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Volatilitiy of World Food Commodity Prices and Renewable Fuel Standard Policy

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ABSTRACT

Biofuel as an alternative fuel which in recent years has become the world's demand for renewable energy fuels and is a major factor underlying the increase in prices of agricultural commodities, especially corn as the main commodity for biofuels in the US. The purpose of this study is to examine the volatility of several world food commodities, namely rice, wheat, corn, and soybeans and to analyze the impact of biofuel development on the price volatility of some world food commodities. This research uses coefficient of variation and volatility analysis with the ARCH GARCH method. Based on the results, the price of food commodities is more volatile after the adoption of the Renewable Fuel Standard 2 (RFS) policy in 2007. The results of the study show that development of biofuels (from corn and soybeans) have a higher level of volatility than the other two commodities (rice and wheat) due to the variance of rice and wheat was lower than corn and soybeans. It means that the greater the relevance of a commodity to the development of biofuels, the higher the price volatility of the commodity. Meanwhile, the expansion of biofuels also made US reduce the amount corn and soybean exports, of course this is what makes the supply of US corn and soybeans decreased and makes the price will increase.

Keywords: Renewable Energy, Volatility, Renewable Fuel Standard Policy, Commodity Prices
JEL Classifications: L5, O13, O21, O44, P18

1. INTRODUCTION

Crude oil prices are increasingly unpredictable and continue to fluctuate from 2002 to 2017, the price of crude oil is very volatile. The highest point in 2007 was 120 dollars per barrel, and soon in 2014, under 40 dollars per barrel (World Bank, 2018). This is caused by factors that influence the level of this fluctuation, both in terms of supply and demand. From the supply side, the nature of crude oil that is not easily renewed makes crude oil supply uncontrollable, plus not many countries have an advantage in crude oil production. Meanwhile, from the demand side, this shows a trend of increasing demand for fuel energy sources due to high economic growth in many countries in the world.

The uncertainty of crude oil prices has caused many countries in the world to start switching to alternative energy sources, namely biofuels. Biofuel development is currently being carried out by many developed and developing countries. Various policies in each country are made to develop renewable energy sources. The development of biofuels is intended to reduce dependence on crude oil, as well as to meet the high demand for fuel.

The development of biofuels created a stronger link between crude oil and the agricultural sector, where biofuels made a closer connection with the increasing demand for agricultural commodities as raw material for biofuels that seemed intended to replace the role of crude oil as an energy source. This linkage also makes the price fluctuations that occur in crude oil often have an impact on commodity raw materials for biofuels. Global crude oil prices that are already very volatile will have an impact on the prices of agricultural commodities used as raw materials also become unstable (Malins, 2017).

The United States is one of the developed countries that develop biofuels, through the Renewable Fuels Standard 2 policy since 2007, the US has implemented a policy to produce as much as 36 billion gallons of biofuels in 2022 (Bracmort, 2018) with the main raw material in the form of corn. And to achieve these targets, the US set annual targets that continue to increase every year. In addition, in carrying out the development of biofuels, the US certainly requires a lot of corn as raw material. In September 2018, 37.9 percent of the total US corn supply was used as raw material for biofuels (USDA-FAS, 2018).

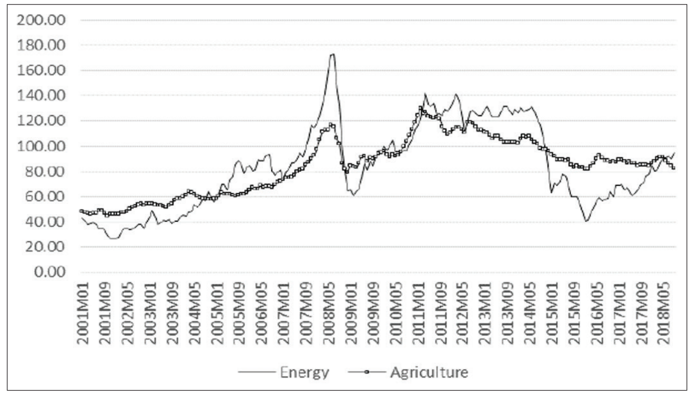
One of the agricultural commodities that has an impact due to increased demand for biofuels is maize as well as wheat and soybean. Increased demand for corn for biofuels is able to reduce soybean production which will also have an impact on rising soybean prices (Naylor et al., 2007; Timmer, 2008). Faostat (2016) stated that the US has the largest market share for maize by 35 percent, in addition to the US also one of the largest exporters of commodity wheat and soybeans. Therefore, the prices of corn, wheat and soybeans in the US domestic market as reference for world prices. Many countries in the world, especially those including developing countries, rely on food supplies in the form of corn, wheat or soybeans through imports. This was proven during the global crisis in 2008, where the development of biofuels played a major role in causing soaring world food prices, making several developing countries experience a food crisis (Dillon et al., 2008; Lin et al., 2011; Ajanovic, 2011).

Indonesia is one of the countries that develop biofuels, which is the biodiesel uses one of the agricultural commodities that are Indonesia's mainstay in the world market, namely oil palm. Through Presidential Regulation No. 66 in 2018, the Government of Indonesia (GOI) established a policy called B20 (Tyson et al., 2018). This policy is a policy of processing palm oil into biodiesel and enforcing the use of biodiesel in fuel oil by 20 percent. The government set this policy to reduce crude oil imports and increase domestic CPO consumption so that later it is expected to strengthen the price of Indonesian CPO on the global market. It is expected, if the new policy into effect lasts longer and will reduce palm oil exported by Indonesia. This is likely to have an impact on rising world palm oil prices.

Indonesia and many other countries involved in world trade, especially raw materials for biofuels, need a number of price stability policies. This policy will be very effective when made by considering the price behavior of each commodity as well as price volatility. The price volatility of a commodity is not used to analyze the price level, but to analyze what the price variants of a commodity look like. In addition, volatility is a variation of the amount of returns received by economic actors (Rahayu et al., 2015). That means high volatility reflects the high risk that must be accepted by economic actors ranging from producers to consumers.

