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Estimation of Short and Long-run Relationship between Selected Food Prices and Macroeconomic Variables in Ghana

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ABSTRACT: Lagged food prices directly cause food price rise in Ghana and indirectly by crude oil and exchange rates. High import prices of agricultural inputs and biofuel discovery are reasons for causality. This paper analysed the short and long-run relationship between crude oil, exchange rate, and selected agricultural food commodity prices in Ghana. Johansen test was applied to lagged time periods to identify cointegration relation and error correction for long run adjustments. Weak exogeneity was also conducted among the cointegration variables. Shocks were transferred from lagged prices to current in Ghana. This causes shocks and speculations in grain markets in Ghana.

Keywords: Cointegration, Food prices, Macroeconomic variables, Vector error correction

Gana'da Seçilmiş Gıda Fiyatları İle Makroekonomik Değişkenler Arasındaki Kısa ve Uzun Dönem İlişkinin Tahmini

ÖZ: Gecikmeli gıda fiyatları, Gana'da mevcut gıda fiyatlarının doğrudan yükselmesine ve dolaylı olarak da ham petrol ve döviz kurlarındaki dalgalanmalara neden olmaktadır. Tarımsal girdilerin yüksek ithalat fiyatları ve biyoyakıtların ortaya çıkması nedenselliğin ana kaynaklarıdır. Bu çalışmada, Gana'daki seçilmiş bazı tarımsal ürün fiyatları ile ham petrol, döviz kuru arasındaki kısa ve uzun dönem ilişkisi analiz edilmiştir. Eşbütünleşme ilişkisi ve uzun dönem hata düzeltme dengesi için gecikmeli sürelere Johansen testi uygulanmıştır. Eşbütünleşme değişkenleri arasında zayıf ekojenlik de varsayılmıştır. Gana'daki ekonomik ve ekonomik olmayan şokların gecikmeli fiyatlardan şimdiki mevcut fiyat düzeylerine aktarıldığı tespit edilmiştir. Bu durum, Gana'daki tahıl pazarlarında yeni şoklara ve spekülasyonlara neden olmaktadır.

Anahtar Kelimeler: Eş bütünleşme, Gıda fiyatları, Makroekonomik değişkenler, Vektör hata düzeltme

INTRODUCTION

Prices of cereals and grains increased by 20% to 30% between 2007-2008 period with a corresponding consumer price index rising (e.g., food inflation) from 193.9 to 246.7 (27%) (Wodon et al., 2008 and GSS, 2009). Similar price volatility emerged at the beginning of 2009 when the food price index began to rise slowly. Prices rose after June 2010 and by January 2011, most food price indexes exceeded the previous 2008 price level (Kilian and Hicks, 2013; Fernandez, 2014). Basically, there are three main factors underpinning the 2007-2008 world food crisis, which attracts the attention of researchers (Heady and Fan, 2008; Abbott et al., 2009; Cooke and Robles, 2009; Hamilton, 2009; Josling et al., 2010; Zhang and Law, 2010; Henderson, 2011; Cairns and Meilke, 2012; Kilian and Hicks, 2013; Fernandez, 2014). The main leading factor is that some of the developing nations like Brazil, Russia, India and China get even richer than ever before and consequently the increased wealth have triggered greater global demand for energy and food products (Abbot,t et al. 2009; Hamilton, 2009, Josling et al., 2010; Cairns and Meilke, 2012; Fernandez, 2014). As energy and food demand increased, the demand for intermediate factor goods ultimately increased. Increasing energy, food and intermediate goods requirements have led to an increase in food commodity prices.

The second important reason is that biofuels, which is milestone in the energy sector, have emerged in the early 2000s, causing the prices of agricultural products to increase by shifting the use of intermediate agricultural products (corn, wheat, cotton, sugar cane) used in the food chain to biofuel production (Mitchell, 2008; Tyner, 2010; Chen and Khanna, 2013; Condon et al., 2013; Fernandez, 2014). Biofuel production, which gets help of some incentives such as subsidies and tax exemptions by governments, fosters the production of certain agricultural commodities for its use, whilst it causes hoarding away of use of large quantity of these products (e.g., grains and vegetable oils) from food chain (Fernandez, 2014). At the same time, the competition between the two sectors has begun by shifting the resources (land, irrigation, machinery, and etc.) used for the food chain to biofuel production. The third reason is that the effects of some macro-economic variables can be listed here.

