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Volatility Transmission between Prices of Selected Agricultural Products with Crude Oil and Exchanges Rates in Ghana and Turkey

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Abstract

Shift from cereals and grains consumption to dairy and meat products, 2006-2008 global food crisis, crude-related and import nature of agricultural production inputs are the causes of current volatility transmission in agricultural markets. Weakening domestic currencies against the US dollar for imported inputs is another contributory factor to agricultural product price volatility. Based on this, the objective was to estimate the volatility transmission along with directions and magnitudes among crude oil and exchange rate with maize, rice and soybean prices in Ghana and Turkey. The volatile behavior of agricultural markets in these countries is a reason for determining the volatility transmission between macroeconomic variables and the selected agricultural product prices and confirms the risk in agricultural product supplies. This was achieved by utilizing data from January, 2000 to December, 2015 on crude oil price and exchange rates with selected agricultural product prices in Ghana and Turkey. We applied the VAR (1)-BEKK MGARCH model for direct and indirect volatility transmissions for that purpose. Results showed exchange rate transmitted more volatility to agricultural product prices compared to crude oil prices in the two countries. In addition, as compared to Ghana, agricultural markets in Turkey are more resistant to fluctuations in macroeconomic variables. Optimal weights showed Turkey with a low price risk compared to Ghana because of the stability of Turkey's Lira relative to Ghana Cedi. Thus long run stabilities in monetary and fiscal policies can reduce uncertainties in agricultural and macroeconomic markets in both countries.

Key words: *Volatility transmission; Agricultural product prices; Macroeconomic variables; Crude oil; Exchange rates; VAR (1)-BEKK MGARCH; Ghana; Turkey.*

JEL classification: *G10; G18; G28; G32; O16; O18; O38.*

1. Introduction

Shift from grains and cereal consumption to dairy and meat products caused an increased in livestock feed demand; current climate change effects, demand for ethanol and biodiesel as alternative source of energy are contributory factors to agricultural price instability (Heady and Fan, 2008; Dillion and Barret, 2015). Global demand for agricultural products has increased the integration of financial and energy markets with adverse effects of shocks and volatility transmission. The competitiveness of agricultural products has pushed prices of these product upwards. According to Hochman *et al*. (2011), the increased global production of biofuel in the last decade is generally led by governments' policies for different objectives such as adding to domestic energy security, promoting rural economic growth, addressing global warming and decreasing fossil fuel prices. The worst affected are grains and cereals such as maize, rice and soybean as sources of biofuels and domestic food consumption. While the demand for these products calls for increased production and supply, the cost of production is generally translated in to producer prices. In recent times, production cost largely depends on the cost of crude oil and crude-related products as well as transportation cost. As such, an increase or a decrease in crude oil prices directly or indirectly translates into general agricultural product prices. Crude oil-related products required for agricultural production is import-based in most developing countries which requires exchange rates. Rising exchange rates indicates increased prices of imports especially for agricultural production inputs (Adom, 2014). Liefert and Persaud (2009) confirmed the relevance of exchange rates in agricultural markets and concluded that, it is a key determinant of domestic prices including the quantity of goods produced, consumed or traded. It is evident that both crude oil price and exchange rate are drivers of food prices globally. In developing countries such as Ghana and Turkey, food expenditure constitutes about 50% of household expenses and this increased after the 2006-2008 global food crises (GSS, 2009; Angelucci *et al*., 2013).

According to Gage *et al*., (2012a), a total of 1 million MT of maize is marketed in Ghana annually with a significant proportion consumed within households. Ghana's maize constitute about 40% (400,000MT in 2015) of the domestic maize produced. Contrary to maize, about 70% of rice consumed in Ghana is imported from Southeast Asia with 500,000 metric ton (MT) (2008), 442,000 MT (2009), 320,000 MT (2010) and 630,000 MT (2011) (Gage *et al*., 2012b). Increased demand for soybean in the last decade is due to biodiesel discovery especially in the U S and EU, coupled with a rapid economic growth in Asia where expanded consumption of animal protein (fed by soybean meal) but African markets remain small in global soybean trade (Sub-Saharan Africa accounts for less than 0.5% of global consumption). An opportunity exists for Africa to increase production due to rising incomes in African urban markets (McFarlane and O'Connor, 2014). From this context, it is evident except for maize, rice and soybean are import-based in Ghana which requires US dollar as a means of trading. As such, Ghana is directly and indirectly affected by trading activities of the US dollar and world crude oil prices.

Contrary to Ghana, Turkey is one of the emerging economies with resilient fiscal and monetary policies with an annual growth rate of 5.0%. Maize consumption in Turkey increased from 6.55 million MT in 2015/2016 to 7.05 million MT for 2016/2017 due to high demand for poultry feed and starch (Karabina, 2016). More than 400 active feed factories with a 30 million MT capacity compete for maize annually and hence the high demand for maize in Turkey. Similar to Ghana, Turkey imports rice since domestic production does not meet consumer demands. Rice production volume was 900 MT in 2011, 880 MT in 2012, 900 MT in 2013 and declined to 830 MT in 2014 with imports at 250 to 550 MT (TUIK, 2017). This is evident that these three agricultural products serve as source of raw materials for household and industrial needs.

The importation, transportation and processing needs of these products expose agricultural product prices to shocks and volatility transmission from major macroeconomic variables such as crude oil price and exchange rates (Durevall *et al*., 2013). Maetz (2013) identified high energy prices, increased demand for cereals and grains for biofuel production, fluctuating exchange rates and rising inflations as factors causing rising food prices especially in developing countries. Todsadee *et al*., (2014) also observed that agricultural product prices are on the increase and experienced significant volatility during the past few years. Between Ghana and Turkey as two emerging economies, maize, rice and soybean constitute a chunk of the domestic grains and cereal production for both household and industrial usage, hence the choice of these agricultural products. Similar to agricultural products, large seasonal variations cause their prices to rise sharply at peak times and then fall back during the off-peak periods (Piot-Lepetit and M'Barek, 2011). The effects of high food prices leads to a reduction in the quantity and quality of food consumed thus increasing food insecurity. This paper therefore revealed the weakness of agricultural product prices in developing countries in the midst of rising exchange rates and domestic crude oil prices. The rapid shock and volatility transmission is largely attributed to the effect of speculation in agricultural product market in both Ghana and Turkey and therefore calls for established agricultural markets. Thus this study presents a comparative feature in terms of showing the effects of price swings and its effects across markets in Ghana and Turkey. The rest of the study is organized as follows: review of relevant literature, methodology, results and discussion as well as conclusion.

2. Literature Review

Literature has mainly focused on transmission between agricultural product markets and specifically world crude oil market. After the year 2000, studies have diverted to nexus between biofuels, agricultural products and world crude oil markets. This bond has been further tightened since first generation biofuels has been produced from agricultural products (mainly maize, sugarcane, and rapeseeds). In this context, Musunuru (2014) applied the BEKK-GARCH[1] model to analyze inter-market price volatility transmission between corn and wheat. Results showed unidirectional volatility transmission from corn to wheat. Common with most time series data, the GARCH approach and its extensions were used to capture the volatility clustering and to predict future volatilities. Serra (2011a) also applied the VECH and BEKK approach in modelling multivariate GARCH (MGARCH) effects in agricultural price transmissions. The VECH was used for modelling conditional means and the BEKK for conditional heteroskedasticity and these were estimated jointly using the standard maximum likelihood approach. A number of researchers used various MGARCH approaches in analyzing volatility spillovers from crude oil to selected agricultural markets (Chang and Su, 2010; Serra, 2011b).

Nazlioglu *et al*., (2013) analyzed volatility transmission between crude oil and agricultural markets by applying the causality in variance test as well as the impulse response functions to daily price data. Data was sectioned into pre and post crisis periods and findings showed no risk transmission from crude oil to the agricultural markets in pre-crisis but with a spillover effect in the post crisis period. This approach fails to place restriction for definiteness as proposed by Engle and Kroner (1995). This led to difficulty in predicting and forecasting future volatility transmission across sections. Moreira (2014) also analyzed commodity price volatilities with expected inflation and GDP levels in a net-exporting economy using Variance Autoregression (VAR), Autoregressive Moving Averages-Generalized Autoregressive Conditional Heteroskedacity ((ARMA-GARCH) and Vector Error Conditional Heteroskedacity (VECH) models. Time series data was categorized into short and long term relationship between commodity prices relative to macroeconomic variables in Brazil from January 2005 to May 2013. This categorization caused a break in observing a continuous effect of volatility and shock transmission from one end to another especially in national macroeconomic variables and indicators measured on a continuous basis. This further confirms the relevance of the BEKK-GARCH approach which does not place restrictions on conditional variances.

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[1] *BEKK-MGARCH is an abbreviation of Baba, Engle, Kraft and Kroner- Multivariate Generalized Autoregressive Conditional Heteroskedacity .*

Hassan and Malik (2007) also parameterized MGARCH model using the BEKK approach to analyze volatility transmission mechanism between varying capitalization stocks. This was successful after simultaneously estimating the mean and conditional variance of sector returns, and showed that sectors interact with each other in terms of shocks and volatility transmissions. This approach avoided a generated regressor problem which is common with two-step estimation (Pagan, 1984). On the contrary Ibrahim (2015) analyzed the oil and food prices in Malaysia using a nonlinear autoregressive distributed lags (NARDL) and bounds test of the model specification suggested the presence of cointegration between food prices, oil prices and real GDP. Findings confirmed the presence of asymmetries in food prices. However, this model failed to parameterized model common with nonlinear time series data thus the effect transmitted from oil prices to food prices will be underestimated.