The energy and agriculture sectors have a similar pattern of price movements. The two sectors experienced high price spikes from 2007 to 2008 (Figure 1), in which both years there was a global food crisis and the implementation of biofuel development policies in a number of countries, especially the US (Dawe, 2010). A few years after the global crisis precisely in 2014, the price index of agricultural commodities declined, this is thought to have occurred because of the decline in world crude oil prices. The decline in world crude oil prices has reduced production costs in the agricultural sector so that the price of commodities produced is also low. This shows the link between the energy sector, namely crude oil and the agriculture sector.

Figure 1: World energy and agriculture commodity price index



Sources: Word Bank, 2019

One of the factors causing the link between the energy sector and the agriculture sector is the development of biofuels. Biofuels become a reliable substitution to overcome the current fluctuations in world crude oil prices. The development of biofuels causes an increase in demand for biofuels raw materials, including corn and palm oil. On the other hand, crude oil prices also affect the price movements of these two commodities (Tyner, 2010, Pal and Mitra, 2017). This results in fluctuations in crude oil prices which will affect fluctuations in the prices of corn and palm oil.

The development of biofuels in the US raises great attention for various countries of the world, especially those involved in the global food commodity trade. This happens because the US is developing biofuels on a very large scale, which has reached 49 percent of total world biofuels production (World Bank, 2018). Even the USDA data from 2006 to 2016 shows that the increase in corn demand for bioethanol is twice as fast as the increase in corn production (USDA-FAS, 2018).

The US cannot continue to increase the amount of biofuel produced with corn. This is supported by the condition of production capacity until 2018, which is almost maximum, reaching 94.6 percent of total production capacity (Renewable Fuels Association 2016), even the US has used as much as 45 percent of corn from total domestic use (USDA-FAS, 2019a), it means that there is almost no gap to increase corn production for biofuels. On the other hand, the target of biofuel development based on RFS 2 will still increase until 2022. Increasing the amount of corn for biofuel will certainly reduce the amount of corn for food, feed, and exports, if this happens there will be a spike in world corn and food prices.

Besides corn, one of the commodities which is also developed into raw material for biofuel by the biggest producing and exporting countries is palm oil, where Indonesia has developed palm oil as biodiesel, which since 2018 has been known as B20 policy. Palm oil is the most efficient vegetable oil commodity. That's because palm oil has a much higher productivity of 3.91 tons/Ha compared to other commodities such as sunflower, rapeseed, and soybean which are 0.77 tons/Ha, 0.83 tons/Ha, and 0.5 tons/Ha (Gabungan Pengusaha Kelapa Sawit Indonesia, 2019; Alam et al, .2019). In contrast to corn, the development of biofuels with palm oil is still possible to be increased. This is because until 2016 there is still a potential of 75 percent more production from biodiesel industry companies that have not been used (Gabungan Pengusaha Kelapa Sawit Indonesia, 2017).

Biofuel development is a surprise demand that will disrupt price movements in the global market (Desfiandi et al., 2019). Movement about prices, not only enough to read with price fluctuations, needs to be analyzed in price trends to change or called volatility. Volatility is often known as price shocks. Shocks that occur on prices, especially on food commodities, will certainly have a major impact on people's welfare.

Brazil as a country categorized as a country with large emerging markets and accompanied by rapid growth in energy demand has succeeded in developing the biofuel industry. If seen from the details of priorities given by the World Bank to countries in this category, there are at least five policy focuses that must be carried out by the Brazilian government. First, the ability to meet growing energy demand from imported sources. Secondly, diversification of energy supply sources. Third, secure capital and invest in the development of resources and infrastructure. Fourth, developing technology to reduce dependence on imported goods. Finally, meeting the basic needs of the community and creating effective demand for energy (World Bank, 2018).

In addition to the policy focus suggested by the World Bank, there are also strategies categorized by Cherp and Jewell (2011) into three perspectives based on sovereignty, robustness, and resilience. These three perspectives are used to implement energy policies so that the country can survive and advance the economy when there are energy constraints and high price volatility. Strategies born from these three perspectives, as well as the policy focus of the World Bank, need to be re-linked to the concepts of roles and status previously explained.

From the perspective of the RFS policy undertaken by the USA then relating to the expected role of Brazil here is categorized into two based on the status dimension explained by Yamin (2014), namely how it plays a role in international regulations related to the environment and in relations with other actors in the system. In the first category related to environmental regulations, it is found that there is a role for implementing control over energy systems related to the ethanol production process as a renewable resource. Whereas, in the second category relating to relationships with other actors, a role is found to vary supply, manage demand growth that can be achieved by developing infrastructure, and manage and develop safer technologies.

The purpose of this study is to analyze price volatility in several food commodities and food commodities that are not related to the development of biofuels in the world, and the impact of biofuel development on the price volatility of several major food commodities in the world.

2. LITERATURE REVIEW

The link between crude oil and agricultural commodities often occurs in one direction, namely crude oil affects agricultural commodities and does not happen otherwise. If related to prices, then in the long run changes in the price of crude oil will be positively correlated with prices of agricultural commodities (Rezitis, 2015). Analysis using the VAR model states that some agricultural commodities that are positively correlated include soybeans, wheat and corn (Wei and Chen, 2016), but there are also studies that state that wheat is not related to crude oil prices, while other related commodities are cotton (Harri et al., 2009), rice, palm oil, meat, sugar, and barley (Pal and Mitra, 2017).

The relationship between the energy sector and the agricultural sector is also closely related to biofuels development policies. Biofuels are often used as substitutes for crude oil whose prices tend to fluctuate greatly, this is proven to occur in the EU where the rising energy prices (crude oil) significantly influence the increase in ethanol production in Brazil. This increase in production will also be correlated with an increase in the price of agricultural commodities which are the raw material for developing biofuels (Zafeiriou et al., 2018). Development of biofuels seems to increasingly link the prices of agricultural commodities with crude oil commodities.

