $52/barrel in 2015 from $99/barrel in 2014, a 47% drop that was fivefold the 9% fall in average prices in 2014. Agricultural commodity prices also continued to decline, with the overall index falling by 13.1% and food prices by 15.4%, mainly due to favorable supply conditions and soft energy prices. While the drop in prices has been largely due to supply factors, subdued demand has also contributed. The recent drop in oil prices and subsequent sharp drop in agricultural commodity prices attracted attention toward the impact of energy price volatilities on food and agricultural product prices.

In the empirical parts of this paper, a Panel-vector autoregressive (VAR) model using macroeconomic variables, food prices, and major energy carriers' prices, with a number of control variables, will be developed in order to capture the response of food prices to energy price impulses. In the next step the variance decomposition will explain the percentage of volatilities of food prices that can be explained by energy price fluctuations.

4. EMPIRICAL RESULTS

4.1 Model Specification

Before explaining the econometric model, the theoretical basis of the model needs to be clarified.

By considering agricultural production inputs, namely Labor (L), Capital (K), and Energy (E), the supply function (Y^s) for agricultural products can be written as Eq. (1):

$$Y^s = F(L, K, E) \tag{1}$$

Using production inputs requires costs to be paid, which can be revealed in the total cost (TC) equation as Eq. (2):

$$TC = w.L + r.K + P_E.E \tag{2}$$

where w denotes wage as monetary compensation paid to a labor force in exchange for work done in the agricultural production process. r shows the interest rate or the rental price of capital, and P_E denotes the price of energy.

By considering total revenue as the supply of agricultural product multiplied by the price of agricultural product ($P.Y^s$) and taking into consideration the above total cost equation, the profit function (π) can be formulated as:

$$\pi = P.Y^s - (w.L + r.K + P_E.E) \tag{3}$$

Assuming imperfect competition[2] in the agricultural market, the profit maximization under the first-order condition will be:

$$\frac{\delta\pi}{\delta Y} = \frac{\delta P}{\delta Y}.Y + P.\frac{\delta Y}{\delta Y} - \left(w.\frac{\delta L}{\delta Y} + r.\frac{\delta K}{\delta Y} + P_E.\frac{\delta E}{\delta Y}\right) = MR - MC \tag{4}$$

$$= (-L_1).Y + P - \left(w.\frac{\delta L}{\delta Y} + r.\frac{\delta K}{\delta Y} + P_E.\frac{\delta E}{\delta Y}\right) = 0$$

$$-L_1.Y + P = w.\frac{\delta L}{\delta Y} + r.\frac{\delta K}{\delta Y} + P_E.\frac{\delta E}{\delta Y}$$

$$P = L_1.Y + w.\frac{\delta L}{\delta Y} + r.\frac{\delta K}{\delta Y} + P_E.\frac{\delta E}{\delta Y} = L_1.Y + MC \tag{5}$$

Moreover, the demand for agricultural products can be formulated as:

$$Y^d = d_0 - d_1.P + d_2.Z \tag{6}$$

By restructuring the above equation, Eq. (7) is formulated as:

$$P = d_0 - \frac{1}{d_1}.Y^d + \frac{d_2}{d_1}.Z = L_0 - L_1.Y + L_2.Z \tag{7}$$

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[2] We are assuming that the labor market, capital market, and energy market are perfect competition.

Following Taghizadeh-Hesary and Yoshino (2014), P indicates the price of agricultural product, Y is the amount of demanded agricultural product, and Z is a vector of other variables that have an impact on the demand for agricultural commodities prices, including interest rate, exchange rate, price of substituting products, etc.