Kuwornu *et al*., (2011) applied GARCH (1, 1) to analyze price volatility implication on food security in Ghana. Specifically, used the Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and the Theil Inequality Coefficient (TIC) to forecast maize, millet and rice. But the approach fails to capture the shocks and volatility transmission from one sector to another sector and hence lacks the ability to forecast effectively compared to VAR (1)-GARCH. Generally, changes in exchange rate are one of the potential sources of oil price volatility transmission to domestic food prices and hence this paper considered the effect of change rate (Lloyd *et al*., 2013). Serra and Zilberman (2013) conducted an extensive review of biofuel-related price transmission and concluded that energy price is a key driver of agricultural prices with instability in the energy markets transmitted to food markets in the long-run. Within the context of this review, the BEKK-GARCH parameterization exposes the effect of biofuels or energy prices transmits volatilities to agricultural product prices (Zhang *et al*., 2008; Alom *et al*., 2011; Long *et al*., 2011; Serra and Gil, 2012). Trujillo-Barrera *et al*., (2012) applied the BEKK-GARCH model to analyze the volatility spillovers in the U.S. crude oil, ethanol and corn futures markets but asymmetry of the BEKK-GARCH was not in agreement with a LM test. Strong and varying volatilities were transmitted from crude oil to corn and ethanol markets. Gardbroek and Hernadez (2013) failed to provide evidence of volatility spillover between energy and grain markets but rather significant unidirectional spillover from corn to ethanol. They achieved these results with a BEKK-GARCH model applied on price data from 1997 to 2011. They further examined the interdependence and dynamics of between these markets and concluded that, a high interaction exists between ethanol and corn especially after the 2006 ethanol production legislation.

Wang and McPhail (2014) examined the impact of energy price shocks on the US agricultural commodity prices volatility by developing a VAR model. They used historical annual data of real crude oil and agricultural commodity prices from 1984 to 2011 and realized that energy price shocks contribute to commodity price variation in the long run. Xiao and Aydemir (2007) had earlier acknowledged suitability of the ARCH, GARCH and the Regime Switching Models (RSM) relative to the ARMA and the RSM. This is because of ARCH ability to capture volatility clustering in most financial time series analysis. The assumption of a constant variance ARMA models which cannot forecast volatility effectively. The RSM since time data exhibit regime changes and the ability to repeat itself in future thus future states or trend can be predicted using parameter estimates from past observations. Abdelradi and Serra (2015) recently applied the Vector Error Correction Models (VECMs) to explain the asymmetric price volatility transmission between food and energy markets in Spain with emphasis on price-level behavior by clearly allowing for non-stationarity and con-integration with the assumption that price variance is constant over time. Their research further motivated the use of MGARCH modelling due to time changing and price volatility clustering but this does not allow for volatility spillovers across different sectors as this current seeks to achieve. Also most of the MGARCH models do not allow for volatility causality linkages and hence they relied on the BEKK model explained by Engle and Kroner (1995). This again confirms the need to apply the VECH and BEKK model for parameterization of the model.

Lahiani *et al*. (2013) took advantage of a literature gap in conditional correlations and volatility spillover effects across agricultural commodities by using the VAR-GARCH model pioneered by Ling and McAleer (2003). VAR-GARCH gives an opportunity to further research into the conditional volatility dynamics of food prices including the conditional correlation across effects and volatility transmission between food prices. This review is necessitated by the indirect effect changes in exchange rate and crude oil price have on agricultural markets.

Based on the above argument, grains and cereals continue to dominate the food consumption component of developing countries including Ghana and Turkey. It is apparent that when the critical effects of volatility transmission between exchange rate and world crude oil price with the selected agricultural products are analyzed between these two countries, findings will improve international trade between the two countries, identify the comparative advantage as well as national and household decision making.

3. Materials and Methods

3.1. Data

Monthly price indices from January, 2000 to December, 2015 for both Ghana and Turkey were used for this analysis. This were prices were selected due to the global food crisis in 2007, 2008 and 2010. This also largely due to the consistency and availability of data for both countries. World crude oil price data was obtained from the World Bank. All prices were deflated into real prices. After calculating real prices, crude oil prices have been converted into the currencies of each country. Exchange rates were also converted into real effective exchange rate to prevent doubling counting. Returns were used to avoid the presence of a unit root in series similar to Hassan and Malik, (2007).

Returns were computed as $R_t = 100 * \ln(\frac{P_t}{P_{t-1}})$, where P_t is either real price levels or closing levels and P_{t-1} is lag value of P_t. Among the three agricultural product prices, maize recorded the highest average price of 0.765 Ghana Cedi and -0.05 Turkish Lira for Ghana and Turkey, respectively while soybean was the lowest for both countries. Especially in Ghana, after 2008, prices of soybeans sharply decreased. The effects of the world food crises (2007-2008 and 2010-2011) are apparent in product markets of both countries (see Figure 1a-1b). In Ghana, the t-values of monthly average returns are all positive except for soybeans, but statistically not different from zero. On the other hand, in Turkey, the t-values of both crude oil and exchange rates were found to be negative and statistically significant. In this context, the fact that oil is tied to US Dollar and the weakness of the TL against the US dollar confirms such a result.

Figure 1a: Log commodity real price or closing levels in Ghana

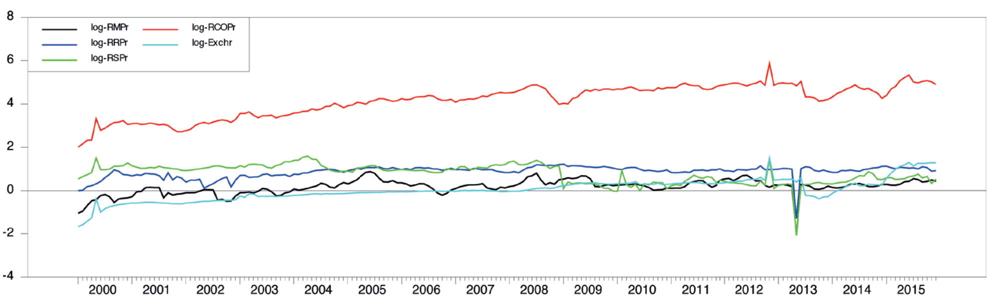
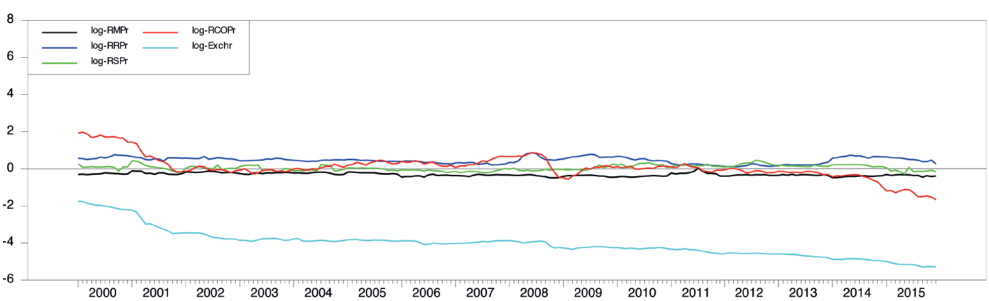


Figure 1b: Log commodity real price or closing levels in Turkey



Relatively small skewness but high kurtosis values in both countries indicate that each return series is not normally distributed. For Ghana maize, maize, rice and crude oil are positively skewed, while soybean and exchange rate are negatively skewed. In contrary, agricultural product markets in Turkey are positively skewed, whilst macroeconomic markets are negatively skewed. These indicate that there is high tendency of having positive extreme return values for agricultural product markets, while extreme negative return values for macroeconomic sectors in Turkey. Especially in Ghana as pointed out by both the standard deviation statistics (squared root of variance) and relatively large kurtosis values with characteristics of sharp peaks and fat tails (leptokurtic), product markets in Ghana appear to be more volatile than Turkey. These also indicate that the probability that outliers may occur is higher than that of normal distribution in Ghana than in Turkey. These results are also confirmed by the large Jarque-Berra statistics for both products shown in Tables 1.

Also, unconditional correlations coefficients categorized into levels (series), returns and volatility (squared returns) showed that Ghana's agricultural product correlates highly with crude oil and exchange rates than estimates from Turkey. In series, unconditional correlation between maize-rice and maize-soybean in Turkey were high compared to Ghana but low in returns and returns square[2]. Between maize, rice, soybean, crude oil price and exchange rate, the unconditional correlations were high in Ghana than in Turkey in return series. For price returns, unconditional correlation coefficients for Ghana were high except for maize-exchange rate (Figure 2a-2b). In returns square, unconditional correlation coefficients were generally higher in Ghana than Turkey (3a-3b). These higher unconditional correlations between the return squares of markets in Ghana indicate the very strong presence of volatility transmission among markets. Especially in Ghana (Figure 3a) the effects of both global world food crises and the 2012-2013 local elections are felt in agricultural products markets, causing excessive volatility in the prices of agricultural products. Meanwhile, these also indicate the volatility clustering phenomenon for which a large (small) volatility is followed by large (small) volatility, showing that prices volatilities in these markets can be forecast to some extent (Haixia and Shiping, 2013). On the other hand, the positive signs between almost all correlations in both countries show the existence of a strong nexus in the same direction between the markets.

Figure 2a: Commodity returns in Ghana

[2] *The same scale was used to have the opportunity to compare returns and squared return across both countries.*

Figure 2b: Commodity returns in Turkey

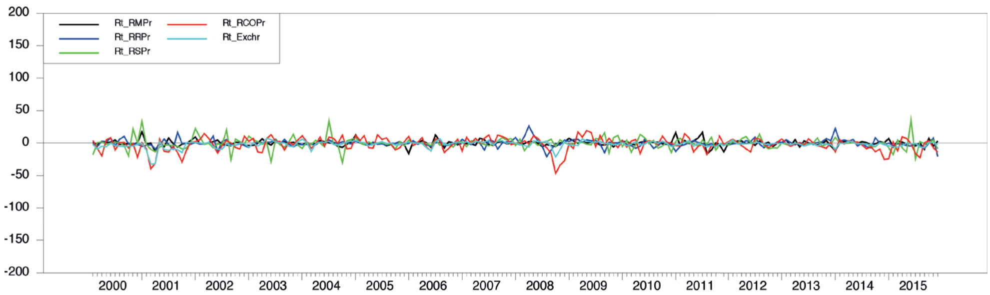


Figure 3a: Commodity squared returns in Ghana

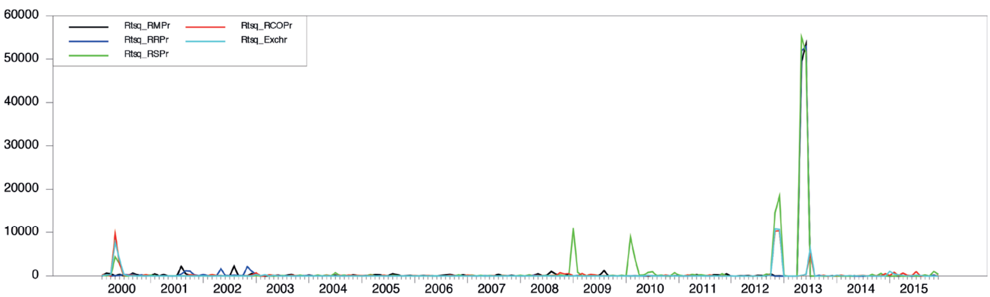
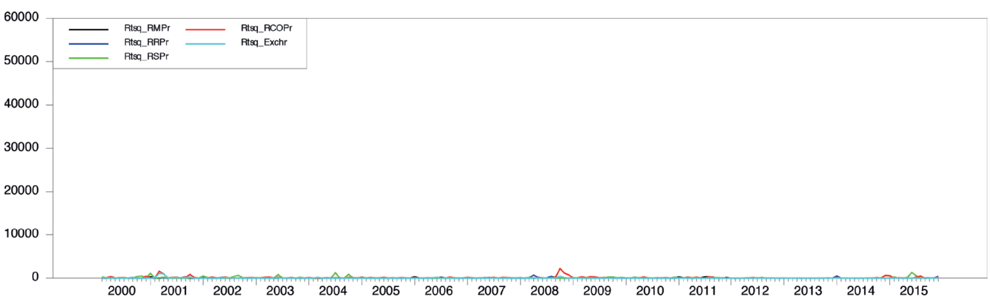