For example, as is known, international trade is made with USA dollars. As the dollar depreciates, imports of countries outside the US are increasing (e.g., because of the gain in purchasing power), causing the prices of agricultural products to rise all the time (Phillip and Friederich, 2013; Fernandez, 2014). On the other hand, as the interest rate increases, the cost of storing the product increases due to the rise in the value of substantial inflow of hot money in markets dampening the demand for food products with ultimately lower agricultural food prices (Bernanke et al., 1997; Barsky and Kilian, 2001; Frankel and Rose, 2010; Fernandez, 2014). Real exchange rates, on the other hand, show a long-run equilibrium with a range of commodity prices, and this remains as a long-run cohesion for commodity prices including energy (Fernandez, 2014). In addition to these factors, some factors worth mentioning are the increased financing or capital flows of future contracts in energy and food commodity sectors that remain responsible for volatility of prices in the last few decades. It was observed that the financialization of the goods in futures markets has led an opened room of speculative trading behavior to have triggered for large volatility swings during the last commodity price peak (Tang and Xiong, 2010; Pen and Sevi, 2013; Fernandez, 2014; Hamilton and Wu, 2014). While it is impossible to assent the supply-side effects (draughts, climate change, policy formations, and etc.) as lamblike in price fluctuations (Heady and Fan, 2008; Kilian, 2008b; 2009; Kilian and Murphy, 2012; Fernandez, 2014), in general the researchers are mainly focusing on the effects of demand-side on the price surge since supply-side effects are generally conveyed to be negligible.

Those who feel the most affected by the price surge in agricultural commodities will undoubtedly be underdeveloped countries. Of course, Ghana is one of these nations in the world. For example, Ghana's 2007-2008 fiscal year witnessed a food price surge due to global food crisis of higher global demand for energy and agricultural products (Osei-Asare and Eghan, 2013; Fernandez, 2014). According to the Ghana Living Standard Survey (2008), Ghana's average annual household expenditure amounts to US$ 2,062.30 with food expenditure accounting for two-fifth of the total household spending. As such, food prices are a key debate in Ghana especially after the 2007-2008 fiscal years. Globally, nominal food prices from 2007-2008 increased to more than 50% once more causing food prices to rise from 2010-2013 (Angelucci et al., 2013). While these sudden increase in food prices was as a result of instability in most parts of the world, macroeconomic factors such as inflation, exchange rates and world crude oil prices worsened the instability of food prices especially in developing countries, where the majority of household income goes to foodstuffs. Developing countries like Ghana were the worst affected thus destabilising national economic and budgetary planning processes in terms of increased cost of production inputs and rising cost of domestic crude oil products. This indicates that exchange rates, inflation and world crude oil prices are in tandem with general agricultural food commodities and hence a variation in any of these macroeconomic variables is transmitted to food price fluctuation.

MoFA (2012) stated that increasing cost of production inputs is one of the major factors contributing to a substantial run-up in food commodity prices in Ghana despite a fertilizer and seed subsidy program, whilst prices of other agro-chemicals, labour, farm implements and packaging materials are on the increase due to the weakness of the local currency against the US dollar. The major trading currencies in the world crude oil are the United States dollars and the euro and hence developing countries like Ghana continue to witness decline in currency strength. Thus, the instability of the Ghanaian Cedi (GC) against the US dollar (US$) is a major reason in the rising input prices with a translated effect on rising food prices (ISSER, 2013). Yeboah, Shaik and Quaicoe (2012) identified one-year lagged exchange rate as the only factor in rising food prices in 13 low income countries.