Following the above theoretical model, we employ below an empirical model (Model 8) in order to estimate the effects of oil price fluctuations on agricultural commodities prices.

$$(8)$$

Price of agricultural foods = $\boldsymbol{F}$ (agricultural land, oil price, interest rate, inflation rate, employment in agriculture, GDP, biofuel prices)

And in the form of an econometric equation and logarithmic form we have Eq. (9)

$$Agrifood_{it} = \beta_0 + \beta_1.Agriland_{it} + \beta_2.oilp_t + \beta_3.interest_{it} + \beta_4.inf_{it} +$$
$$\beta_5.Agriem_{it} + \beta_6.GDP_{it} + \beta_7.biofuel_{it} + \varepsilon_t \qquad (9)$$

In Eq. (9), $Agrifood$ indicates agriculture food price. $Agriland$ and $oilp$ show agriculture land and global oil price, respectively. $interest$ represents real interest rate and inf is general price inflation rate. While $Agriem$ denotes employment in agriculture sector, GDP and $biofuel$ are gross domestic product and biofuel prices.

To estimate this equation, we will run a Panel-VAR model for a sample of Asian economies. Furthermore, some preliminary tests, such as a unit root test and a stability test, are employed to ensure the reliability of Panel-VAR estimation results.

4.2 Data Source and Descriptive Statistic

The data used in this study are taken from the World Development Indicators, the FAO (Food and Agriculture Organization), the British Petroleum (BP) Statistical Review of World Energy, and the Energy Information Administration (EIA), and cover the period 2010–2016 for eight Asian countries, namely Bangladesh, the PRC, Indonesia, India, Japan, Sri Lanka, Thailand, and Viet Nam. The variables used are food prices (consumer prices, food indices (2010=100)), agricultural land (% of country's land), global oil price (average of WTI and Brent), real interest rate, inflation rate, employment in agriculture sector (% of total employment in a country), GDP (constant 2005 US dollars), and biofuel prices (average of biodiesel and bioethanol in trillion Btu).

Food prices has a high volatility based on its high standard deviation. Employment in agricultural sector among the eight Asian nations has a maximum and minimum of 65.30 and 3.70 %, respectively. The share of agricultural land from the total land of these nations has a mean of 42.80%, with a maximum of 72.23%, while the minimum is only 12.33%. Biofuel price has 62.87% volatility and has a maximum and minimum of 189.35 and 11.31, respectively. As regards economic size (GDP), among these eight nations there are huge economies such as Japan, the PRC, and India, whereas Sri Lanka and Viet Nam can be classified as small economies among our samples. Inflation rate in these countries reaches a maximum of 23.11%, while the minimum is only 1.71%. Oil price has a volatility of 31.24, which denotes some shocks between 2010 and 2016. Finally, real interest rate reaches a maximum of 12.32%, whereas its minimum is −11.01.

Table 1 represents the correlation matrix. The correlation between food prices and oil price is positive. Food prices is positively related to biofuel prices. The relation between production inputs (agricultural land, agriculture employment) and food prices is positive. The relation between inflation rate and production inputs (agricultural land, agriculture employment) is negative. The correlation indicates a positive correlation between GDP and all the other variables.

Table 1: Correlation Matrix

	Agricultural Food Price	Employment in Agriculture Sector	Agricultural Land	Biofuel Price	GDP	Inflation Rate	Oil Price	Real Interest Rate
Food price	1.00	–	–	–	–	–	–	–
Employment in agriculture sector	0.69	1.00	–	–	–	–	–	–
Agricultural land	0.52	0.61	1.00	–	–	–	–	–
Biofuel price	0.42	0.38	0.08	1.00	–	–	–	–
GDP	0.77	0.51	0.21	0.05	1.00	–	–	–
Inflation rate	0.36	−0.58	−0.44	0.72	−0.35	1.00	–	–
Oil price	0.79	−0.42	−0.11	−0.27	−0.03	0.44	1.00	–
Real Interest rate	0.32	−0.19	−0.37	0.08	0.42	−0.05	0.14	1.00

Note: Variables are in logarithmic form.

Source: Authors' compilation from EViews 9.0.