Figure 3b: Commodity squared returns in Turkey



Except for prices of maize, rice and soybean from Turkey, all the agricultural product prices for Ghana showed significant autocorrelations derived from the Ljung-Box statistic. On the other hand, multivariate autocorrelation test (HM-Q test) confirms existence of autocorrelation among return and squared return series in both countries. Mean equation for all products and the two macroeconomic variables were tested for the presence of ARCH effect proposed by Engle (1982). As individual LM tests show that ARCH effects are present in individual return series for both countries, ARCH effects were also confirmed in return series by multivariate LM test where the null under the multivariate LM test is that the series are mean zero, not serially correlated and with a fixed covariance matrix. We can see these relationships in Figures 2a through Figure 3b that all series show a very high volatility over time in both countries. In particular, we can see that the return and squared return series in Ghana have fluctuated very rapidly over time, compared to Turkey. Among the agricultural product prices for Ghana and Turkey, soybean recorded the highest variance and confirms the volatile behaviour relative to maize and rice. This also confirms the role of soybean in ethanol and livestock feed production in these two countries. Again in these figures we can see the effects of both 2007-2008 and 2010-2011 world food crises with the sharp declines in product returns especially in Ghana.

As part of process of assessing the appropriateness of the data towards further analysis, we applied unit root tests. Under different lags selection based on the Akaike Information Criterion (AIC), since the return series is composed of the first differences of the natural logarithm, Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit tests confirmed this notion that all the individual return series do not include unit roots for Ghana and Turkey indicating return series are stationary. We can now proceed with MGACRH estimation because our return series are all free of unit root problem and have ARCH effects individually and jointly. In multivariate GARCH model as the observations were from monthly data with a relatively low level, variance-covariance of the parameters was obtained using the robust method (Hwang and Pereira, 2006). Rezitis and Ahammad (2016) estimated a multivariate GARCH model by applying similar method to the 50 observations of series[3]. On the other hand, Gardebroek and Hernandez (2013) and Wu *et al.* (2013) reported results of the multivariate GARCH model without using the robust method as both the number of observations and the data categorized into two parts during the study period (before and after 2006) were smaller than the number of observations at hand.

[3] *All estimates were performed under RATS 9.2. Possible biased standard errors have been corrected using the ROBUSTERRORS option of RATS 9.2.*

Table 1: Descriptive statistics of Ghana's price returns

Descriptive Statistics	Maize	Rice	Soybean	Crude Oil	Exchange Rate
Mean	0.765	0.476	-0.007	1.508	1.533
Variance	668.843	634.102	990.379	295.510	242.439
t-stat (Mean=0)	0.409 (0.683)	0.261 (0.794)	-0.003 (0.998)	1.213 (0.227)	1.361 (0.175)
Skewness	0.248 (0.165)	0.018 (0.919)	-0.399** (0.025)	0.200 (0.263)	-0.263 (0.141)
Kurtosis	61.398*** (0.000)	71.367*** (0.000)	32.975*** (0.000)	18.5193*** (0.000)	29.425*** (0.000)
Jarque-Bera	30002.486*** (0.000)	40534.209*** (0.000)	8658.468*** (0.000)	2730.689*** (0.000)	6892.810*** (0.000)
LB-Q (10)	26.883** (0.003)	40.679*** (0.000)	76.547*** (0.000)	36.698*** (0.000)	64.739*** (0.000)
LB-Q^2 (10)	46.864*** (0.000)	47.522*** (0.000)	62.547*** (0.000)	40.014*** (0.000)	52.580*** (0.000)
HM-Q (10)			52.580*** (0.000)		
LM-test (10)	13.168*** (0.000)	13.941*** (0.000)	13.882*** (0.000)	8.693*** (0.000)	7.807*** (0.000)
MLM-test (10)			2352281.60*** (0.000)		
Unit Root Tests					
ADF	-19.957*** (lags=0)	-11.013*** (lags=3)	-7.546*** (lags=5)	-7.234*** (lags=5)	-20.518*** (lags=0)
KPSS	0.031 (lags=0)	0.070 (lags=3)	0.044 (lags=5)	0.169 (lags=5)	0.068 (lags=0)
Correlations (Series)					
Rice	0.981				
Soybean	0.879	0.899			
Crude Oil	0.892	0.892	0.718		
Exchange Rate	0.888	0.891	0.745	0.957	
Correlations (Returns)					
Rice	0.875				
Soybean	0.670	0.707			
Crude Oil	0.079	0.124	0.414		
Exchange Rate	0.091	0.113	0.481	0.884	
Correlations (Squared Returns)					
Rice	0.997				
Soybean	0.933	0.934			
Crude Oil	0.024	0.022	0.281		
Exchange Rate	0.023	0.022	0.285	0.982	

Note: *LB and HM-Q denote Ljung-Box and the Hosking's multivariate Q-statistic for serial dependence tests in residuals and/or squared residuals, respectively, while LM and MLM denote Lagrangian and multivariate Lagrangian tests for ARCH effects, respectively. The null under MLM test is that the series are mean zero, not serially correlated and with a fixed covariance matrix. ADF denote for Augmented Dick-Fuller test considering with constant and trend variables. The critical values vary with lags selected. In parenthesis are associative p-values.*

Table 2: Descriptive statistics of Turkey's price returns

Descriptive Statistics	Maize	Rice	Soybean	Crude Oil	Exchange Rate
Mean	-0.050	-0.164	-0.231	-1.885	-1.860
Variance	21.593	31.236	75.062	109.305	25.995
t-stat (Mean=0)	-0.150 (0.881)	-0.407 (0.684)	-0.369 (0.712)	-2.492** (0.014)	-5.043*** (0.000)
Skewness	0.148 (0.404)	0.421** (0.018)	0.542*** (0.002)	-1.088*** (0.000)	-2.725*** (0.000)
Kurtosis	3.708*** (0.000)	5.144*** (0.000)	4.951*** (0.000)	2.279*** (0.000)	12.861*** (0.000)
Jarque-Bera	110.129*** (0.000)	216.270*** (0.000)	204.439*** (0.000)	79.096*** (0.000)	1552.853*** (0.000)
LB-Q (10)	16.427* (0.088)	21.166** (0.020)	15.801 (0.106)	30.308*** (0.001)	66.446*** (0.000)
LB-Q^2 (10)	18.871** (0.042)	16.835* (0.078)	10.055 (0.436)	42.486*** (0.000)	53.592*** (0.000)
HM-Q (10)			354.904*** (0.000)		
LM-test (10)	1.538 (0.130)	1.714* (0.081)	0.969 (0.472)	4.699*** (0.000)	8.322*** (0.000)
MLM-test (10)			53579.72***((0.000)		
Unit Root Tests					
ADF	-9.966*** (lags=2)	-10.302*** (lags=0)	-9.171*** (lags=3)	-9.044*** (lags=0)	-5.983*** (lags=2)
KPSS	0.020 (lags=2)	0.051 (lags=0)	0.045 (lags=3)	0.288 (lags=0)	0.633** (lags=2)
Correlations (Series)					
Rice	0.981				
Soybean	0.985	0.972			
Crude Oil	0.750	0.761	0.743		
Exchange Rate	0.641	0.654	0.629	0.965	
Correlations (Returns)					
Rice	-0.016				
Soybean	0.189	-0.014			
Crude Oil	0.074	0.115	0.059		
Exchange Rate	0.228	0.082	0.149	0.671	
Correlations (Squared Returns)					
Rice	0.212				
Soybean	0.256	0.099			
Crude Oil	0.192	0.139	0.124		
Exchange Rate	0.201	0.138	0.096	0.713	

Note: *LB and HM-Q denote Ljung-Box and the Hosking's multivariate Q-statistic for serial dependence tests in residuals and/or squared residuals, respectively, while LM and MLM denote Lagrangian and multivariate Lagrangian tests for ARCH effects, respectively. The null under MLM test is that the series are mean zero, not serially correlated and with a fixed covariance matrix. ADF denote for Augmented Dick-Fuller test considering with constant and trend variables. The critical values vary with lags selected. In parenthesis are associative p-values.*

3.2. Econometric model

The first step in the theory of volatility is to observe the general characteristics of most price time series data. These characteristics include the presence of a unit root, tendency of prices of related markets to co-integrate. A mean equation is specified which is the first step in multivariate GARCH models (MGARCH) (Engle and Kroner, 1995). Generally, the mean equation for each return series is expressed as:

$$R_{i,t} = \mu_i + \psi R_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

where R_{it} is the return on series *i* between time t and t_1, μ_i is a long-term drift coefficient, and ε_{it} is error term for the return on series i at time t. Some series are composed of real prices (e.g., selected agricultural products and crude oil prices), while others are composed of closing levels (e.g., exchange rate).