The dramatic rise in food prices has attracted the attention of researchers, governments and policy analysts in less developed and developing countries where food expenditure ranks high in household consumption (Rude and An, 2015). The instability of exchange rate is one of the key factors in price surge along with spill-over effects among food commodities. Rising exchange rates indicates runup prices of imports especially for agricultural production inputs (Adom, 2014), yet on the other hand Maetz (2013) earlier identified high energy prices, increased demand for cereals and grains for biofuel production, fluctuating exchange rates and rising inflation among factors causing rising food prices, especially 2006-2008 food crisis. Golberg and Knetter (1997) concluded that exchange rate has the effect of a unit change in local currency import prices due to a unit change in exchange rate between importing and exporting countries and the resulting effect (positive or negative) on import prices, inflation and food prices. This is an indication that Ghana's inflation, exchange rates and world crude oil prices have a relation with domestic food prices. These factors tend to move with food prices especially in the long run. Ghana is no exception as far as food price variation is concerned, especially anytime there is a unit change in world crude oil prices and the exchange rates of the dollar. This is confirmed by the co-movement of crude oil and grain prices during the 2007-2008 timeframe (Campiche et al., 2007). Past research works such as Enu and Attah-Obeng (2013), concentrated on Ghana's agricultural production side to an extent that key macroeconomic factors such as inflation, exchange rates and crude oil prices especially in relation to agricultural commodity prices leaves a huge gap.

We have presented in this study that whether there are both short and long run equilibrium between macroeconomic variables and prices of major selected agricultural commodities in Ghana. If the equilibrium exists, then by analysing their directions and sizes using multivariate cointegration analysis. This work diverges from previous studies in many respects: it uses a multivariate analysis among macroeconomic variables and prices of selected agricultural commodities in such a way that by searching also the existence of a cointegration among the prices of selected agricultural products. It also reveals the extent to which prices of products or macroeconomic variables have been identified as weakly exogenous in the system. Lastly, the outputs of the current study will benefit policy makers and related firms in fields in taking more effective decision-making actions and better forward reading.

Literature review will be given in the subsequent section. We then outlined Materials and Methods used for the analysis. Results discussed in greater detail in Results and Discussion Section. In the Conclusion Section, recommendation and proposals that are compatible with the results obtained will be brought forward.

Literature Review

Engle and Granger (1987) proposed a model for determining co-movement of time varying variables known as cointegration. This is achieved when a linear combination of time series variables is stationary and hence common with macroeconomic variables like inflation, exchange rates, world crude oil prices and prices of agricultural food commodities. Brooks (2014) confirmed that many time series move together and are non-stationary over time due to factors such as market forces of demand and supply. Nortey et al. (2015), applied the Johansen test of cointegration between inflation and exchange rates in Ghana by rejecting the null hypothesis of cointegration among the variables, which is a precondition for Vector Error Correction Model (VECM). This is evident that exchange rates Granger-cause inflation but not the reverse was the case after a pair-wise Granger causality test was conducted. However, the above mentioned research omitted a major factor in rising exchange rates in Ghana such as the world crude oil prices with a corresponding effect on food prices. Lardic and Mignon (2008) earlier analysed the long-run relationship between crude oil prices and food prices and found evidence of asymmetric cointegration, by concluding that rising crude oil prices causes prices of goods and service to rise, whilst Obayelu and Salau (2010) analysed the agricultural response to prices and exchange rate in Nigeria through an application of cointegration and the VECM. They found that variables used were integrated of the same order by conducting the unit root test of the Augmented Dickey Fuller procedure (ADF). Results of VECM for short run adjustment towards the long run relationship showed a linear deterministic trend indicating that food and export prices together with exchange rates are responsible about 57% of the variation in Nigeria. Natanelov et al. (2011), questioned whether there is a co-movement of agricultural commodity futures prices and crude oil prices by applying Johansen cointegration approach. The scope of their analyses was before and after the discovery of biofuel as an alternative source of energy using cereals and grains as raw materials and findings indicates co-movement between crude oil prices and maize prices due to biofuel discovery.