4.3 Empirical Estimations

As mentioned earlier, some preliminary tests need to be applied to ensure the correctness and reliability of empirical estimation results. As the first step, we have to evaluate the stationarity of all series. Under the panel framework, we performed a popular panel unit root test (Fisher-Augmented-Dickey-Fuller (Fisher-ADF)) on all series at levels and first differences. The results are summarized in Table 2.

Table 2: Panel Unit Root Test Results

Variable	Fisher-ADF	H0	Stationary
Food price	3.63	Accept	No
D(Agricultural food price)	71.15	Reject	Yes
Employment in agriculture sector	9.11	Accept	No
D(Employment in agriculture sector)	70.09	Reject	Yes
Agricultural land	2.78	Accept	No
D(Agricultural land)	77.31	Reject	Yes
Biofuel price	19.19	Accept	No
D(Biofuel price)	36.57	Reject	Yes
GDP	7.70	Accept	No
D(GDP)	40.07	Reject	Yes
Inflation rate	21.02	Accept	No
D(Inflation rate)	55.64	Reject	Yes
Oil price	9.57	Accept	No
D(Oil price)	27.72	Reject	Yes
Real interest rate	21.02	Accept	No
D(Real interest rate)	60.62	Reject	Yes

Note: D (X) denotes the first differences; Fisher-ADF = Fisher-Augmented-Dickey-Fuller.

Source: Authors' compilation from EViews 9.0.

The Panel unit root results represented in Table 2 imply that all series are nonstationary in levels, whereas the first differences of all variables using the Fisher-ADF test show stationary results. Hence, there is integration of order 1 or I(1) between variables. Due to the nonstationary series, we provide a Kao residual cointegration analysis to find out whether the series are cointegrated. Table 3 reports the result of this panel cointegration test.

Table 3: Kao Residual Cointegration Test

Series: Agrifood; Agriland; oilp; interest; inf; Agriem; GDP biofuel		
	t-statistic	**Probability**
ADF	0.861	0.19

Note: $Agrifood$ indicates agriculture food price. $Agriland$ and $oilp$ show agriculture land and global oil price, respectively. $interest$ represents real interest rate and inf is general price inflation rate. While $Agriem$ denotes employment in agriculture sector, GDP and $biofuel$ are gross domestic product and biofuel prices.

Source: Authors' compilation from EViews 9.0.

Considering the null hypothesis of this test as "No cointegration," based on a p-value of 0.19, we can accept the null hypothesis. Therefore, series are not cointegrated (the finding is in line with Avelos (2014), who found a nonexistent cointegration relationship between oil and corn prices) and we can use the Panel-VAR model.

To find out the responses of food price to different impulses from various variables, we employ impulse response functions (IRF) under the Panel-VAR approach. Impulse response functions are the best w0.ay to explore any response of economic variables to the impulse of an indicator.

Figure 6 illustrates the accumulated response of food price to different impulses. The major result here is the positive response of food prices to oil price. This means that any sharp increase in global oil price leads to an increase in agricultural food prices. This finding is in line with Alghalith (2010), Esmaeili and Shokoohi (2011), and Pal and Mitra (2018), who found a link between oil price and food prices. Furthermore, the response of agricultural food price to any positive shock from labor wage rate is positive, whereas its response to any shock from other production input, i.e., agricultural land, is negative. Moreover, any sharp increase in inflation rate leads to an increase in prices of agricultural products, while a sudden increase in real interest rate increases food prices, which is significant for six periods and after that becomes insignificant. Agricultural food price responds positively to any biofuel price shock. Finally, it can be seen that a positive impulse in GDP causes a positive response in agricultural food price, which is significant up to eight periods and after that becomes insignificant.