The most popular non-linear models used in financial models are the Autoregressive Conditional Heteroskedasticity (ARCH) models or Generalized Autoregressive Conditional Heteroskedasticity (GARCH). Brooks (2014) added that there are different multivariate GARCH specifications in literature and the widely used are the VECH, the diagonal VECH and the BEKK models. In each case, there are *N* assets whose return variances and covariance are to be specified. But based on the limitations of the VECH and DVECH models in terms of positive definiteness, the VAR (1) - BEKK MGARCH model was applied as proposed by Engle and Kroner (1995) by applying t-distribution to capture leptokurtosis effects inherited in series. That is the H_t matrix becomes positive definiteness always and expressed as:

$$H_t = CC' + A'\varepsilon'_{t-1}A\varepsilon_{t-1} + B'\mathrm{H}_{t-1}\mathrm{B} \quad (2)$$

where H_t is a 5x5 variance-covariance matrix, C is 5x5 upper triangular coefficient matrix, while A and B are 5x5 parameter matrices for each country. H_t matrix is defined as: (3)

$$H_t = CC' + \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \varepsilon_{t-1}\varepsilon'_{t-1} \begin{bmatrix} a_{11} & a_{21} & a_{31} & a_{41} & a_{51} \\ a_{12} & a_{22} & a_{32} & a_{42} & a_{52} \\ a_{13} & a_{23} & a_{33} & a_{43} & a_{53} \\ a_{14} & a_{24} & a_{34} & a_{44} & a_{54} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \end{bmatrix} H_{t-1} \begin{bmatrix} b_{11} & b_{21} & b_{31} & b_{41} & b_{51} \\ b_{12} & b_{22} & b_{32} & b_{42} & b_{52} \\ b_{13} & b_{23} & b_{33} & b_{43} & b_{53} \\ b_{14} & b_{24} & b_{34} & b_{44} & b_{54} \\ b_{15} & b_{25} & b_{35} & b_{45} & b_{55} \end{bmatrix}$$

where indices refers to maize, rice, soybean crude oil and exchange rate. This analysis following Kroner and Ng (1998a) applied for an asymmetric specification of the multivariate VAR (1)-BEKK MGARCH model to ensure covariance matrix will be positive semi-definite for non-negativity of estimated variances. The variant of MGARCH model is further applied in order to detect volatility transmission between different series, including the persistence of volatility within each series. For this reason, the BEKK parameterization was used for the analysis for each country. Its log-likelihood function with t-distribution is as follows:

$$L_t = \ln\left[\frac{\Gamma\left(\frac{v+n}{2}\right)v^{\frac{n}{2}}}{(vn)^{\frac{n}{2}}\Gamma\left(\frac{v}{2}\right)(v-n)^{\frac{n}{2}}}\right] - \frac{1}{2}\ln|H_t| - \frac{1}{2}(v+n)\ln\left(1+\frac{\varepsilon_t' H_t^{-1}\varepsilon_t}{v-2}\right) \tag{4}$$

where n is the numbers of return series in mean equation, ε_t is the residuals of the n mean vector equations, v is the degree of freedom (where v>2) and Γ(.) is the gamma function. Parameter estimates are obtained by maximizing equation 4 with BFGS algorithm [4, 5].

3.3. Optimal portfolio weights and hedge ratio estimation

Based on the BEKK-GARCH model, optimal portfolio ratio and hedge ratios for each of agricultural product price and macroeconomic variable was designed. The aim was to minimize risk at expected investment returns between Ghana and Turkey. Optimal holding weights are expressed as a weight of *i* (agricultural markets) in sector *j* (crude oil market) at time, t (Kroner and Ng, 1998b; Hassan and Malik, 2006; Gencer and Musoglu, 2014). This is expressed as;

$$w_t^{i,crude\ oil} = \frac{h_t^{crude\ oil} - h_t^{i,\mathrm{crude}\ oil}}{h_t^i - 2h_t^{i,\mathrm{crude}\ oil} + h_t^{crude\ oil}} \tag{5}$$

$$w_t^{i,crude\ oil} = \begin{cases} 0, & if\ \ w_t^{i,crude\ oil} < 0 \\ w_t^{i,crude\ oil}, & if\ \ 0 \le w_t^{i,crude\ oil} \le 1 \\ 1, & if\ \ w_t^{i,crude\ oil} > 1 \end{cases} \tag{6}$$

Where $w_t^{i,crude\ oil}$ represents the weight of sector i (e.g., three agricultural product markets) in crude oil market at time t; h_t^i and $h_t^{crude\ oil}$ are the estimated conditional variances of sector *i* and crude oil sector, respectively while $h_t^{i,crude\ oil}$ is the conditional covariance of *i* and crude oil markets at time t. These are all derived from the BEKK-GARCH equations. Kroner and Sultan (1993) further estimated optimal hedge ratios of asset portfolios through an expression below;

$$\beta_t^{i,crude\ oil} = \frac{h_t^{i,crude\ oil}}{h_t^{crude\ oil}} \tag{7}$$

[4] *In the first stage, the simplex method is used to obtain reliable initial values and these coefficients are then used in the BFGS algorithm. The above distribution is consistent to our data because each return series are over-kurtosis indicating the maximum likelihood estimation under normal distribution may not handle the data in this structure. In addition, the fact that the shape parameter is statistically significant in our analysis strengthens the above relation.*

[5] *Unitary effects of this model are generally neglected by researchers. The marginal effects on each conditional variance were derived. Delta method was used to construct standard errors of these estimates. We will not show how we derived them here because of page limitation, but we can send out derived marginal effects and their corresponding RATS program upon request by readers.*

Where $\beta_t^{i,\, crude\ oil}$ is the amount of a short position requirement for sector *i* market to hedge a one-dollar long position in crude oil sector.

4. Results and Discussions

4.1. Diagnostics tests

Included in Table 3 are parameter estimates and their-related diagnostic test from the five return series analysed simultaneously by the VAR (1)-MGARCH BEKK parameterizations for each country. We will discuss diagnostic test results before discussing effects of parameter estimates for each country.

Diagnostics related to model selections are presented in panel D of Table 3. Values from Wald test statistic rejected diagonal VAR model for Ghana and Turkey with high statistical confidence (Wald statistic = 190.43 and $p<0.000$ for Ghana and Wald statistic = 481.55 and $p<0.000$ for Turkey). These results show that the average returns of product markets affect each other, thus yielding spillover transmission perhaps with asymmetry among markets in each country. Further, the cross products of the diagonal parameters as well as the coefficients of all five own covariance parameters (diagonal parameters) in both matrices A and B were set to zero. This was to ensure no time-varying conditional variances of the five return series. Eventually, "No GARCH" models for both countries were reliably rejected with high statistical significance (see Table 3). With the rejection of the "No GARCH" model, time-varying volatilities are widespread in the return series in both countries. The results further indicate that modeling of the data with a constant co-variance structure will lead parameter estimates to be biased, inconsistent and inefficient.

Diagonal GARCH models assuming zero off-diagonal parameters in the A and B matrices in the VAR (1)-MGARCH BEKK models are rejected for both countries (Wald statistic = 65073.32 and $p<0.000$ for Ghana and Wald statistic = 83448.51 and $p<0.000$ for Turkey). If off-diagonal elements (e.g., coefficients) are nonzero, half of them are in matrix A that contains effects of short-term shocks, and the remaining halves are in matrix B which contain volatility effects, they indicate shocks and volatility transmissions with different magnitudes and signs between markets. On the other hand, past crude oil or the exchange rate returns has been found to be insignificant on agricultural markets for Ghana, while the individual effects of the past lags of either crude oil or exchange rate market on agricultural commodity markets are significant for Turkey. However, as the hypothesis was simultaneously considered, agricultural markets were statistically significantly affected by past returns of both crude and exchange rate markets in both countries.

Table 3 also presents the diagnostic test results for both countries with individual Ljung-Box Q and Q2 and multivariate Ljung-Box (MLBQ) test performed for serial correlation. Almost all individual Ljung-box Q and Q2 and Hosking's multivariate Q and Q2 statistics show no significant serial dependence on residuals and/or squared residuals, respectively. These results provide a guarantee of the suitability of the MGARCH BEKK model we are progressing. The observed insignificant test statistics echoed with results provided by Grier *et al.* (2004), Rahman and Serletis (2012), Sadorsky (2014) and Damba *et al*. (2017). On the other hand, all individual McLeod-Li tests except maize market in Turkey for ARCH effects show that there are no ARCH effects on remaining errors, whilst the multivariate LM (MLM) test for both countries suggests the opposite. However, the MLM test under the null hypothesis assumes that series have mean zero, not serially correlated and a fixed covariance matrix. Perhaps the individual autocorrelation problem in some series may have caused such a consequence. We have followed the Rahman and Serletis (2012) method to test whether the mean and variance of standardized residuals, $\hat{z}_{jt} = \frac{\varepsilon_{jt}}{\sqrt{\hat{h}_{jt}}}, j = 1,...,5$ are different from zero and one, respectively. The individual t-test results show that the standardized residuals of return series have zero mean and variance one. We, therefore, conclude that the remaining error of the model contains no any ARCH effects in the standardized residuals and residual squares and the VAR (1)-MGARCH BEKK model is compatible with our data.