The energy sector and the agricultural sector are two difficult sectors to separate. Before the biofuels development policy, the two had a relationship, namely crude oil as an input for the agricultural sector, not to mention the development of biofuels which seemed to be a new adhesive between the energy sector and the agricultural sector at this time. The development of biofuels had an impact in the form of an increase in the prices of some biofuel's raw material commodities. A scenario was made for four commodity raw materials for biofuels namely cassava, corn, sugar and wheat. The scenario is to see price changes due to the development of biofuels if expansion continues. The results of the scenario stated that the expansion biofuels in these four commodities will cause prices to increase respectively as follows: 11.2 percent, 26.3 percent, 11.5 percent and 8.3 percent (Von Braun, 2007). The price increase is not only in the scenario, in fact biofuels have contributed about 70 to 75 percent increase in agricultural commodity prices in the 2008 crisis, the rest is explained by other factors such as rising crude oil prices and the weakening dollar (Mitchel, 2008). Meanwhile, corn commodity itself as a raw material for biofuels in the US also experienced an increase in prices due to two things namely the development of biofuels and economic growth. Economic growth accounts for around 50 percent, while the development of biofuels accounts for 23 percent as a cause of rising corn prices (Hochman et al., 2012). The development of biodiesel in Europe also shows the same thing. Every increase of one exajoule of biodiesel production will increase the price of European vegetable oil by 16 to 171 percent, and for sugar-based bioethanol will increase the world price of sugar by 40 percent per one exajoule bioethanol (Malins, 2017).

Increased production of biofuels made from corn is one of the causes of soaring world corn prices. Corn price movements are influenced by several factors originating from the supply and demand sides. From the supply side the main factor that often occurs is weather changes. Changes in weather will greatly affect the amount of corn that can be harvested (Westcott, 2013). The weather played a major role when there was a surge in corn prices in 2012. However, the magnitude of the price spike in 2012 was also influenced by the development of biofuels. If there is no development of biofuels, the pricoe of corn in 2012 will be lower by 40 percent (Carter et al. 2012).

Palm oil is another type of commodity that also plays a role in the development of biofuels. However, unlike corn, palm oil prices are actually less sensitive to biofuels production (Mohammadi et al. 2017). This is because the reference price of world palm oil is Malaysia, but the percentage of palm oil used for biofuels is very small. Research by Mohammadi et al. (2015) also mentioned that the dominant factors affecting the movement of Malaysian palm oil prices were Malaysian palm oil production and soybean oil prices. Indonesia, as the largest producer, is not a determinant of global palm oil price movements.

Price increases do not only occur in commodities that are used as raw materials for biofuels. More than that, many other commodities are also affected by the development of biofuels. Every hundred percent increase in biofuels production will cause an increase in food commodity prices by 21.9 percent (Ncube et al., 2018). Not only food commodities, but other commodities such as chicken, pork, beef, eggs, bread, milk and various cereals also increased by around 10 to 30 percent due to the development of ethanol from corn in the US (Pimentel et al., 2008).

The flow of international prices to domestic prices can occur due to several factors. These factors are transportation and marketing costs that are formed in international trade activities, the existence of various government policies in each country such as export taxes, non-tariff barriers, import duties and so on that affect the policies in other countries, differences in currency exchange rates, the influence of different market structures between countries and also influenced by the extent of management of a commodity (Zorya et al., 2012). Research conducted by Buguk et al. (2003) also supports one of these factors, where in fact the market structure strongly influences the transmission of prices and volatility observed in a supply chain. Global prices transmitted to domestic prices indicate the degree of sensitivity of domestic prices to global price shocks (World Bank, 2018).

The term volatility transmission, also known as spillover volatility, often occurs in agricultural markets with various market conditions and various flow directions in volatility transmission. This transmission can occur in two different commodities, such as the corn market and the soybean market, both of which are the most important commodities in the US. In both markets, there is transmission of volatility from the corn market to the soybean market but this does not happen otherwise (Zhao and Goodwin, 2011). This transmission apparently did not only occur in the US market, but also occurred between countries namely US, Europe and Asia. Spillover volatility is found in interactions between China and Japan in soybean commodities, while it also occurs between the Corn and Wheat markets in Chicago, US and other markets in Europe and Asia (Hernandez et al 2014). Three wheat exporting countries namely US, EU and Canada also showed interaction between the three that caused spillover volatility, namely from the EU to Canada, as well as from the EU and Canada to the US (Yang et al., 2003).

In contrast to these conditions, Volatility spillover can occur between two different sectors. In recent years many biofuels have been developed. The development of biofuels creates a close relationship between the agricultural sector and the energy sector. The relationship is in the form of spillover volatility between crude oil prices and some agricultural commodities (Haile et al., 2016; Bergmann et al., 2016; Kumar, 2017; Saghaian et al., 2018; Xiarchos and Burnett, 2018). The shocks that occur on world crude oil prices have a very strong influence on the prices of some agricultural commodities that have links to the development of biofuels, some of which are corn and palm oil.

Basically, the analysis of the transmission of volatility uses the basic ARCH GARCH model, only then to see the conditional mean is combined with other methods. The combination of the GARCH method can also be done with vector autoregression (VAR). In the study of Bergmann et al. (2016) VAR is used to capture the effect of price transmission between two different markets. Then the combination with the GARCH model is used for take into account the magnitude of the transmission of potential volatility. But some are just using the ARCH GARCH model but with different types. In the study of Fabozzi et al. (2004) and Haile et al. (2010), the effects of spillover volatility are examined only by using the GARCH model without combining with other methods. The type of ARCH GARCH model used is TGARCH.

3. METHODOLOGY

The type of data used in this study is secondary data, in the form of time series data which includes data on monthly prices of rice, monthly prices of corn, monthly prices of soybeans and monthly prices of world wheat from January 1960 - September 2018 obtained through the Internet namely the World Bank's Pink Sheet Data, and there are also data derived from various journals and literature related to research.

In this study, the analysis to be conducted is the analysis of data distribution with coefficient of variation. The coefficient of variation is a measure of variance that is often used to compare the spread of data between variables. The prices of the four food commodities namely rice, wheat, corn and soybeans will be divided into three periods; the coefficient of variation will then be compared between periods and will also be compared between the commodities studied.

The next analysis conducted is the analysis of volatility. Volatility is a measurement concept that is used to see the magnitude of price fluctuations in a period of time. This concept uses variance and standard deviations to find out how quickly the data changes. In general, time series data have variances that tend to be constant over time (homoscedasticity). However, in the economic and business fields what often happens is the opposite, variance often changes over time. The price level that occurs tends to be erratic over time because it is so easy to change (Firdaus, 2011).