In the case of oil price volatilities' effects on food prices, it would be useful to see the responses of all other variables to any shock from oil price. Figure 7 depicts the response of different variables to any impulse from oil prices. It is obvious that GDP responds negatively to any shock from oil prices. Inflation responds positively to oil price shocks, which is significant up to four periods and after that it becomes insignificant. These results are in line with Taghizadeh-Hesary and Yoshino (2016) and Taghizadeh-Hesary et al. (2016). Real interest rate has a negative response to a shock from oil prices, which is significant for two periods and after that becomes insignificant. This is in line with the recent findings of Leduc and Sill (2004), Kormilitsina (2011), Taghizadeh-Hesary and Yoshino (2014), Yoshino and Taghizadeh-Hesary (2014), and Yoshino and Taghizadeh-Hesary (2016). The response of biofuel prices to any sharp
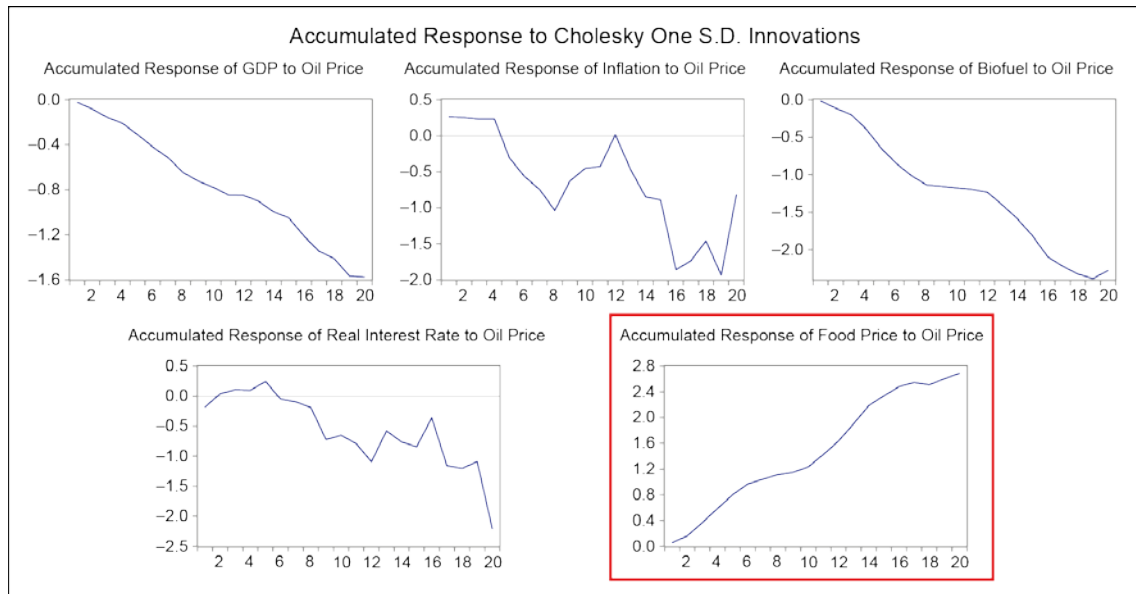
positive change in global oil price is negative. Food price has a positive response to any impulse from global oil price.