Nazlioglu (2011) used evidence from nonlinear causality analyse of the relationship between world oil and agricultural commodity prices with an observation that, co-movements between product prices have called for further research in assessing price transmission from crude oil prices to food prices. Results concluded that, crude oil prices and food prices did not influence each other in linear causality case, whilst contrary to nonlinear causality of feedbacks between crude oil and food prices, a persistent unidirectional nonlinear causality from crude oil prices to soybeans and maize were confirmed. Nazlioglu and Soytas (2012), again applied a panel cointegration and Granger causality methods to confirm that agricultural prices can be expressed as a function of crude oil prices and exchange rate. This was assessed for twenty commodities including barley, maize, wheat, sorghum, soybeans, rice, cotton, crude oil and exchange rates by concluding that the effect of crude oil prices on agricultural commodity prices and exchange rate movement cannot be overlooked. Findings concluded that there is strong evidence of an impact of crude oil prices and exchange rates on agricultural commodity prices. Durevall, Loening and Birru (2013) analysed the determinants of inflation in Ethiopia by applying the VECM on cereals and non-food prices. Results showed that inflation had increasingly associated with food and non-food prices. On the other hand, Wang, Wu and Yang (2014), applied the VECM for cointegrated time series variables of the same order of integration in order to capture the joint dynamics than vector autoregression (VAR), by using a structural VAR (SVAR) to assess the effect of oil prices on agricultural food prices. Abdelradi and Serra (2015) assessed Johansen cointegration approach including unit root tests as precondition for time series analysis. They assumed that time series of commodity prices generally have unit roots and prices of related products have a tendency to co-movements which can result from the presence of an equilibrium relationship among individual series that are cointegrated. The end result is volatility which changes over time and displays a clustering behaviour. Findings indicates that in the long-run, an increase in oil price will cause a corresponding increase in biofuel which use grains and cereals as raw materials for production. Serra (2015) again applied the theory of cointegration and error-correction test for the non-stationarity and co-movement of millet prices in Niger. This was to assess the level of market integration using the cointegration model in Africa. Finding revealed a cointegration between producer and consumer prices especially in the long run in terms of transaction costs. From these reviewed literature, it is evident that there exists a research gap between the combined relationship between macroeconomic variables and agricultural product prices in developing countries by the Johansen cointegration and VECM approaches. Also, it was observed that previous studies failed to test for weak exogeneity with error adjustments. Theoretically, this gap in weak exogeneity in cointegrating equations failed to identify the causality effects among cointegrating vectors. Also, this paper categorized vectors into two categories; agrifood prices with macro variables and a combine effect of both food prices and macro variables. Based on this, this paper assessed which macroeconomic variables have an increased relationship with maize, rice, sorghum, soybeans, beans and cocoa in Ghana. This paper further assesses which of these commodities co-moves with these macroeconomic variables in both the short-run and long-run equilibrium.

MATERIAL AND METHOD

An integrated two or more-time series data which are cointegrated have an error correction representation and vice versa (Engle and Granger, 1987). To avoid a spurious regression, the concept of cointegration and error correction model, ECM, were introduced (Alemaehu, Ndung'u and Zerfu, 2011). The theory of cointegration was pioneered by Granger (1986) while the error correction model was introduced by Phillip (1954), which has played an important role in analysing both the short-run and long-run adjustment processes. As a precondition for time series econometric analysis, various tests such as unit root test has to apply to determine stationarity or non-stationarity of a series (Myers, 1994). General prices of related sectors have a tendency to co-move and this is caused by the presence of equilibrium relationship between price series that are known as cointegration (Abdelradi and Serra, 2015). A Johansen approach was applied to test for cointegration between agricultural food prices and each of the macroeconomic variables (exchange rates and world crude oil prices).

Vector Autoregressive (VAR) models are methods for interpreting a number of co-related series. For more than one series of VAR of *n* order, an equation can be expressed as:

$$P_t = \mu + \sum_{i=1}^{n} \Gamma P_{t-i} + \varepsilon_t \qquad (1)$$

where P is an (Mx1) vector series at time t, μ is an (Mx1) constant vector, Γ is an (MxM) matrix coefficients of lagged series at i periods to changes in current series, μ is an (Mx1) constant vector and ε_t is an (Mx1) independently identified and distributed (iid) errors. This equation shows that either prices of agricultural products, crude oil or exchange rate is a function of n lags of itself, a constant with an error term. As the study seeks to understand the relationship between exchange rate and crude oil prices with prices of major food prices in Ghana, a VECM proposed by Johansen (Johansen, 1988, 1991; Johansen and Juselius, 1990) was appropriately chosen for speed of adjustments. These address both short and long-run price dynamics and at the same time creates linkages between two or more markets under study (Serra, 2015). Based on this, VECM was expressed as:

$$\Delta P_t = \alpha_0 + \Pi P_{t-1} + \sum_{i=1}^{k} \Gamma_i \, \Delta P_{t-i} + \varepsilon_t \qquad (2)$$