Table 3: Maximum likelihood estimates of VAR (1)-BEKK GARCH (1, 1) for both Ghana and Turkey

Mean estimate	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey
	Maize (i=1)	Maize (i=1)	Rice (i=2)	Rice (i=2)	Soybean (i=3)	Soybean (i=3)	Crude Oil (i=4)	Crude Oil (i=4)	Exchange Rate (i=5)	Exchange Rate (i=5)
Panel A: Conditional Estimates										
Const	0.204 (0.274)	0.122 (0.613)	0.454 (0.921)	-0.012 (-0.061)	0.772 (1.061)	-0.194 (-0.459)	1.611*** (2.793)	-0.165 (-0.298)	0.816*** (5.068)	-0.496** (-2.726)
ψ_{i1}	0.227*** (3.784)	-0.118* (-2.213)	-0.007 (-0.137)	-0.077* (-2.174)	0.044 (0.709)	0.013 (0.134)	0.009 (0.242)	0.155 (1.185)	0.034*** (3.616)	-0.004 (-0.069)
ψ_{i2}	-0.032 (-0.509)	0.077* (2.206)	0.077* -0.297***	--0.297*** (-6.210)	0.241*** (4.098)	-0.020 (-0.396)	0.075 (0.891)	0.115*** (3.227)	0.014 (1.511)	0.044 (0.780)
ψ_{i3}	-0.026 (-0.837)	0.010 (0.512)	0.048** (2.082)	0.046* (2.3401)	-0.056 (-1.233)	-0.068 (-1.282)	-0.046** (-1.977)	0.156* (2.399)	-0.017** (-2.473)	0.053* (1.961)
ψ_{i4}	0.088 (1.275)	-0.087*** (-4.162)	0.050 (1.454)	0.046* (2.126)	0.091 (1.261)	0.055 (1.197)	0.030 (0.621)	0.188** (3.201)	-0.039*** (-2.778)	0.001 (0.082)
ψ_{i5}	0.045 (0.646)	0.181*** (7.866)	-0.093 (-1.172)	0.031 (0.904)	-0.237** (-2.188)	-0.017 (-0.162)	-0.030 (-0.333)	0.450*** (4.860)	0.027 (0.510)	0.447*** (8.881)
Panel B: Variance Estimates										
C_{i1}	11.535*** (11.566)	0.924 (2.308	5.830*** (7.819)	-1.940*** (-5.580)	1.440 (1.603)	-1.250*** (-3.96)	2.781** (2.510)	0.652* (1.785)	0.436** (2.127)	-0.062 (-0.377)
C_{i2}			-2.956*** (-3.455)	1.523*** 4.83922	5.813*** (4.944)	-6.183*** (-17.226)	2.331** (2.289)	-2.620*** (-14.948)	-0.125 (-0.360)	-0.332* (-2.369)
C_{i3}					-8.324*** (-5.170)	-0.001 (-0.0001)	-3.378*** (-3.310)	-0.000 (-0.002)	-0.794** (-2.127)	-0.000 (-0.001)
C_{i4}							-0.000 (-0.000)	-0.000 (-0.001)	-0.000 (-0.000)	-0.000 (-0.001)
C_{i5}									-0.000 (-0.000)	-0.000 (-0.000)

α_{i1}	0.113*** (4.781)	0.471*** (4.329)	0.618 (13.149)	-0.084 (-1.149)	0.071 (1.719)	0.001 (0.011)	0.225 (1.919)	0.152** (2.666)	-0.352 (-1.540)	-0.150 (-1.472)
α_{i2}	-0.010 (-0.561)	-0.236* (-2.046)	0.469 (11.887)	1.164*** (8.676)	0.047 (2.091)	0.076* (2.093)	0.098 (1.081)	-0.093* (-1.803)	-0.205 (-0.556)	-0.188* (-2.103)
α_{i3}	0.196*** (3.289)	-0.429*** (-4.369)	-0.296 (-9.313)	0.085 (0.841)	0.683 (10.732)	0.425*** (5.885)	-0.054 (-0.495)	0.252** (3.096)	0.728 (2.883)	-0.232 (-1.562)
α_{i4}	-0.025 (-1.131)	0.382*** (4.813)	0.145 (7.118)	0.701*** (8.670)	-0.109 (-6.835)	0.069 (1.341)	-0.191 (-1.945)	0.150*** (4.355)	1.668 (15.843)	0.225** (3.2712)
α_{i5}	0.002 (0.205)	0.032 (1.440)	-0.014 (-5.531)	0.040 (0.648)	-0.007 (-0.991)	-0.063*** (-4.401)	0.226 (5.576)	0.017 (0.976)	1.228 (8.068)	0.446*** (19.573)
b_{i1}	0.022 (0.382)	0.049 (0.683)	0.021*** (0.382)	0.165** (3.237)	0.330*** (6.117)	0.018 (0.793)	0.235* (1.906)	-0.330*** (-11.299)	-0.441** (-3.223)	-0.054 (-1.312)
b_{i2}	-0.263*** (-8.724)	-0.069 (-0.698)	-0.262*** (-8.723)	0.392*** (4.283)	-0.284*** (-8.899)	0.067* (2.016)	-0.106 (-1.046)	-0.123*** (-4.530)	0.475*** (4.098)	0.045 (0.602)
b_{i3}	-0.225** (-2.516)	0.231 (1.186)	-0.225* (-2.515)	0.281* (1.774)	-0.067 (-0.993)	-0.156*** (-4.173)	0.383*** (5.233)	0.258*** (-5.021)	-0.368* (0.149)	0.402** (2.626)
b_{i4}	0.156*** (8.887)	-0.192* (-2.239)	0.155*** (8.887)	-0.087* (-2.103)	-0.067 (-0.993)	1.100*** (12.389)	-0.900*** (-17.771)	0.243*** (11.378)	1.010*** (9.002)	-0.616*** (-77.143)
b_{i5}	0.010 (0.379)	-0.111* (-1.883)	0.009*** (0.379)	-0.001 (-0.035)	-0.067*** (-0.993)	0.364*** (9.679)	-0.075*** (-3.39)	-0.240*** (-12.105)	0.107* (1.872)	0.644*** (28.806)
Shape par.	3.175*** (16.581)	6.902*** (5.999)								

Table 3: Maximum likelihood estimates of VAR (1)-BEKK GARCH (1, 1) for both Ghana and Turkey cont.

Mean estimate	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey
	Maize (i=1)	Maize (i=1)	Rice (i=2)	Rice (i=2)	Soybean (i=3)	Soybean (i=3)	Crude Oil (i=4)	Crude Oil (i=4)	Exchange Rate (i=5)	Exchange Rate (i=5)
Panel C: Diagnostic Tests										
LB-Q (10)	2.092 (0.996)	12.066 (0.280)	6.706 (0.753)	10.244 (0.419)	11.313 (0.334)	13.790 (0.183)	18.061* (0.054)	7.982 (0.631)	25.673*** (0.004)	19.543** (0.034)
LB-Q^2 (10)	0.109 (1.000)	22.649** (0.012)	0.114 (1.000)	11.861 (0.295)	3.414 (0.970)	5.514 (0.854)	15.610 (0.111)	7.050 (0.721)	6.040 (0.811)	7.280 (0.699)
HM-Q (5)	For Ghana = 139.927 (0.170)					For Turkey =112.917 (0.773)				
HM-Q^2 (5)	For Ghana = 51.571 (1.000)					For Turkey =105.146 (0.901)				
McL (10)	0.109 (1.000)	22.649** (0.012)	0.114 (1.000)	11.861 (0.295)	3.414 (0.970)	5.514 (0.854)	15.610 (0.111)	7.050 (0.721)	6.040 (0.811)	7.280 (0.699)
MLM-test	For Ghana = 3069.97***(0.000)					For Turkey = 2222.23***(0.000)				
MLM^2-test	For Ghana = 44818.45***(0.000)					For Turkey = 2965.84***(0.000)				
z_i	-0.080 (0.430)	0.009 (0.910)	-0.091 (0.452)	-0.016 (0.822)	-0.067 (0.578)	-0.002 (0.981)	-0.008 (0.897)	-0.033 (0.648)	0.110 (0.145)	-0.055 (0.419)
z_i^2	1.982 (0.917)	1.091 (0.999)	2.821 (0.916)	0.902 (0.999)	2.815 (0.960)	1.159 (0.999)	0.688 (1.000)	0.980 (0.999)	1.094 (0.999)	0.873 (0.999)

Panel D: Testing some Hypotheses

		Ghana	Turkey
Diagonal VAR	H_0: All off-diagonal elements of ψ_i are jointly zero	190.426*** (0.000)	481.548*** (0.000)
No GARCH	H_0: $\alpha_{ij} = b_{ij} = 0$ for all i, j =1,…,5	1362384.777*** (0.000)	607733.432*** (0.000)
Diagonal GARCH	H_0: All off-diagonal elements of A and B are jointly zero	65073.323*** (0.000)	83448.513*** (0.000)
No Past Crude Oil Effects on Selected Agricultural Price Returns in VAR	H_0: $\psi_{14} = \psi_{24} = \psi_{34} = 0$	4.793 (0.187)	37.722 *** (0.000)
No Past Exchange Rate Effects on Selected Agricultural Price Returns in VAR	H_0: $\psi_{15} = \psi_{25} = \psi_{35} = 0$	6.120 (0.106)	195.788*** (0.000)
No Past Crude Oil and Exchange Rate Effects on Selected Agricultural Price Returns in VAR	H_0: $\psi_{14} = \psi_{15} = \psi_{24} = \psi_{25} = \psi_{34} = \psi_{35} = 0$	31.879*** (0.000)	354.435 *** (0.000)
AIC		35.529	31.375
SBC		37.170	33.016
Log Likelihood		-3279.302	-2884.623

Note: **, ** and *** are statistically significant at 10%, 5% and 1% respectively. LB and HM denote Ljung-Box and the Hosking's multivariate Q statistic for serial dependence tests on residuals and/or squared residuals, respectively, while McL and MLM denote McLeod-Li test and multivariate Lagrangian tests for ARCH effects on residuals and/ or squared residuals, respectively. The null under MLM test is that the series are mean zero, not serially correlated and with a fixed covariance matrix. In parenthesis are associative p-values.*

Included in panel A of Table 3 are estimates of lag returns on current returns for selected agricultural products both for Ghana and Turkey. While the corn market in Ghana was positively affected by its lag, this effect was found to be negative in Turkey. Also, while the corn market in Ghana is not affected by the lag markets of other products, this market in Turkey is positively affected by rice and exchange rate markets and negatively influenced by crude oil market. Similarly, rice market in Ghana was negatively influenced from its past market whilst it was negatively affected by soybean market. However, in Turkey, this market is positively affected both by its own market, soybean and crude oil markets, whilst it was negatively affected by the corn market. Interestingly, the soybean market is only negatively affected by the exchange rate market in Ghana, whilst in Turkey this market has not been affected by any market including its own past market. On the other hand, when we look at the movements in the macroeconomic markets (e.g., crude oil and exchange rate markets) the crude oil market in Ghana is positively affected by the rice market and negatively influenced by the soybean market. In Turkey, this market was positively affected by its own market, soybean and exchange rate markets. While the exchange rate market in Ghana was positively affected by the corn market, it was negatively affected by soybean and crude oil markets. On the other hand, in Turkey, this market has been positively affected by its own market and soybean market.

When we look at the relationship between the conditional return markets between the two countries, compared to Ghana, agricultural markets in Turkey are mostly tied to each other and both to crude oil and exchange rate markets, while crude oil and exchange rate markets of both countries are affected by the movement in agricultural markets, showing that the nexus between markets is not symmetrical.