Figure 6: Accumulated Response of Food Price to Impulse of Variables
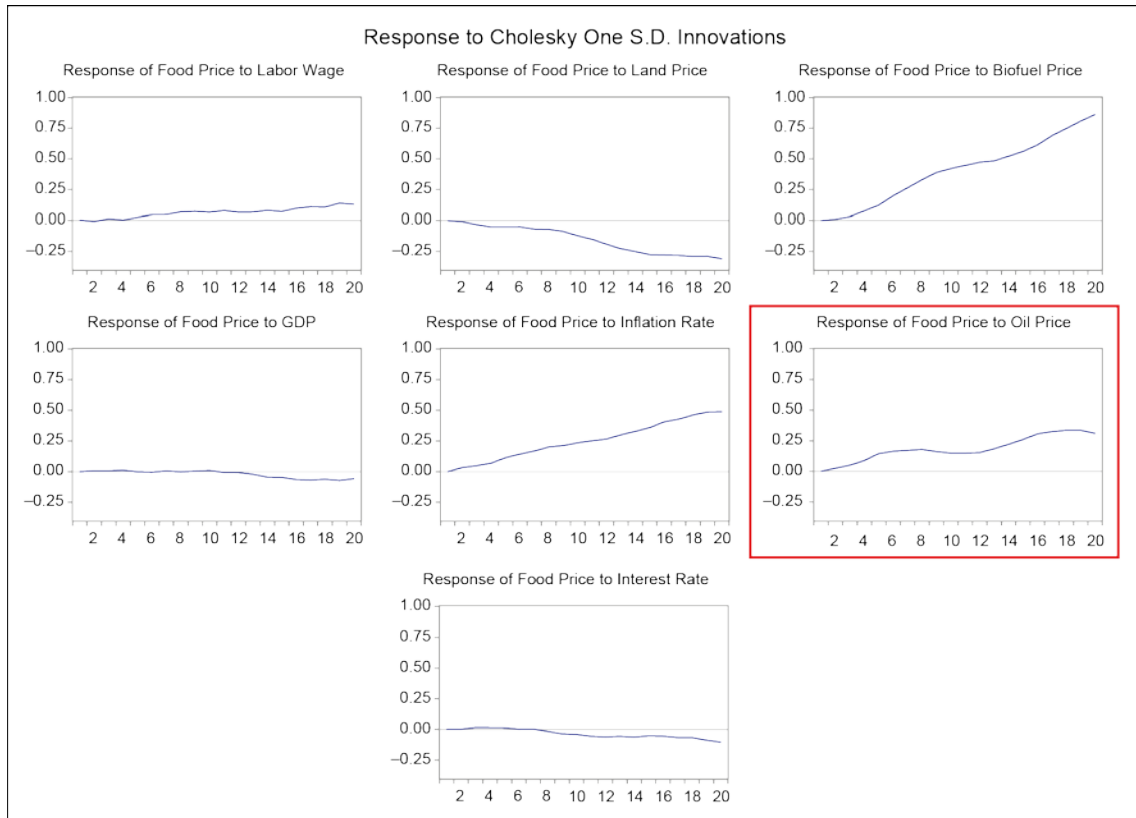
Source: Authors' compilation from EViews 9.0.

Figure 7: Accumulated Response of Variables to Impulse of Oil Price

Source: Authors' compilation from EViews 9.0.

After applying the impulse response function, in order to find more results, we perform the variance decomposition (VD) estimation, which indicates which one of the variables can provide explanatory power for a variation in food prices. Table 4 illustrates shares of different variables in food price volatilities.

Table 4: Variance Decomposition of Food Price

Period	Oil Price	GDP	Inflation Rate	Biofuel	Land Price	Food Price	Labor Wage	Real Interest Rate
1	0.00	0.00	0.00	0.00	0.00	99.97	0.02	0.00
2	4.81	0.00	2.70	0.02	0.09	91.93	0.42	0.00
3	7.32	0.05	2.80	0.63	0.18	87.97	0.50	0.51
4	13.51	0.09	3.80	1.00	0.53	79.86	0.46	0.72
5	19.17	0.15	4.20	1.24	0.57	73.02	0.63	0.98
6	25.91	0.25	4.84	1.28	0.71	65.14	0.81	1.01
7	31.73	0.37	5.15	1.23	0.75	58.75	1.02	0.95
8	37.53	0.51	5.53	1.09	0.79	52.55	1.16	0.80
9	42.46	0.68	5.76	0.92	0.77	47.46	1.29	0.63
10	46.88	0.85	5.97	0.74	0.75	42.92	1.37	0.48
11	50.57	1.03	6.11	0.58	0.71	39.14	1.43	0.38
12	53.69	1.21	6.23	0.46	0.67	35.87	1.46	0.36
13	56.23	1.39	6.30	0.39	0.63	33.13	1.47	0.42
14	58.27	1.56	6.36	0.37	0.58	30.78	1.48	0.56
15	59.84	1.72	6.38	0.42	0.54	28.81	1.47	0.78
16	61.02	1.87	6.39	0.53	0.50	27.12	1.47	1.07
17	61.83	2.01	6.38	0.71	0.46	25.69	1.46	1.43
18	62.32	2.13	6.35	0.95	0.43	24.48	1.45	1.85
19	62.53	2.25	6.31	1.26	0.40	23.46	1.44	2.31
20	62.49	2.34	6.27	1.64	0.37	22.59	1.43	2.82