In general, time series data analysis uses the assumption of ordinary least square (OLS). However, this assumption requires that the residual variance of the data be homoscedasticity. If these conditions are not met, the resulting coefficient will experience bias. Meanwhile, volatility is a situation where the connotation is unstable, random and difficult to predict. The impact is that volatility has no homoscedasticity residual variance, but heteroscedasticity or tends to be not constant. Sometimes a data has very high volatility but at the next point has a very low volatility. According to Enders (2008), modeling the concept of volatility requires a method that can overcome this heteroscedasticity problem.

$$Y_t=\beta_0+\beta_1 X_t+\epsilon_t \quad (1)$$

$$Y_t = \beta_0+\beta_1 Y_{t-1}+\cdots+B_p Y_{t-p}+a_0 \varepsilon_t+\cdots+a_q \varepsilon_{t-q} \quad (2)$$

$$\sigma_t^2 = \alpha_0 + \alpha_t\varepsilon_{t-1}^2 + \alpha_2\varepsilon_{t-2}^2 + \cdots \alpha_q\varepsilon_{t-p}^2 \quad (3)$$

$$\alpha_t^2 = \alpha_1 Resid\left(-1\right)^2 + \alpha_2 Resid(-2)^2 + \cdots + \alpha_p Resid(-p)^2 \quad (4)$$

But sometimes, a variance is not only influenced by the volatility of the previous period, but is also influenced by the variance of the previous residuals, two previous periods, three or even up to the previous q period. Therefore, Bollerslev then refines the ARCH model by incorporating elements of past period volatility and residual variance (Enders, 2008). The model is named the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model, the GARCH (q) model which can be stated as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \alpha_2\varepsilon_{t-2}^2 + \cdots + \alpha_p\varepsilon_{t-p}^2 + \lambda_1\sigma_{t-1}^2 + \cdots + \lambda_q\sigma_{t-q}^2 \quad (5)$$

Thus:

$$\sigma_t^2 = C + \alpha 1 Resid(-1)^2 + \alpha 2 Resid(-2)^2 + \ldots + \alpha \mathrm{p} Resid(-p)^2 + \lambda 1\mathrm{Garch}\left(-1\right) + \lambda 1\mathrm{Garch}(-2) + \ldots.. + \lambda 1\mathrm{Garch}\left(-\mathrm{q}\right) \quad (6)$$

Volatility analysis is carried out in four stages, namely: the stage for the identification of ARCH effects, model estimation, model evaluation and calculation of volatility values (Firdaus, 2011). The four stages will be used to find the value of volatility in the four food commodities related in the study. These commodities are rice, wheat, soybeans and corn. Therefore, volatility in the data will be seen as a whole in the data period January 1960 to September 2018, which is then divided into three periods and uses monthly data. In addition to knowing the volatility of each commodity, it will also be seen about the impact of the establishment of the Renewable Fuels Standard policy starting in 2007 on the price volatility of each commodity tested.

Then the last step is to forecast using the best model that will be used to estimate the price volatility of each food commodity being tested. This stage is done by entering parameters into the equation obtained. Variance forecasting for the ARCH model is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \alpha_2\varepsilon_{t-2}^2 + \ldots + \alpha_p\varepsilon_{t-p}^2 \quad (7)$$

Then the forecasting for GARCH is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \alpha_2\varepsilon_{t-2}^2 + \cdots + \alpha_p\varepsilon_{t-p}^2 + \lambda_1\sigma_{t-1}^2 + \cdots + \lambda_q\sigma_{t-q}^2 \quad (8)$$

4. RESULTS AND DISCUSSION

4.1. Data Distribution Analysis with Variation Coefficients

One of the simplest ways to measure data diversity is to analyze data distribution using coefficient of variation. The coefficient of variation is done by comparing the standard deviation value with the average value which is then expressed in percent. This analysis is carried out on the price data of each commodity tested which is divided into 3 time periods. The results of calculating the coefficient of variation can be seen in Table 1.

Table 1 showed that the coefficient value of the biggest variation occurred in period 1 namely when the 1973 food crisis occurred. This indicates that the crisis caused commodity price data to be highly dispersed or not uniform between one time and another. While for the 2008 food crisis it was also described as having a high data distribution but it was not as big as the 1973 food crisis.

Analysis of the data distribution with the coefficient of variation only looks at the data distribution briefly, and cannot read the magnitude of the volatility that occurs in the price data of each commodity. It required an analysis tool that can read the movement of the price volatility from period 1 to period 3 in a clearer and more detailed. Model identification, which is done in four stages, where the first stage is to identify the price data of a commodity that will be tested whether it contains the effects of heteroscedasticity problems or not.

Correlogram test results as on Table 2 showed that the four food commodities tested tend to have ACF values that are far from zero and even tend to approach one in the first 15 lags, even to the 30th lag still tend to be far from zero, this the first evidence of heteroscedasticity. Meanwhile, the value of kurtosis in the four food commodities tested showed the fourth has a value of more than three, it becomes the second evidence which states that the four food commodities tested contain heteroscedasticity problems (Yang et al., 2003). Based on the two tests that have been carried

Table 1: Presentation of predicted changes in commodity prices for biofuels in 2020 (in two scenarios)

Commodities	Biofuels expansion	Expansion of biofuels drastically
Cassava	11.2	26.7
Corn	26.3	71.8
Sugar	11.5	26.6
Wheat	8.3	20.0

Source: Von Braun, 2007

Table 2: The test results identify heteroscedasticity problems

Commodities	ACF results	Lag Prob 1 -5	Kurtosis	Heteroscedasticity problems
Rice	Not close to zero	Significance	4.049663	Exist
Wheat	Not close to zero	Significance	4.198701	Exist
Corn	Not close to zero	Significance	5.608313	Exist
Soy bean	Not close to zero	Significance	3.544022	Exist

Source: Firdaus, 2011; Author, 2019

out, it can be concluded that the price of rice, wheat, corn and soybeans contains heteroscedasticity problems.

According to Firdaus (2011) and Rahayu et al. (2015), to find the best ARIMA model for the prices of some food commodities is to do a data stationarity test, which is done by conducting an augmented Dickey Fuller Test (ADF TEST). If the absolute value of the ADF Test statistic is greater than the critical value seen through the probability value that is less than the 5 percent real level so the data is said to be stationary. If the data is not stationary, it must be done differencing until the data is stationary. Table 3 presents a summary of the ADF Test results on the prices of the four food commodities tested.