On the other hand, the parameters derived from the log-likelihood function for the variance equations did not show unitary effects of variables included in variance equations on the short and long term variances, so their unitary effects along with their statistics using delta method were calculated. We will discuss them in the subsequent section.

4.2. Shock transmission between maize, rice, soybean with crude oil and exchange rate

Findings showed significant shock transmissions among and between the three agricultural product prices with crude oil price and exchange rate in the short run as shown in Table 4 below. These are categorized into direct ($\varepsilon^2_{i,t)}$ and indirect ($\varepsilon_{i,t}\varepsilon_{j,t,}$ where $i \neq j$) shocks. Volatility of maize markets in Ghana and Turkey is significantly characterized by its lagged own shocks. This is an attribute of maize grain price in Ghana where previous month's price has effect on current price. There were evidence of shocks on long term volatility from rice market to the maize market, while cross-market shock interactions of maize with soybean and crude oil markets impacted on maize prices in Ghana. Contrary to findings in Ghana, the conditional variance for the maize market in Turkey was characterized by its cross-market shock with crude oil.

The volatility in the rice market was characterized by its own lagged prices in both countries, showing increased shocks in the rice market based on the conditional volatility. While the long-term volatility in the rice market in Ghana was affected by speculations of soybean price, but the conditional volatility of this market in Turkey was affected by more cross-interactions of other markets showing the volatility in this market is more sensitive to shocks of other market than in Ghana. This is attributed to Turkey being a net importer of rice and any speculation in world agricultural markets are instantaneously transmitted to this market. Meanwhile, the short-term interactions of this market with both crude oil and exchange rate reduced the ambiguity in the conditional volatility of this market in both countries. Also, the short-term interaction of the soybean market with the crude oil market played a decisive role in reducing the uncertainty of the rice market in Ghana, the interaction of the soybean with exchange rate market has been a trigger for uncertainty in the rice market in Turkey. This can be attributed to the role of soybean for livestock, human and energy needs in Ghana. Ghana's strategy of reducing petroleum fuel prices with an inclusion of biofuels from soybean has cause price shocks over the past years (Antwi *et al.*, 2010). Lastly, the short-term relationship between crude oil and the exchange rate markets has been a factor in increasing the conditional variance of the rice market in Ghana, while this effect was insignificant in Turkey.

Own return shocks were observed among soybean markets in both countries at 1% and 5% significant levels respectively. There exists a short-term uncertainty of cross-markets on soybean. For example, short-term shocks of both maize and exchange rate markets have impacts on the conditional volatility in soybean market in Turkey, whilst the rice market has an influential effect in the Ghanaian soybean market. Only Turkey's soybean market received shock transmission from current and past exchange and confirms Richards *et al.*, (2012) conclusion on the relationship between soybean, crude oil price and exchange rates in developing countries. Own but positive shock transmissions were observed among domestic exchange rates in both countries. This confirms Campa and Goldberg (2006) that due to exchange rate pass-through, current exchange rate is affected by past exchange rate. Meanwhile the cross-interactions between the agricultural commodity markets and between agricultural and oil and exchange market have determined the conditional volatility of soybean markets in both countries. While some of these interactions have increased the volatility of the soybean market, some have been seen to decrease it. So, pass-through across cross markets in Ghana and Turkey differ significantly according to the country's location and economic scale. In this context, current and lag shock transmissions and disturbance indicates the sensitive nature of grain and cereal prices in developing countries especially with the shift to meat and dairy product consumptions (Hochman *et al.*, 2011). The increased demand for soybean oil, cake and biodiesel confirms price speculation on current soybean market returns.

Domestic crude oil price in Turkey also received price shocks from maize and rice prices at 10% and 1% significance levels, respectively. This may be attributed to the role of maize and soybean as animal feed and sources of ethanol and biodiesel in the country. Past crude oil market shocks affected current crude oil markets in Turkey but not in Ghana. Only Turkey's domestic crude oil market received indirect market shock from maize and crude oil market itself, while in Ghana crude oil market received shock transmission from co-movements of rice with soybean, rice with crude oil, rice with exchange rate, soybean with soybean with crude oil, and crude oil with exchange rate markets.

Exchange rate markets received shock transmissions from cross-markets in both countries. In Ghana, the exchange rate market is directly influenced by short-term news and speculative news from the rice and crude oil markets, whilst this market is only affected by the soy bean market. Also exchange rate market in both countries received price shock from its past behaviour. On the other hand, the co-movement of agricultural markets within itself, or the joint movement with the crude oil market and exchange markets, does not have any significant impact on the exchange rate volatility. Only the joint movement of the soybean market with the exchange rate market in Turkey and co-movement of the crude oil market with the exchange rate market in Ghana influenced the volatility in exchange rate sector.

4.3. Conditional variance-covariance estimates for volatility transmissions

Direct ($h^2_{i,j,t}$)and indirect ($h_{i,j,t}$, where $i \neq j$) volatility transmission estimates as presented in Table 4 for Ghana and Turkey confirms the sensitive nature of agricultural markets to crude oil prices and domestic exchange rates. As can be seen in the table, the effects of long-term volatilities on conditional variance of each market are more persistent than that of short-term shocks outlined in previous section. Own return volatility was observed among maize market in Turkey but not in Ghana but indirectly, past maize market transmitted volatilities to rice and crude oil markets in Ghana. This is attributed to role of maize as the major staple food in Ghana.

Positive own return volatilities were transmitted among rice markets in both Ghana and Turkey but indirectly, lag rice volatilities transmitted conditional volatilities to markets of maize, crude oil and exchange rate in Ghana. This may be attributed to the 2006-2008 food crisis situation where maize price rose and hence rice was an option for household consumption. Own and positive volatility was observed among soybean market in Turkey but not in Ghana and this can be attributed to the demand for soybean as livestock feed in Turkey. Indirectly, lag soybean volatilities transmitted volatilities positively to markets of maize and rice in Ghana but not in

Table 4: Marginal effects of shock transmission between world crude oil price, exchange rate and selected agricultural product prices in both Ghana and Turkey

Mean estimate	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey
	Maize (i=1)	Maize (i=1)	Rice (i=2)	Rice (i=2)	Soybean (i=3)	Soybean (i=3)	Crude Oil (i=4)	Crude Oil (i=4)	Exchange Rate (i=5)	Exchange Rate (i=5)
$\varepsilon^2_{1,t}$	0.012* (2.390)	0.222* (2.165)	0.000 (0.280)	0.0556 (1.023)	0.039 (1.644)	0.185* (2.185)	0.001 (0.566)	0.147* (2.407)	0.000 (0.103)	0.001 (0.720)
$\varepsilon^2_{2,t}$	0.381*** (6.574)	0.007 (0.574)	0.220*** (5.943)	1.356*** (4.338)	0.088*** (4.656)	0.007 (0.420)	0.021 (3.559)	0.492*** (4.335)	0.000** (2.766)	0.002 (0.324)
$\varepsilon^2_{3,t}$	0.005 (0.859)	0.000 (0.005)	0.002 (1.045)	0.006 (1.047)	0.467*** (5.366)	0.181** (2.942)	0.011 (3.417)	0.005 (0.671)	0.000 (0.496)	0.004* (2.201)
$\varepsilon^2_{4,t}$	0.051 (0.959)	0.023 (1.333)	0.010 (0.540)	0.009 (0.902)	0.003 (0.247)	0.064 (1.548)	0.037 (0.973)	0.023* (2.178)	0.051** (2.788)	0.000 (0.488)
$\varepsilon^2_{5,t}$	0.124 (0.769)	0.0226 (0.736)	0.042 (0.280)	0.035 (1.051)	0.530 (1.442)	0.054* (0.781)	2.782 (7.922)	0.051 (1.636)	1.508*** (4.035)	0.199*** (9.787)
$\varepsilon_{1,t}\varepsilon_{2,t}$	0.140*** (4.779)	-0.079 (-1.152)	-0.010 (-0.558)	-0.549* (-2.030)	-0.116** (-2.911)	-0.073 (-0.801)	-0.007 (-1.032)	0.537*** (4.157)	-0.000 (-0.201)	0.003 (0.710)
$\varepsilon_{1,t}\varepsilon_{3,t}$	0.016* (1.666)	0.001 (0.011)	-0.001 (-0.526)	-0.036 (-1.460)	0.268*** (4.254)	-0.366*** (-3.307)	0.005 (1.088)	0.053 (1.355)	-0.000 (-0.199)	-0.005 (-1.521)
$\varepsilon_{1,t}\varepsilon_{4,t}$	0.051* (1.693)	0.144* (1.909)	-0.002 (-0.472)	0.044 (1.209)	-0.021 (-0.469)	-0.217* (-2.526)	0.010 (1.020)	0.115*** (3.593)	0.001 (0.206)	0.001 (0.688)
$\varepsilon_{1,t}\varepsilon_{5,t}$	-0.080 (-1.416)	-0.142 (-1.224)	0.004 (0.463)	0.089* (2.027)	0.286** (3.085)	0.199 (1.462)	-0.083 (-1.117)	0.172** (2.810)	0.005 (0.208)	0.029 (1.445)
$\varepsilon_{2,t}\varepsilon_{3,t}$	0.088* (1.833)	-0.000 (-0.011)	0.0442* (2.041)	0.176* (2.189)	-0.404*** (-6.685)	0.073 (0.819)	-0.032*** (-3.673)	0.096 (1.347)	0.000 (1.017)	-0.005 (-0.585)
$\varepsilon_{2,t}\varepsilon_{4,t}$	0.278* 2.02693	-0.026 (-1.076)	0.092 (1.132)	-0.216* (-1.649)	0.032 (0.500)	0.043 (0.793)	-0.055* (-2.045)	0.211*** (4.396)	-0.006 (-4.122)	0.001 (0.836)
$\varepsilon_{2,t}\varepsilon_{5,t}$	-0.435 (-1.441)	0.025 (0.891)	-0.192 (-0.541)	-0.437* (-1.952)	-0.431* (-2.455)	-0.040 (-0.689)	0.484*** (6.841)	0.316** (2.920)	-0.035 (-5.277)	0.0356 (0.647)
$\varepsilon_{3,t}\varepsilon_{4,t}$	0.032 (1.141)	0.000 (0.011)	0.009 (0.998)	-0.014* (-1.679)	-0.074 (-0.506)	0.215* (2.496)	0.042* (2.059)	0.021 (1.189)	-0.003 (-0.946)	-0.002 (-1.087)
$\varepsilon_{3,t}\varepsilon_{5,t}$	-0.050 (-1.151)	-0.000 (-0.011)	-0.019 (-0.506)	0.028 (-1.422)	0.995* (2.428)	-0.198 (-1.437)	-0.362*** (-6.918)	0.031 (1.375)	-0.018 (-0.936)	-0.056*** (-4.175)
$\varepsilon_{4,t}\varepsilon_{5,t}$	-0.158 (-1.279)	-0.046 (-1.012)	-0.040 (-0.734)	0.035* (1.847)	-0.079 (-0.516)	-0.117 (-1.101)	-0.638* (-1.815)	0.068*** (3.794)	0.556*** (4.188)	0.015 (0.995)