where Δ is the difference operators, P_t is an (M x 1) vector of prices of maize, rice, soybeans, sorghum, beans and cocoa, world crude oil price and exchange rate, respectively of I(1) endogenous variables, α_0 is a Mx1-dimensional vector of constant and ε_t is k-dimensional vector of the stochastic error term assumed to be normally distributed with $N\left(0,\sigma^2\right)$ properties. Π is the long-run matrix in which the number of cointegrating vectors (α, speed adjustment towards long-run equilibrium and β', long-run parameters) were determined within the system, whilst Γ is the vector of parameters representing the short-term relationship (Enders, 2010; Brooks, 2014).

The restricted forms of the cointegrating vectors and the speed of adjustment can be tested as follows:

Restrictions are placed on the vector error corrections, β , and the speed of adjustments, α , for r cointegrating equations. The restriction is undertaken by normalizing the variables under β such that $\beta' X$ is stationary and a product of the linear combination of the cointegrating variables in X and β. Each of the variables in the two cointegrating vectors are ***"normalise"*** by considering the coefficient of the dependent variable to be -1 through a null hypothesis, H_0. As they are detailed in the textbooks (Enders, 2010; Brooks, 2014), to save more space both the relevant constraints on the cointegrating vector space and the tests (e.g., weak exogeneity) will not be presented in matrix format here.

Data

Monthly data from January, 2000 to December, 2015 on Ghana's Producer Price Indices (PPI) and exchange rate were collected from the Ghana Statistical Service (GSS) and Bank of Ghana (BoG). Also, monthly world crude oil prices were drawn from the World Bank (WB). Monthly nominal food prices of maize, rice, soybeans, sorghum, beans and cocoa were drawn from the Ministry of Food and Agriculture (MoFA). Monthly nominal exchange rates were deflated using the inflation between Ghana and the USA in to reel effective exchange rate to remove the tendency of inflation. Food prices were also deflated into real food prices and same for crude oil prices.

Table 1. Descriptive statistics of world crude oil price, Ghana's inflation, exchange rates and selected food prices (GH₵)

Descriptive Statistics	Maize	Rice	Soybean	Sorghum	Beans	Cocoa	Crude Oil	Exchange Rate
Mean	1.248	2.468	2.360	2.193	2.676	8.684	65.78	0.096
Std. Dev.	0.368	0.508	0.899	1.922	0.735	2.149	21.86	0.061
Skewness	0.307	-1.156	0.291	1.919	-0.416	0.170	0.10	0.483
Kurtosis	3.832	4.758	2.479	7.305	3.414	3.380	1.99	1.770
Jarque-Bera	8.553	67.505	4.877	266.064	6.921	2.086	8.45	19.585
Probability	0.014	0.000	0.087	0.000	0.031	0.352	65.78	0.000

Note: 192 Observation used

Table 1 below shows the descriptive statistics of the macroeconomic variables (crude oil price and exchange rate) and selected food prices from Ghana. Average food prices from 2000-2015 showed cocoa recording the highest of 8.68 Ghana Cedi (GH₵) per kilo due to the domestic and international demand as a raw material for the confectionary, beverage and cosmetic industries. As such, monthly cocoa prices are set on the world market and also the leading revenue contributor to the Gross Domestic Product (GDP) of Ghana (Onuamah et al., 2013; ISSER, 2016). Beans recorded the next highest average price of 2.68GH₵ per kilo and this is attributed to the protein supplement requirements. Also, with the introduction of a National School Feeding and Buffer Stock programs by the Ghana government, beans is currently serving as an alternative source of protein towards creating markets for smallholder farmers in Ghana. Rice also recorded an average price of 2.47 GH₵ next to average beans price and the least domestic food price among the selected food prices was maize at 1.25 GH₵ per kilo during 2000 to 2015. Maize is the staple food commodity in Ghana and there are lots of efforts and interventions by both government and the private sector towards its affordability and hence the low price among food prices. Also, the introduction of the national food buffer stock company which mobilize excess maize as a mechanism to reduce maize price hikes caused by shocks and volatility transmissions can be attributed to this low price. The food buffer approach keeps maize in-stock to advert future shortage leading to price hike. Among the macroeconomic variables, the price of an average crude oil price was 65.78 US$ with Ghana's domestic exchange rate at 0.096 GH₵. High Jacque-Bera statistic was also recorded for exchange rate and statistically significant at 1%.