The price data of the four food commodities tested show the absolute value of the ADF Test which is smaller than the critical value in the level data. So, we need differencing to make the data stationary (Firdaus, 2011). The first differentiation shows that the ADF Test value is greater than the critical value of each commodity, so the data is said to be stationary.

Furthermore, the ADF Test results on the four commodity prices tested reached stationary after First Differencing, with the absolute value of the ADF Test being higher than the critical value at 1 percent, 5 percent, and 10 percent. The ADF Test results are presented in Table 3 as follows:

After the stationary data, the next step is to tentatively find the best ARIMA model, which is chosen based on the criteria: parsimonious, significant coefficient, invertibility and stationarity, convergent, has the smallest AIC and SC (Firdaus, 2011), has the smallest standard of regression and sum square residual, has the largest adj R square value, and has the largest F statistic. Based on these criteria, the best ARIMA model for rice, wheat, corn and soybean price data is as shown in Table 4 as follows:

After getting the best ARIMA model, the next step is estimation of the ARCH/GARCH model. Identification of heteroscedasticity problems at an early stage can indicate the effects of ARCH, but to better ensure that the ARCH LM test is performed. The existence of heteroscedasticity problems is important to do, because if the data does not contain heteroscedasticity, then the ARCH GARCH method cannot be used. If the statistical F probability is less than 0.05, it can be concluded that the data contain ARCH effects.

ARCH effect test results that have been done are shown in Table 5. Based on these results, it can be concluded that the price data for each commodity tested contains the ARCH effect because all four have a probability value of <0.05. The next step is to determine

Table 3: ADF test results for the world's four food commodities

Commodities	ADF test level	ADF Test First Differencing
	t-statistics	t-statistics
Rice	–2.713*	–7.869***
Wheat	–2.454	–10.795***
Corn	–2.362	–6.402***
Soy bean	–1.979	–6.917***

Source: Firdaus, 2011; Author, 2019. *Significant level of 10 percent, *significant level of 5 percent, ***significant level 1 percent

Table 4: ARIMA model best food commodity prices

Commodities	The Best ARIMA model
Rice	ARIMA (0,1,1)
Wheat	ARIMA (0,1,1)
Corn	ARIMA (2,1,2)
Soybean	ARIMA (2,1,1)

Source: Enders, 2008; Firdaus, 2011; author, 2019

the best ARCH GARCH model tentatively. Determination of the best model is done through several criteria, namely having the lowest AIC value, having a significant coefficient, the sum of the coefficient values not more than 1 and not having a negative value, having the smallest sum square residual value and the largest log likelihood value. Based on these criteria, the best ARCH / GARCH model is obtained for each commodity (Table 6).

Based on Table 6, the selected ARCH GARCH model is an adequate model. This can be seen from several tests that have been done. First the Jarque Berra test, the probability of the prices of the four food commodities tested was significant so that the data concluded were spread normally.

Furthermore, the L Jung Box test on Table 7 shows that autocorrelation has not been found in the error, this can be seen from the probability of lag 1 to 15 which is not significant. Meanwhile, the ARCH LM test on Table 7 shows a probability greater than 0.05 which indicates that the ARCH effect has not been found in the chosen model.

The final stage of the ARCH GARCH method is to make an equation of the output that has been generated from each selected ARCH RCH model for each commodity, as explained in equations 4 and 6 in the theoretical framework section. The equation is as follows:

a. Rice

$$\sigma_t^2 = 33.26615 + 0.216441\varepsilon_{t-1}^2 + 0.704511\sigma_{t-1}^2$$

The above model provides information that the rice price variance is influenced by the rice price volatility in the previous period

Table 5: ARCH effect test results of the best ARIMA models

Commodities	The best ARIMA model	F-Statistics
Rice	ARIMA (0,1,1)	45.949*
Wheat	ARIMA (0,1,1)	6.491*
Corn	ARIMA (2,1,2)	12.265*
Soybean	ARIMA (2,1,1)	77.229*

Source: Enders, 2008; Firdaus, 2011; author, 2019. *Significant at 5 percent level

Table 6: The best ARCH GARCH model for world food commodities

Commodities	The best ARCH GARCH model
Rice	GARCH (1,1)
Wheat	GARCH (1,1)
Corn	ARCH (1,0)
Soybean	GARCH (1,2)

Source: Enders, 2008; Firdaus, 2011; author, 2019

and the rice price variance in the previous period. The ARCH coefficient of 0.216441 indicates that low rice price volatility is due to the relatively small value (not close to 1). Meanwhile, the GARCH coefficient of 0.704511 indicates that the shocks variance on the price of rice will last a long time, this is seen through its coefficient which is close to one.

b. Wheat

$$\sigma^2 = 0.360190 + 0.240850 e_{t-1}^2 + 0.838110 \sigma_{t-1}^2$$

Just like rice commodities, the wheat variance model above provides information that the wheat price variance is also influenced by the volatility of the previous period's wheat price and the variance of the previous period's wheat price. ARCH coefficient of 0.240850 indicates that the volatility of wheat prices is also relatively low, this is because the value is relatively small (not close to 1). However, this value is still higher when compared to the volatility of rice. Meanwhile, the GARCH coefficient of 0.838110 indicates that the shocks variance in the price of wheat will also last a long time, this is seen through the coefficient that is close to one.

c. Corn

$$e^2 = 34.97622 + 0,605989 e_{t-1}^2$$

Different from the two previous commodities, the corn commodity forms the ARCH model (1.0). This indicates that the corn price variance is influenced only by the volatility of corn prices in the previous period.

The value of the ARCH coefficient of 0.605989 indicates volatility which is high because the value is close to one.

d. Soybean

$$e^2 = 1.540001 + 0.467776 e_{t-1}^2 + 0.238140 e_{t-1}^2 + 0.439032_{t-2}^2$$

Based on the GARCH model (1.2) above, the soybean commodity price variance is influenced by the price volatility of the previous period and the residual variance of the two previous periods. The value of 0.467776 shows that the volatility value is quite high compared to the volatility of rice and wheat but not as high as the volatility of corn. Meanwhile, the GARCH rate coefficient when added to 0.677172, this value is quite high, which means that the shock of soybean price variance will also last long.