Source: Authors' compilation from EViews 9.0.

According to Table 5, the food price variance decomposition analysis reveals that oil price fluctuation has a large and major share in food price volatilities of about 62.49% in the 20th period. Its share in the second period is 4.81% and gradually its share in food price volatility rises and in the last year period reaches 62.49% among all other regressors. The second share is for the food price by itself, which is the self-explanatory reason that causes 22.59% of the variance in food prices in the 20th period. In other words, the previous accumulated inflation in food prices creates more inflation in food prices in the future. The third reason is the general inflation rate, which explains about 6.27% of the variance in food prices in the 20th period. A higher inflation rate means an increase in the price of various inputs for the production of agricultural products, including wage rates, price of machinery, seeds, fertilizers, price of energy inputs, and other inputs, which raises the production cost, and pushes up agricultural product costs and food prices. The fourth reason is the real interest rate, which in the 20th period explains about 2.82% of the volatilities of food prices. As Figure 6 shows, an increase in real interest rate increases food prices, which is significant for six periods and after that becomes insignificant. An increase in interest rate increases the cost of capital in agricultural production, and therefore increases the production cost in different sectors, including agricultural products, thereby raising the prices of agricultural products and food. Recently the agricultural sector became more automated which means it became more capital-intensive than in the past, and hence more elastic in relation to interest rate movements. The fifth reason behind food price volatilities is the GDP growth rate, which explains 2.34% of the variance in food prices

after 20 periods. A higher income level will increase the level of demand for different consumer products including foods, which shifts the prices upward. The sixth reason behind the volatilities in food prices is biofuel prices, which explain 1.64% of food price variance. When the biofuel (e.g., bioethanol[3]) market is booming, the demand for different agricultural commodities that can be used as the source of biofuel such as corn, sugarcane, or sweet sorghum increases, which pushes up the price of these commodities, which are basic agricultural commodities and have an impact on general food prices. However, it is clear that the share of biofuel prices in food price volatilities is not so large and is not among the main causes of food price increases. But as the demand for biofuels is increasing, in future there will be more concern regarding their impact on food prices and endangering food security. Other variables are wage rate and land prices, whose shares are statistically small and their movements respectively explain only 1.43% and 0.37% of the volatilities of food prices. Overall, we can conclude that oil price fluctuation has positive short- and long-run effects on agricultural food prices.

5. CONCLUSIONS AND POLICY IMPLICATIONS

The purpose of this study was to find the answer to the question of whether oil markets have any explanatory power on the movements of food prices. To this end, through the selection of eight Asian economies, namely Bangladesh, the PRC, Indonesia, India, Japan, Sri Lanka, Thailand, and Viet Nam, a Panel-VAR model was applied for series over the period 2000–2016. Moreover, to discover the effect of energy (crude oil) prices on food prices, we employed some control variables, including agricultural land and employment as two main production inputs, along with GDP, inflation rate, real interest rate, and biofuel price.

From the estimation results, the following conclusions can be drawn:

- First, there is a positive correlation between oil price and food price. Furthermore, the relation between biofuel price and food price is positive, while the correlation between oil price and biofuel price is negative. The trends of these two kinds of prices show that since 2008, the correlation between these two variables has become negative. The evidence of an influential role of oil price and biofuel production in food prices is in line with Hang and Quentin Grafton (2015) and Ibrahim (2015).