Note: **, ** and *** are statistically significant at 10%, 5% and 1% respectively.*

Turkey. Only Turkey's domestic crude oil price received positive and indirect price volatility from soybean markets. Both countries domestic exchange rates received positive volatilities also from soybean prices. Among the macroeconomic variables, that is crude oil price and exchange rate, crude oil market transmitted more volatilities within the two countries compared to exchange rates and confirms Ghosh, (2011) and Yousefi and Wirjanto, (2004) conclusion that same effect or magnitude is observed from both negative and positive crude oil price shocks on exchange rate volatility with a permanent effect on exchange rate volatility. Own market volatility was observed among crude oil markets in both countries but indirectly, lag domestic crude oil volatilities transmitted persistent volatilities to maize, rice and also soybean markets in Turkey and exchange rates in both countries. Past (h^2_{55}) exchange rates markets transmitted indirect volatilities to domestic crude oil price in both countries but own volatility was observed among exchange rate itself in Turkey and not in Ghana.

Indirect volatility from maize and rice markets was transmitted negatively to rice but positively to crude oil prices only in Ghana. Any long term price shock in maize and rice causes volatilities in other markets such as rice itself. Conditional volatilities in soybean and maize ($h_{31,t}$) transmitted volatilities positively to rice in Ghana and also to crude oil and exchange rates in Turkey. Also, indirect conditional volatilities were transmitted from domestic crude oil and maize markets ($h_{41,t}$) to soybean market in Ghana but negatively to crude oil market in Ghana and Turkey. Only Turkey's domestic exchange rate received volatility transmission from crude oil and maize markets and can be attributed to the import volumes of maize during the food crisis period. Ghana's rice received indirect but negative conditional volatility from co-movement of exchange rate with maize ($h_{14,t}$) market but positively, exchange rate and maize transmitted positive long-term volatilities to crude oil markets in both countries.

Indirect long-term persistent volatilities were transmitted negatively to maize and rice markets in Ghana but positively to rice market in Turkey. Also in Turkey, soybean and crude oil markets received positive perennial volatility transmissions but only Ghana's exchange rate received positive transmission. Rice and crude oil ($h_{24,t}$) markets transmitted indirect perdurable volatilities positively to maize market in Ghana but negatively in Turkey. It also transmitted negative volatility to rice market in Turkey but positively, it transmitted perennial volatility to soybean market in Ghana. Domestic crude oil markets from both countries received perdurable conditional volatilities from rice market and crude oil market ($h_{24,t}$) itself. Indirect long-term persistent volatilities were transmitted from rice and exchange rate ($h_{25,t}$) markets to maize and rice markets in Ghana. At the same time, rice and exchange rate markets transmitted perennial volatilities to domestic crude oil markets in both countries including exchange rate itself in Ghana. This can be attributed to the need for US dollar in procuring crude oil from the international markets and hence a translated effect on domestic prices. Soybean and crude oil markets combined to transmit volatilities positively to maize but negatively to rice markets in Ghana. Only Turkey's soybean, crude oil and exchange rates (negatively) markets from both countries received perennial volatility from soybean and crude oil markets as well. Soybean and exchange rate further transmitted volatility positively to maize but negatively to rice markets in Ghana. It further transmitted volatility negatively to soybean itself and crude oil market in Turkey but to exchange rate itself in both countries. It indicates that, past exchange rate combine with agricultural food prices has effect on current exchange rates.

Finally, crude oil and exchange rate ($h_{45,t}$) markets combined to transmit volatility negatively to soybean markets in both countries but more significant in Turkey. It ($h_{45,t}$) further transmitted volatilities negatively to crude oil market itself in both countries. This confirms Hasanov *et al*., (2016) conclusion that crude oil and exchange rates uncertainty is responsible for the significant decline in price returns of major feedstock like soybean and maize. Also, Turkey's exchange rate received indirect volatility negatively from crude oil and exchange rate itself. Although crude oil alone does not predict food prices in Ghana as found by Mensah *et al*., (2016), our findings confirms that role of a combine effect of crude oil and own exchange rate markets uncertainties in the long run in Ghana. Similar to Gosh (2011) and Zhang *et al*., (2008), it can therefore be concluded that an increase in crude oil price returns causes a depreciation of domestic currencies *vis-à-vis* the US dollar.

Table 5: Marginal effects of volatility transmission between world crude oil price, exchange rate and selected agricultural product prices in both Ghana and Turkey

Variable	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey
	$h_{11,t+1}$	$h_{11,t+1}$	$h_{22,t+1}$	$h_{22,t+1}$	$h_{33,t+1}$	$h_{33,t+1}$	$h_{44,t+1}$	$h_{44,t+1}$	$h_{55,t+1}$	$h_{55,t+1}$
$h^2_{11,t}$	0.001 (0.191)	0.199*** (9.787)	0.069*** (4.362)	0.005 (0.349)	0.051 (1.258)	0.054 (0.593)	0.024*** (4.443)	0.037 (1.119)	0.0001 (0.190)	0.012 (0.942)
$h^2_{22,t}$	0.174*** (3.528)	0.027 (1.619)	0.215*** (4.551)	0.154* (2.142)	0.061 (1.257)	0.079 (0.887)	0.015** (2.732)	0.008 (1.052)	0.018** (2.640)	0.0000 (0.017)
$h^2_{33,t}$	0.109** (3.059)	0.000 (0.400)	0.081*** (4.450)	0.005 (1.008)	0.005 (0.497)	0.024* (2.087)	0.002 (0.471	1.210*** (6.194)	0.007* (1.785)	0.132*** (4.839)
$h^2_{44,t}$	0.056 (0.953)	0.109*** (5.650)	0.011 (0.523)	0.015* (2.265)	0.147** (2.617)	0.067* (2.510)	0.811*** (8.886)	0.059*** (5.689)	0.006* (1.697)	0.057*** (6.052)
$h^2_{55,t}$	0.195 (1.612)	0.003 (0.657)	0.226 (2.049)	0.002 (0.301)	0.135 (1.232)	0.161 (1.313)	1.020*** (4.501)	0.380*** (38.571)	0.012 (0.936)	0.415*** (14.403)
$h_{21,t}$	-0.018 (-0.368)	0.016 (0.635)	-0.243*** (-4.907)	-0.054 (-0.686)	-0.112 (-1.319)	0.130 (1.222)	0.038*** (4.665)	0.033 (1.404)	0.003 (0.396)	0.000 (0.035)
$h_{31,t}$	0.014 (0.383)	0.002 (0.512)	0.149*** (6.970)	-0.009 (-0.623)	0.030 (1.323)	-0.072 (-1.098)	-0.013 (-0.934)	-0.423* (-2.221)	0.002 (0.396)	-0.081* (-1.891)
$h_{41,t}$	0.010 (0.365)	-0.033 (–0.669)	0.056 (1.048)	0.017 (0.670)	-0.173* (-1.965)	-0.119 (-1.062)	-0.280*** (-9.088)	-0.094* (-2.425)	-0.002 (-0.391)	0.053* (1.958)
$h_{51,t}$	-0.019 (-0.375)	-0.005 (-0.616)	-0.250*** (-3.684)	-0.006 (-0.415)	0.1659 (1.315)	0.186 (1.323)	0.314*** (5.578)	0.237* (2.247)	0.002 (0.344)	-0.143* (-1.812)
$h_{23,t}$	-0.275*** (-4.11)	0.006 (0.767)	-0.264*** (-6.069)	0.053* (1.984)	-0.033 (-1.106)	-0.088* (-1.691)	-0.010 (-0.812	-0.191* (-2.210)	0.022** (2.635)	-0.001 (-0.035)
$h_{24,t}$	-0.196* (-1.783)	-0.109** (-2.890)	-0.099 (-1.041)	0.096*** (-3.711)	0.191* (1.926)	-0.145 (-1.642)	-0.223*** (-5.148	-0.042* (-2.100)	-0.020** (-2.610)	0.001 (0.035)
$h_{25,t}$	0.368** (2.772)	-0.018 (-1.286)	0.441*** (3.638)	0.036 (0.607)	-0.183 (-1.339)	0.225 (1.208)	0.250*** (6.638)	0.107* (2.110)	0.028* (1.946)	-0.002 (-0.035)
$h_{34,t}$	0.156 (1.598)	-0.012 (-0.797)	0.061 (1.008)	-0.017* (-1.655)	-0.052 (-1.020)	0.081** (2.695)	0.074 (0.938)	0.535*** (8.324)	-0.012** (-2.835)	-0.174*** (-6.093)
$h_{35,t}$	-0.291* (-2.313)	-0.002 (-0.590)	-0.270** (-3.247)	0.006 (0.525)	0.050 (1.245)	-0.126* (-2.190)	-0.083 (–0.996)	-1.357*** (-11.357)	0.018** (2.809)	0.469*** (9.321)
$h_{45,t}$	-0.208 (-1.207)	0.036 (1.359)	-0.102 (-0.840)	-0.011 (-0.551)	-0.283* (-1.780)	-0.207* (-2.174)	-1.820*** (-7.122)	-0.300*** (-11.485)	-0.016 (-1.444)	-0.309*** (-12.056)

Note: **, ** and *** are statistically significant at 10%, 5% and 1% respectively.*

Conditional correlation estimates revealed that between agricultural products and crude oil and exchange rate, showed that world food crisis occurred in 2001, 2003, 2008-2009, and 2011 in both countries (Figures 4a-5b). Especially in Ghana, after the second half of 2012, agriculture products markets with both world crude oil and exchange rate markets displayed a very high volatility over time. In this country, soybean markets with crude oil and exchange rate markets showed on average a positive conditional correlation over time, whilst, on the contrary, maize and rice markets jump up and down with both crude oil and exchange rate markets. On the other hand, in Turkey time-varying conditional correlations have exhibited a similar tendency over time, but the response of the three agricultural product markets to the crude oil market is totally different from that of the exchange rate market. This difference varies depending on the internal dynamics of the products (in general supply and demand), the uncertainties along with the economic movement in the world market, and the value of the local currency against the foreign currency. Also, the conditional correlations varying with time show asymmetric patterns in both countries showing increases with an increase in crude oil and exchange markets, decreasing with a decrease in these markets.