The food crisis of 1973 and 2008 had an impact on the increasing volatility of some food commodities such as rice, wheat and soybeans, as shown in Figure 2 shown by the peak of the high graph in the two years. Rice commodities that do not have a direct relationship with the issue of biofuels (Wei and Chen, 2016; Xiarchos and Burnett, 2018; Zafeiriou et al., 2018), have a tendency to be low volatility seen surges only occur during crises. In the amount of wheat commodities, the price spike in the 2008 crisis was far higher than the 1973 crisis.

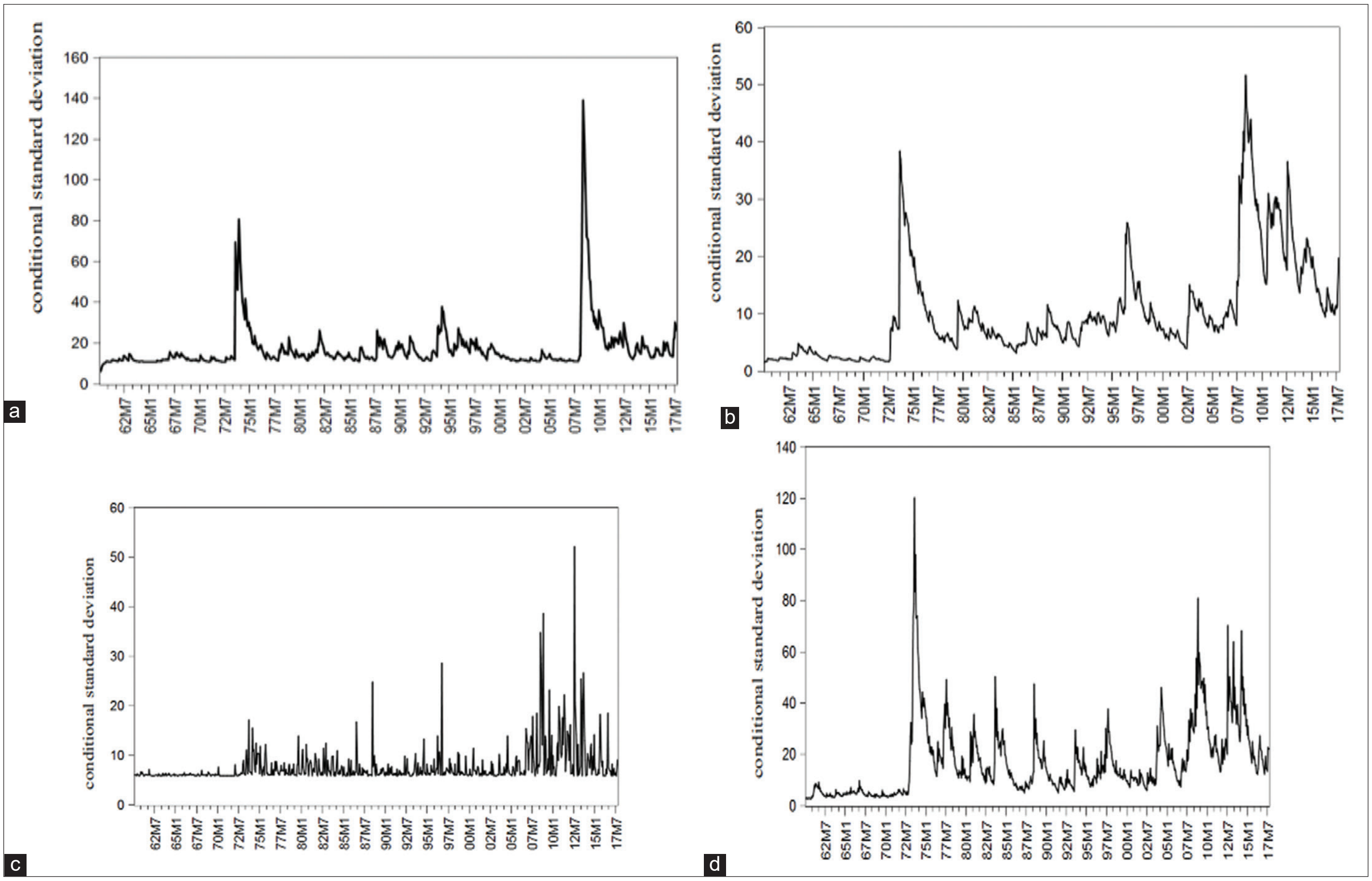
The high volatility of wheat in the two crises was due to the drought that hit several wheat exporting countries, the 2008 crisis was exacerbated by the decline in the amount of wheat exports from the US (USDA-FAS, 2011; Pal and Mitra, 2017) which was allegedly also influenced by the expansion of biofuels which changed the price structure of all food commodities in the US. Meanwhile conditions are inversely proportional to soybean commodities where the 1973 crisis was actually higher than the crisis in 2008.

Another case with corn commodity, price spikes only occurred in 2008 and not in 1973. This is due to the development of biofuels in the US which was marked by the renewable fuel standard (RFS) policy in 2005 and increased in 2007 (Renewable Fuels Association, 2016). The contents of the policy are in the form of US biofuels production target in 2022 which is 36 billion gallons. To achieve the target of the policy, the US continues to increase biofuels production. The development of corn-based biofuels began around 2000 and culminated in 2007 and 2008, this had an impact on increasing corn prices and increasing corn volatility since 2007. Volatility of corn prices increased again in 2012 due to a decrease in production corn in the US due to drought (USDA-FAS, 2015).

In addition, volatility in food prices in the US is also expected to increase imports of Brazilian ethanol to the US in 2017. According to Gallo (2017) After the MoU between Brazil and the US, it is evident that the amount of Brazilian ethanol exports to the US has increased sharply. from 1,423,757 giga litres (Gl) at the end of 2007 to 2,933,807 Gl at the end of 2008. However, high export figures faced several obstacles when the US implemented Brazilian ethanol import tariffs. Despite encouraging the use of ethanol as a substitute for oil and gasoline, the US actually imposes a tax and import duty of 54 cents per gallon for imported ethanol (Mathews, 2012). This value is equivalent to 14.27 cents per litre which is a significant burden for Brazil given the high level of ethanol exports to the US. This tax caused Brazil's ethanol export figure to drop to 1,148,744 Gl. At the end of 2009 and reached 547,596 Gl at the end of 2010 (Gallo, 2017). However, after this import tariff period ended in 2011, Brazilian ethanol exports to the US increased again to 1,036,123 Gl and increased sharply at the end of 2012 to 1,558,211 Gl (Gallo, 2017).