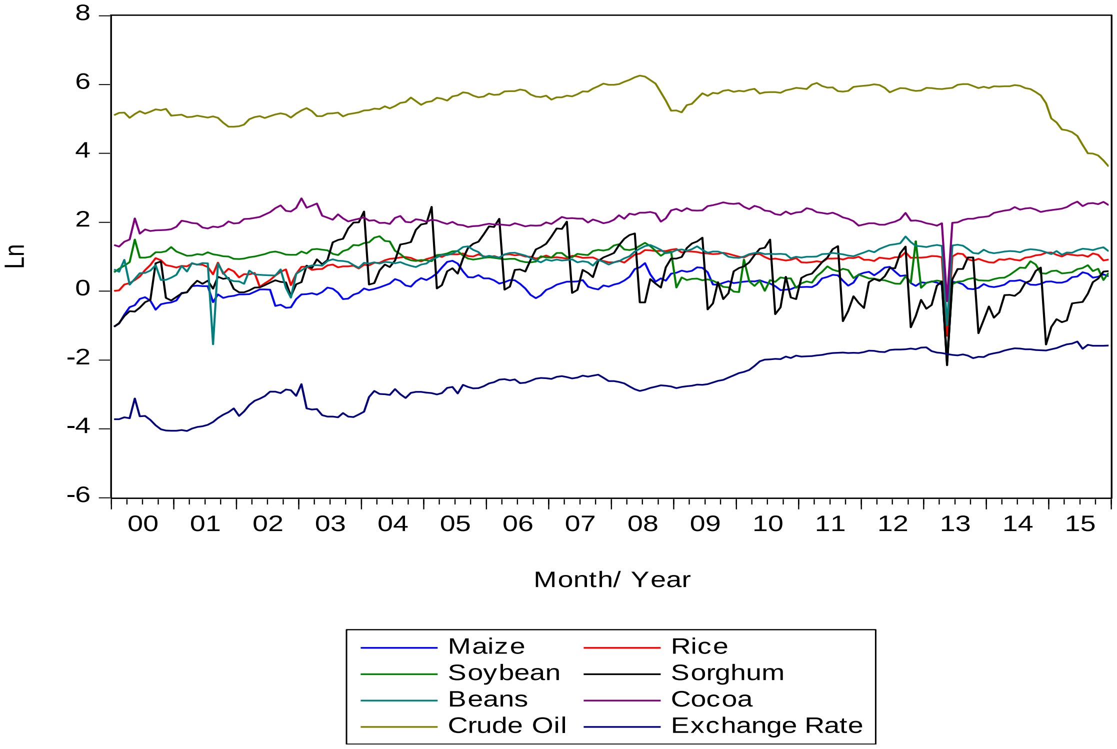


Figure 1. Graphical representation of world crude oil price, Ghana's monthly exchange rate and selected food prices (2000-2015).

Figure 1 below is a graphical display of the trends of world crude oil price and Ghana's domestic exchange rate with maize, rice, soybeans, sorghum, beans and cocoa prices in Ghana during 2000-2015 production seasons. Plots were in log returns against months per year. From the figure below, monthly cocoa price showed price stability until the last quarter of 2013 where it recorded a sharp decrease in price together with rice and soybeans. Exchange rate showed a fluctuating behaviour at the last quarter of 2004 to 2015. World crude oil price was stable until 2006 when rose steadily till mid-2008 where there was a decrease in price but rose again from 2009 with a steady decline in 2014. The fluctuating trend and behaviour of world crude oil price witnessed a slight rise in all the food price except a sharp decline in cocoa, rice and soybean prices in 2013. A trend was observed among prices of cocoa, soybeans, rice, maize and exchange rates as shown in the graph. Sorghum displayed a sharp rise and fall through 2000 to 2015. Also from Figure 2 below, all the food prices observed clustering behavior from 2000 to the end of 2015 especially for maize and cocoa. World crude oil price and exchange rate recorded high clustering behavior from 2000 to 2015. This confirms the rate of change of Ghana's domestic currency against the US dollar. But world crude oil price recorded the highest clustering characteristics and further confirms the changes in crude oil price in the world market. All the agricultural food prices showed levels of fluctuations in stationarity and confirms the behavior of agricultural product prices after the discovery of biofuels (ISSER, 2014).