- Second, based on the impulse response function results, following any shock from oil price, the agricultural food prices show a positive response. An increase in oil price may directly increase the cost of production of agricultural commodities and food products. The main reason is that in different parts of primary (used as fuel in tractors, fertilizers, etc.) and secondary (drying, cooling and storage, transport and distribution) production of agricultural products, oil and derivatives are used. Hence, any increase in oil prices leads to an increase in the cost of production.

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[3] Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane, or sweet sorghum.

- Third, the findings revealed that a higher inflation rate has a significant positive impact on food prices. Inflation means an increase in the price of various inputs for the production of agricultural products, including wage rates, price of machinery, seeds, fertilizers, price of energy inputs, and other inputs, which raises the production cost, and pushes up the price of agricultural product costs and food prices.

- Fourth, the paper revealed that real interest rate movements also significantly explain the volatilities in food prices. An increase in real interest rate increases food prices, which is significant for six periods and after that becomes insignificant. An increase in interest rate increases the cost of capital in agricultural production, and therefore increases the production cost in different sectors, including agricultural products, thereby raising the prices of agricultural products and foods. Recently the agricultural sector became more automated, which means it became more capital-intensive than in the past and hence more elastic in relation to interest rate movements.

- Fifth, the GDP growth rate also significantly explains the variance in food prices. A higher income level will increase the level of demand for different consumer products, including foods, which shifts the prices upward.

- Sixth, the paper found that the impact of biofuel (bioethanol, biodiesel) prices on food prices is statistically significant but explains less than 2% of the food price variance. However, by increasing the demand for biofuel, especially in advanced countries, there should be more concern about the global increase in agricultural commodities prices and endangering food security, especially in vulnerable economies.

- Finally, the variance decomposition showed that oil price is the major component explaining the fluctuation in food prices. Oil price fluctuation has positive short- and long-run effects on agricultural food price volatilities.

Because of the large impact of energy price fluctuations on agricultural product prices, and due to an increasing share of industrialized agricultural production and more GHG emissions, which is the result of more use of fossil fuels in this sector, it is necessary to diversify the energy consumption in this sector, from too much reliance on fossil fuels to an optimal combination of renewable and nonrenewable energy resources'. The conclusion that there is a need for energy diversification in the agriculture sector is in line with Dahlberg (1992), who suggests that energy should be diversified in the agriculture sector from fossil fuels to any adoptable energy sources within the environment.

Renewable energy resources can be used directly by the end-use sectors of the agrifood chain or indirectly through integration with conventional energy supply systems that are mainly based on fossil fuels and nuclear power (Figure 8).

The IFES shown in Figure 9 is a landscape/seascape perspective aimed toward a future sustainable and secure agrifood supply system both in high-GDP and low-GDP countries (IEA 2009). This conceptual integrated food energy system can be a useful pattern for Asian economies who care about food security. It can provide biological foresights for these countries along with the increased production of agricultural products.