Measuring the value of volatility in the four world food commodities namely rice, wheat, corn and soybeans previously was also conducted

Figure 2: A volatility graph of four world commodities. a (Rice). b (Wheat). c (Corn). d (Soybean)



Source: USDA-FAS, 2019

by Haile et al. (2016). In this research, the value of volatility is used to see the response of supply and allocation of land in dealing with food prices that tend to be volatile. Price volatility turns out to have a negative relationship with the supply response of the commodity. High volatility indicates a high risk that must be faced by producers, and the high risk causes the response of producers to produce these commodities will decline (Fabozzi et al., 2004; Bergmann et al., 2016; Xiarchos and Burnett, 2018). In their research, Haile et al. (2016) measured food price volatility using the logarithmic standard deviation method. If the results in the study are compared with the results of the calculation of volatility by the ARCH GARCH method in this study, the results are not much different.

Both illustrate the same pattern in the form of high volatility in food commodities when the food crisis occurred in 1973 and 2008. For wheat and corn commodities, the highest volatility occurred during the 2008 food crisis. Meanwhile for soybeans, the volatility in 1973 was slightly higher than the volatility there 2008. However, for rice commodity there is a slight difference namely the 2008 food crisis in the graph in this study illustrated with higher volatility than 1973, but in the study of Haile et al. (2016) it was 1973 which had the highest volatility value.

4.2. Analysis of World Food Prices in Three Periods

In addition to being presented in graphical form, the ARCH GARCH model that has been selected for each commodity is used for the analysis of the time period by dividing the study period into three periods namely the period January 1, 1960 to July 1975 (the 1973 crisis), the period of August 2, 1975 to August 2007 (after the 1973 crisis) and the period 3 September 2007 to September 2017 (the 2008 crisis). This is done to see how much the coefficient and volatility changes in the model when viewed in three different time periods.

Table 8 showed that the commodity of rice has a constant value that continues to increase from period 1 to period 3. This indicates that the 1973 food crisis did not have an impact on the high value of variance. On the contrary, the food crisis in 2008 caused an impact of the high value of rice variance, indicating that prices were getting further from the average. Unlike the constant value, the volatility value is the opposite. The volatility value which is indicated by the value of the Residual coefficient $(-1)^2$ (the ARCH term) precisely illustrates the two food crises that occurred. It can be seen that the value of volatility in period 1 is greater than periods 2 and 3, and period 3 is greater than period 2. This indicates that the crisis that occurs changes in the value of volatility, especially crises that occur suddenly as in period 1 Another value that can be analysed for rice is the value of the GARCH coefficient (–1). This value illustrates what the trend of variance will look like. Based on this value, for rice commodities it has a shock variance that will last a long period of 1 to 3 only that in period 3 the value has slightly declined.

The above model provides information that the rice price variance is influenced by the rice price volatility in the previous period and the rice price variance in the previous period. The ARCH coefficient of 0.216441 indicates that low rice price volatility is due to the relatively small value (not close to 1). Meanwhile, the GARCH coefficient of 0.704511 indicates that the shocks variance on the price of rice will last a long time, this is seen through its coefficient which is close to one.

Wheat commodities are also not related to the development of biofuels in the US. The constant value in the food crisis in 2008 showed a high increase, for the 1973 food crisis the same as rice which only caused a low variance value. For the value of volatility in the ARCH rate, the highest volatility period also occurs in period 1, period 3 then period 2. This is due to well-read volatility price changes, especially those that occur suddenly. The GARCH term coefficient value (-2) in period 2 shows an insignificant value because the probability value exceeds the alpha value of 10 percent. Based on the GARCH coefficient (–1) in periods 1 and 3, it is known that the shock variance in wheat commodities did not last long.

Another case with corn commodities that are directly related to the development of biofuels, especially in the US. ARCH GARCH model that is formed namely ARCH (1.0) means that the equation of variance in the price of corn is only influenced by the value of the previous volatility. The coefficient value of Residual $(-1)^2$ still shows high volatility in period 1, the same as wheat and rice, only the value in period 3 is declared insignificant.

Meanwhile the value of the constant in the corn variance equation also shows a value that continues to increase in periods 1 to 3. Of these values, the most interesting is the jump in the value of the constant from period 2 to period 3 which increased by 6 times from period 2. This indicates that the 2008 food crisis caused irregularities in prices far from the average price data. The reason is an increase in corn supply in the US followed by an increase in the amount of corn turned into ethanol (Carter et al. 2012).

Table 7: Test results for the adequacy of the model test

Commodities	Jarque Berra Test	L Jung Box	ARCH LM Test
	JB value	Lag 1-15	Prob.
Rice	44291.15*	not significant	0.9938
Wheat	16320.00*	not significant	0.9379
Corn	19358.97*	not significant	0.7922
Soybean	1578.64*	not significant	0.8574

Source: enders, 2008; Firdaus, 2011; author, 2019. *Significant at 5 percent level

Table 8: Analysis of food commodity prices in three periods

Commodities	Variables	Period 1	Period 2	Period 3	Total
		Coefficient	Coefficient	Coefficient	Coefficient
Rice	C	0.238	8.480***	48.376**	33.266***
	Resid $(-1)^2$	0.478***	0.133***	0.324***	0.216***
	GARCH (–1)	0.836***	0.824***	0.653***	0.705***
Wheat	C	0.372***	17.1000***	49.174**	0.360***
	Resid $(-1)^2$	3.188***	0.247***	0.460**	0.241***
	GARCH (–1)	0.162***	0.448**	0.496***	0.838***
Corn	C	2.874***	28.092***	191.932***	34.976***
	Resid $(-1)^2$	1.337***	0.243***	0.098	0.606***
Soybean	C	0.000*	0.000***	15.913***	1.540*
	Resid $(-1)^2$	0.487***	0.291***	0.007***	0.468***
	GARCH (–1)	0.844***	0.730***	1.962***	0.238***
	GARCH (–2)	–0.192**	–0.287***	–0.985***	0.439***