RESULTS AND DISCUSSIONS

Table 2 below presents results of a unit root test for stationarity in levels and in first difference due to long term shock effects on agricultural food prices. Test results confirms or rejects the stationarity or otherwise of the data in order to avoid spurious results. The Augmented Dickey-Fuller (ADF) test was applied to each series under investigation. Test results revealed world crude oil price and effective exchange rate were stationary in difference but not in levels. Maize price was stationary both in levels and in first difference except none in levels. Rice price was also stationary in both levels and at first difference except under constant and trend, and none in levels. For soybeans and beans, there was stationarity in first difference but only under trend and constant in levels. Sorghum and cocoa prices showed stationarity only in first difference but not in levels. These results were observed under various appropriate lag lengths (k) as shown in the table below. These results further confirm that in the long run, both crude oil price, exchange rate and food prices in Ghana will have a constant mean, variance and autocorrelation over time. Based on this, a

Johansen cointegration test was then applied to determine the presence of co-movement among the series. Emphasis was on the co-movement between world crude oil prices and Ghana's monthly exchange rates relationship with prices of maize, rice, soybeans, sorghum, beans and cocoa in both the short-run and long-run respectively.

Table 2. Unit root results for world crude oil price, Ghana's exchange rates, and selected agricultural food commodity prices (Augmented-Dick-Fuller Test)

Test in Levels					Test in First Difference			
Price/ Rate	**Constant**	**Constant and Trend**	**None**	**k**	**Constant**	**Constant and Trend**	**None**	**k**
Maize	-3.98**	-4.28**	-0.64	0	-8.74***	-8.73***	-8.741***	3
Rice	-3.00*	-2.91	0.23	4	-9.85***	-9.92***	-9.84***	3
Soybean	-2.65	-4.16*	-0.86	1	-12.93***	-12.91***	-13.00***	1
Sorghum	-1.30	-2.02	-0.62	13	-4.97***	-5.19***	-4.989***	12
Beans	-2.33	-4.34**	0.16	3	-10.03***	-10.01***	-10.02***	3
Cocoa	-2.53	-2.72	0.34	2	-12.98***	-12.95***	-12.95***	1
Crude Oil	-1.96	-1.56	-0.88	2	-9.36***	-9.47***	-9.38***	0
Exchange Rate	-0.25	-2.473	1.336	3	-6.968***	16.927***	-6.701***	2

Note: *, ** and *** are 10%, 5%, and 1% critical values respectively.

Following Johansen (1992), and Harri, Nalley and Hudson (2009) to examine the presence of cointegration relationship between the variables, an appropriate lag length (k) and a cointegration rank (r) were determined. According to Asteriou and Hall (2011), cointegration is the overriding requirement for non-stationary time series data. Time series data for macroeconomic variables like crude oil price and exchange rate and prices of food products follow a trend pattern and hence, a spurious regression challenge will likely occur in agricultural policy formulation especially for non-stationary series. Based on this, the Johansen approach was preferred to the Engle-Granger approach due to number of variables involved making it appropriate for cointegration determination. As a precondition for determining the Johansen maximum likelihood approach, an optimal lag length was determined similar to Yu, et al. (2006a) and Saghaian (2010). A lag length of 2 was chosen from the Akaike Information Criterion (AIC) due to the long-run effect required and later reduced to check the optimal value of Schwarz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) in accordance with the Johansen approach. The lag selection is showed in Table 3 below.

Table 3. Lag selection criteria for cointegration

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1937.576	NA	0.211094	21.1476	21.2873	21.2042
1	-709.640	2335.748	6.77E-07	8.4961	9.7541*	9.0060*
2	-635.807	134.023	6.10e-07*	8.3892*	10.7655	9.3523
3	-596.308	68.264	8.04E-07	8.6555	12.1500	10.0718
4	-546.295	82.086	9.53E-07	8.8076	13.4203	10.6771
5	-503.422	66.641	1.23E-06	9.0372	14.7682	11.3600
6	-444.481	86.488	1.36E-06	9.0922	15.9414	11.8683
7	-378.602	90.942*	1.42E-06	9.0718	17.0392	12.3010
8	-335.731	55.452	1.95E-06	9.3014	18.3871	12.9840

*****indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final Prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.