Figure 8: Use of Renewable Energy Resources in Agrifood Chain
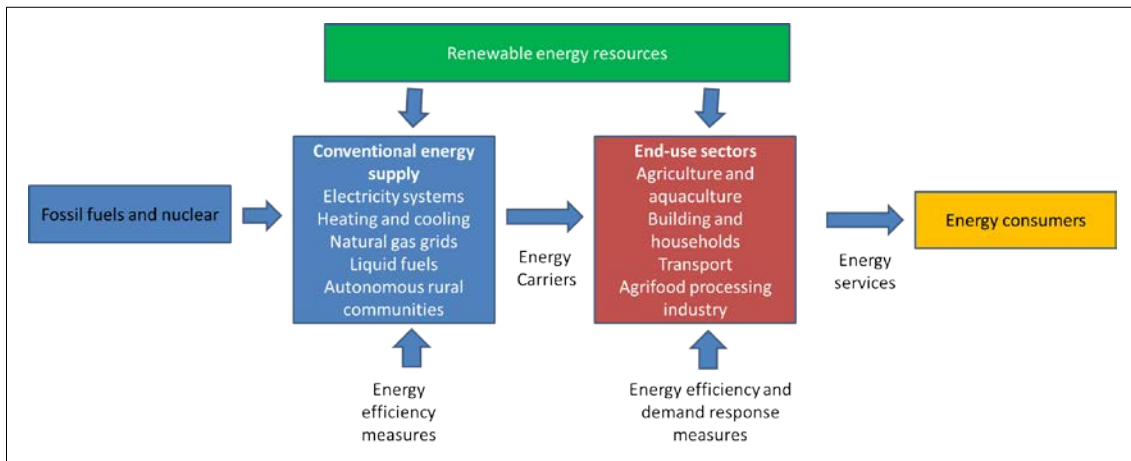
Source: IPCC (2011).

Figure 9: A Conceptual Integrated Food Energy System (IFES)
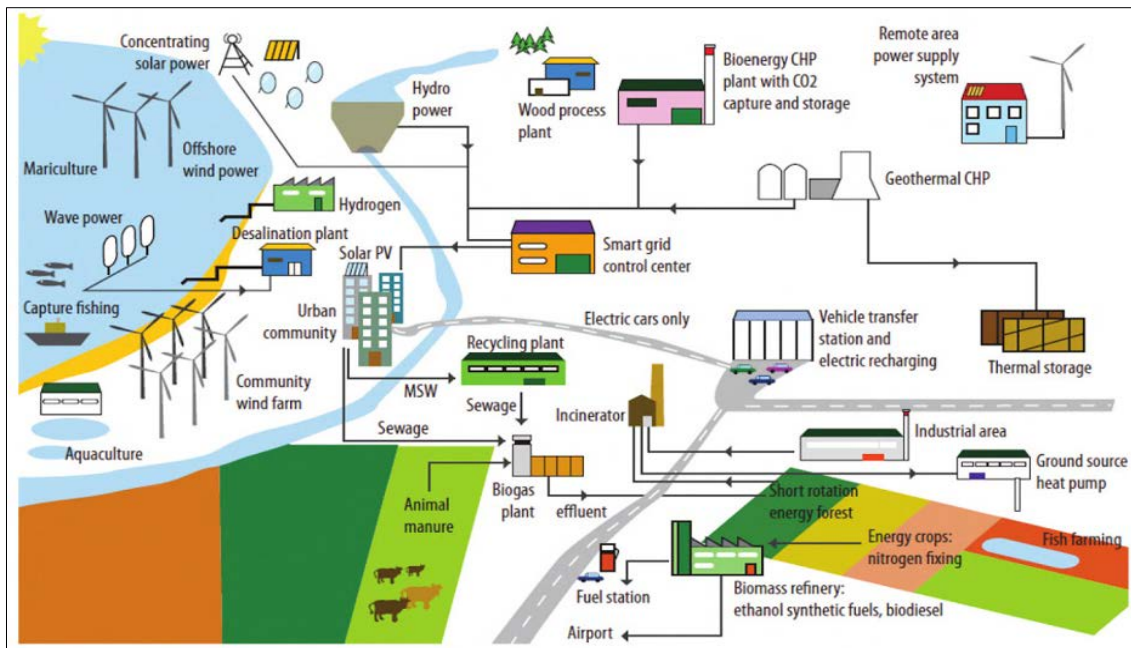
Source: IEA (2009).

Based on the study findings and conclusions, our recommendations for future research are as follows. Additional study is needed related to the comparison of oil price effects on agricultural food prices in Asian nations clustered by their income levels. Furthermore, research is needed to confirm the similarity or dissimilarity of energy price effects on agricultural food prices. In addition, regional panel studies are recommended for future studies.

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