Source: Firdaus, 2011; Author, 2019. *, **, ***Significant at 10 percent, 5 percent and 1 percent level

Table 9: Supply and consumption of corn in the US

Information Transactions	2007/08	2009/10	2011/012	2012/13	2014/15	2016/17	2017/18
Million bushels							
Beginning stocks	958	1304	1624	1708	989	821	1731
Production	11,807	13,038	12,092	12,447	10,755	13,829	13,602
Imports	11	20	14	28	160	36	68
Supply total	12,776	14,362	13,729	14,182	11,904	14,686	15,401
Million bushels							
Feed and residual	6162	5913	5182	4795	4315	5040	5114
Food, seed and industrial	2686	4387	5025	6426	6038	6493	6648
Ethanol and product	1323	3049	3709	5019	4 641	5124	5224
Domestic, total	8848	10,300	10,207	11,221	10,353	11,534	11,763
Exports	1814	2437	1849	1834	730	1920	1901
Use, total	10,662	12,771	12,737	13,005	11,083	13,454	13,664
Ending stocks	2114	1624	1624	1128	821	1232	1737
Avg. farm price	2.06	4.2	4.2	5.18	6.89	4.46	3.61

Source: USDA-FAS, 2019

Based on data from the USDA (USDA-FAS, 2019) that can be seen in Table 9, in 2004/2005 10 percent of US corn supply was used for ethanol production, but in 2015/2016 the amount of corn used as ethanol was 33 percent (USDA-FAS, 2018). Bioethanol production in the US is not only intended for domestic energy sources, but also for export (Saghaian et al., 2018). The amount of bioethanol exported from the US began to increase since 2007, the amount began to surge in 2010 and continues to tend to be stable until now (Renewable Fuels Association, 2016). At present, 57 percent of global ethanol production is controlled by the US.

Other commodities, namely soybeans, are related to the development of biofuels. Equation variance of the GARCH model (1,2) shows that the soybean price variance is influenced by the value of the previous volatility, the value of the residual variance of one previous period and the two previous periods. Not unlike other commodities, the constant value also shows a value that continues to increase even though not as large as other commodities.

Likewise, the value of the coefficient of ARCH or Residual $(-1)^2$ is only high in period 1, namely during the 1973 food crisis. The value of the GARCH coefficient (–1) in each measured period is very high to near 1, which indicates the shock variance that occurs in soybean prices will last a long time. Soybean is a commodity that has a connection with the development of corn-based biofuels in the US. The high demand for corn will cause the price of corn to increase, the higher the price of corn will also increase the area of land used to grow corn, but this actually makes soybean land area reduced, this is proven through research conducted by Haile et al. (2016) which shows a positive relationship between the price of corn and the area of corn land, but there is also a negative relationship between the price of corn and soybean land area.

The target of biofuels production is 36 billion gallons per year 2022 makes the demand for food commodities in the US increase, this has an impact on high food prices in the US and the increasing cost of food per capita in the US (Schnepf, 2010). Changes in the structure of food prices in the US cause changes in the structure of world food prices, this is caused by the US is the largest exporter world of corn, soybeans and wheat (Wei and Chen, 2016; Saghaian et al., 2018). The development of biofuels will cause the allocation of agricultural commodities used as raw material for biofuels is reduced to be consumed, Denny et al. (2011) stated that. In his research related to the development of CPO which is used as a bioenergy raw material will make the amount of CPO to be consumed reduced and this also contributes to the surge in prices of these commodities (Desfiandi et al., 2019). In addition, the expansion of biofuels also made US reduce the amount corn and soybean exports, of course this is what makes the supply of US corn and soybeans decreased and makes the price will increase.

Reducing corn and soybean exports from the US is still able to be overcome because several countries such as Argentina and Brazil actually export more than before, but the development of biofuels in the US has played a role in increasing world food prices (Ncube et al., 2018). Currently, food is indeed available and can be said to be sufficient to meet the world's food needs, but the price of such food commodities, especially for high corn, makes it difficult for some developing countries to compensate with the purchasing power of people who are classified as low. The increase in prices is expected to continue as long as the US is still making its biofuels production target targeted until 2022.

The development of biofuels had a major impact on the volatility of the four foods tested. This is particularly evident from the constant values in period three, namely the period in which biofuels were intensively developed. A constant value that is much greater than before means that the volatility of the prices of the four food commodities is quite stable with high variance values, even less likely to be influenced by the effects of ARCH and GARCH (Rahayu et al., 2015). So, it can be said that the effect of past food price volatility and future forecasts has little effect, so that food price volatility is quite stable. This proves that the hypothesis regarding the development of biofuels causes the volatility of food commodity prices to increase, otherwise proven.

The total column showed the total variance equation model from periods 1 to 3. From this column it can be concluded that the commodity with the highest volatility during the study period was corn, followed by soybeans, wheat and finally rice. This proves the hypothesis that the greater the linkage of a commodity to the development of biofuels, the higher the volatility. While the price movement with the largest variance is shown by the large constant values in the commodity of corn and rice, which means that the prices of these commodities have large deviations.

5. CONCLUSION

Based on an analysis of world food price volatility in the range of 1960 to 2017, the development of biofuels tends to cause an increase in price volatility in food commodities. Commodities that are directly related to the development of biofuels (corn and soybeans) have a higher level of volatility than the other two commodities that are not directly related to the development of biofuels (rice and wheat). So, the greater the relevance of a commodity to the development of biofuels, the higher the price volatility of the commodity. As the provisions of the RFS which determines the maximum limit set by the US federal program that requires transportation fuels sold in the United States contains a minimum volume of renewable fuel. Thus, the expansion of biofuels also made US reduce the amount corn and soybean exports, of course this is what makes the supply of US corn and soybeans decreased and makes the price will increase.

Some recommendations made are that the development of biofuels causes an increase in prices for food commodities. This is because high demand is faced with limited supply. To reduce the increase in prices that occur, then this increased demand should be balanced by the availability of increased supply which can be done by means of new technological breakthroughs, and the results of an analysis of the impact of biofuels development on price volatility shows that there is a link between the development of biofuels on world food prices, by using a causal analysis or policy simulation conducted.

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