Figure 4a: Conditional correlations between returns of selected agricultural products and crude oil in Ghana

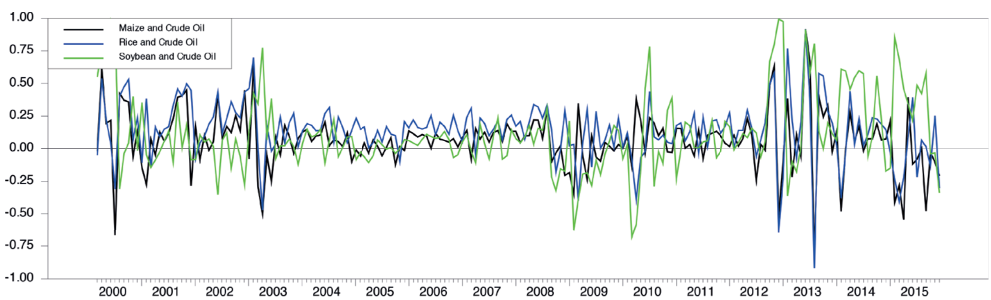


Figure 4a: Conditional correlations between returns of selected agricultural products and crude oil in Turkey

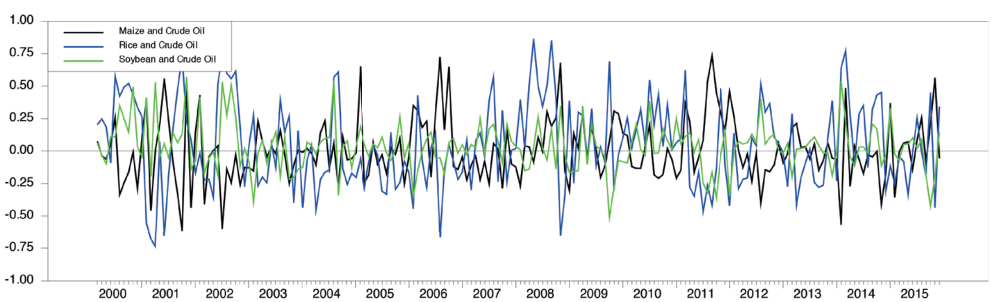


Figure 5a: Conditional correlations between returns of selected agricultural products and exchange rate in Ghana

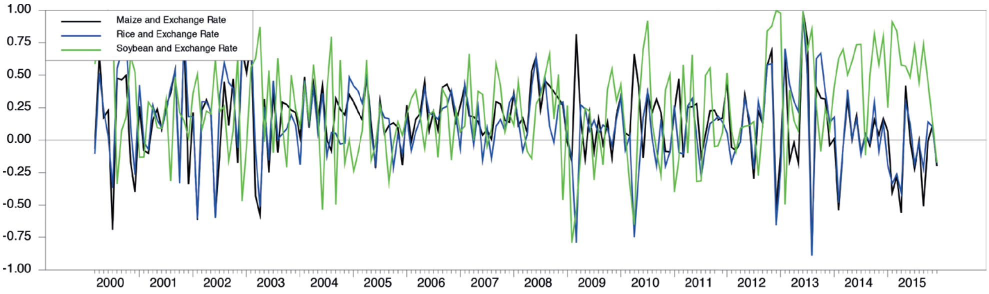
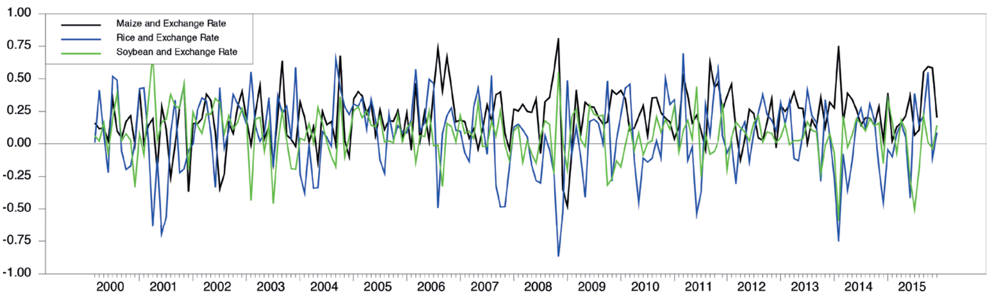


Figure 5a: Conditional correlations between returns of selected agricultural products and exchange rate in Turkey



4.4. Optimal portfolio weights and hedge ratios

The analysis identified an effective investment decision between Ghana and Turkey due to the comparative advantage in producing and marketing maize, rice and soybean. This was based on decisions of asset pricing, risk management and portfolio allocation for efficient estimation of time-varying covariance matrix (Kroner and Ng, 1998; Hassan and Malik, 2006; Sadorsky, 2014). For hedging effectiveness, VAR (1) - MGARCH BEKK parameterization was the best option for optimal hedge rationing in terms of variance portfolio minimization (Chang *et al.*, 2011). After assessing the shocks, direct and indirect volatility transmissions, it was appropriate to reduce the risk associated with changing crude oil price.

Expected returns were assumed to be zero and the risk minimizing portfolio weight $w_t^{i,\ crude\ oil}$, and the hedge ratios $\beta_t^{i,\ crude\ oil}$ are presented in Table 6 below. For both countries, the mean $w_t^{1,\ crude\ oil}$ for maize-crude oil were 0.427 and 0.860, indicating that for a 1 Ghana Cedi and 1 Turkish Lira portfolios, 42.7 pesewas and 86 Kuruş[6] should be invested in maize for the two countries while 57.3 pesewas and 14 Kuruş

[6] *Coins equivalent.*

should be invested in crude oil. Mean portfolio weights for rice were 0.61 and 0.75 indicating that for every 1 Ghana Cedi and 1 Turkish Lira portfolios, an investor should invest 61 pesewas and 75 Kuruş on rice for Ghana and Turkey while 39 pesewas and 25 Kuruş should be invested in crude oil. Also, for a 1 Ghana Cedi and 1 Turkish Lira portfolios, 45 pesewas and 62.5 Kuruş should be invested in soybean while 55 pesewas and 37.5 Kuruş for crude oil. Results showed Turkey recorded high optimal portfolio weights for the three agricultural commodities in the face of the changing crude oil prices and indicates that, it is efficient to reduce the risk and uncertainty in maize, rice and soybean in Turkey than in Ghana. This is can be attributed to the ability of the Turkish Lira (TL) to adjust to changes in crude oil and the US dollar rate.

In order to minimize risk in these three agricultural products due to changing crude oil price, hedge ratios for the products were estimated similar to Kroner and Sultan (1993). Hedge ratios $\beta_t^{i,\ crude\ oil}$ for these products relative to crude oil price in both countries were 0.139 and 0.01 for maize; 0.154 and 0.087 for rice; 0.107 and 0.03 for soybean. This implies that, on average, for every 1 Ghana Cedi long position in the maize market, an investor hedge 13.9 pesewas in the crude oil market while for a 1 Turkish Lira long position, an average of 1 Kuruş can be hedged in the crude oil market in Turkey. For a 1 Ghana Cedi long position in the rice market, an investor should hedge 15.4 pesewas in the crude oil market while for a 1 Turkish Lira long position in Turkey's rice market, an investor hedge 8.7 Kuruş in the crude oil market. Finally, for a 1 Ghana Cedi long position in the soybean market, 10.7 pesewas should be hedged in the crude oil market while for a 1 Turkish Lira short position in the soybean market, 3 Kuruş should be hedged in the crude oil market. This therefore indicates that, it is efficient to invest in maize, rice and soybean markets in Turkey than in Ghana.

Table 6: Optimal portfolio weight and hedge ratios for Ghana and Turkey

Optimal Portfolio Weight/ Hedge Ratio	Ghana	Turkey	Ghana	Turkey	Ghana	Turkey
	Maize/ Crude Oil	Maize/ Crude Oil	Rice/ Crude Oil	Rice/ Crude Oil	Soybean/ Crude Oil	Soybean/ Crude Oil
$w_t^{i,\ crude\ oil}$	0.427	0.860	0.610	0.750	0.447	0.628
$\beta_t^{i,\ crude\ oil}$	0.139	0.010	0.154	0.087	0.107	0.030

5. Conclusion

A shift from cereals and grains to dairy and meat product consumption, food crisis of 2006-2008 and the discovery of biofuel as alternative source of energy are the factors causing fluctuating food prices in both Ghana and Turkey. This is evident from the monthly food price trends of 2000-2015 production seasons. As two emerging economies in Sub-Saharan Africa and Eurasia, this analysis identified Turkey as an investment hub between the two countries although Ghana can enhance production and pricing options. Also, the geographical location of both Ghana and Turkey plays an important role in price formulation and fluctuation. This is evident from the shock and volatility transmissions among these selected agricultural product prices and also between the agricultural product prices with crude oil price and exchange rates. The worst affected agricultural product was Turkey's soybean price and this is evident by the increased demand for livestock feed and edible oil in Turkey and also Turkey as a net importer of this product. Crude oil price indirectly transmits shocks and volatilities in Ghana through import cost on inputs, handling of agricultural inputs and the spatial transportation of agricultural products from farms to marketing centres. The cross shocks and volatility transmissions also confirms that markets interact and hence the need for hedging. Based on the rising crude oil prices and the weak domestic currencies against the U.S. dollar, it is economically viable and a good investment decision to opt for maize, rice and soybean in Turkey than in Ghana but Ghana will be the destination market for these products. It is economical efficient to invest in rice in Ghana and maize in Turkey. The demand for alternative source of energy using ethanol and biodiesel from maize and soybean, the shift from grains and cereals to meat and dairy products, increasing cost of crude-related agricultural inputs such as inorganic fertilizer and the rising cost of transportation.

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