The first step is to determine the integration of world crude oil prices, exchange rates as well as prices of maize, rice, soybeans, beans and cocoa[1] in both the short and long-run equilibriums. Test of Johansen (1992) approach was applied to the variables under study to test for co-integration based on the *λmax* test and the trace test similar to Harri, Nalley and Hudon, (2009). *λmax* test is derived from $\lambda_{max} = -T \ln(1-\lambda_{r+1})$ and λ's is the eigen values for the $\Pi = \alpha\beta'$ matrix. Findings from the Johansen cointegration approach showed the presence of two cointegrating equations in the long run at 5% critical value. This is displayed in Table 4 including the Johansen's maximum likelihood values. Linear deterministic trend was used for the test relations. Results of the trace and maximum eigen values confirmed two cointegrating equations and thus rejected the null hypothesis (r=0); hence LR tests showed the presence of a stationary, linear combination among word crude oil price, exchange rate and food prices in Ghana. It is possible that either one or more of the variables under study will be independent of the two cointegrating vectors. Also, the Johansen trace test based on the maximum likelihood method showed the presence of two cointegrating equations at 5% confirming a common trend (Obayelu and Salau, 2010). This confirms that in both the short-run and long-run equilibrium, monthly world crude oil prices, and Ghana's exchange rates co-move with agricultural food prices in Ghana. This calls for an error correction approach towards equilibrium. Figure 3 above also presents the two cointegrating relation graphs.

Based on the Johansen's cointegration test result in Table 4, a VEC model was applied. The presence of the two cointegration equations between world crude oil price, effective exchange rate, and agricultural food prices is a basis for VECM estimation as shown in Tables 5a, 5b, 5c, 5d, 5e and 5f, respectively. This includes the diagnostic statistic test for weak exogeneity. Table 5a below shows the cointegrating vectors (β) and the adjustment coefficients (α) for error correction in the long-run.

Table 4. Johansen cointegration test results for macroeconomic variables and food prices in Gana.

Ho: Rank=r	H1: Rank>r (n-r)	Eigenvalue	Likelihood Ratio	Trace Statistic	Trace 0.05 Critical Value	Maximum Eigen Statistic	Maximum Eigen 0.05 Critical Value
0	8	0.2838*	-756.23	207.417	159.530	63.416	52.363
1	7	0.2307*	-753.2241	144.000	125.615	49.824	46.231
2	6	0.1722	-728.3122	94.176	95.754	35.913	40.078
3	5	0.1280	-710.3557	58.263	69.819	26.024	33.877
4	4	0.1019	-697.3438	32.240	47.856	20.409	27.584
5	3	0.0476	-687.1391	11.830	29.797	9.263	21.132
6	2	0.0128	-682.5078	2.568	15.495	2.442	14.265
7	1	0.0007	-681.2870	0.126	3.841	0.126	3.841

Note: *** (*) denotes rejection of hypothesis at 1% (5%) significance level, L.R. test shows two cointegrating equations at 5% significance level.

Table 5a. Vector error correction estimates for world crude oil price, Ghana's exchange rates and agricultural food prices

Cointegrating vectors β' and adjustment coefficient α										
	Maize	Rice	Soybean	Beans	Cocoa	Crude Oil	Exchange		β'_1X	β'_2X
β_1	1	0	0.017	-0.523	0.019	0.000	2.339	**Maize (α_1)**	-0.049	0.032
β_2	0	1	-0.295	-0.759	-0.039	-0.001	1.636	**Rice (α_2)**	0.173	-0.180
								Soybean (α_3)	-0.304	0.054
								Beans(α_4)	0.612	0.001
								Cocoa(α_5)	-0.106	0.212
								Crude Oil (α_6)	1.822	7.159
								Exchange (α_7)	0.000	0.003

[1]Since sorghum is stationary in all unit root tests, it is left out of analysis in subsequent sections.

The speed of adjustment for crude oil, α_6 =7.159 to the cointegration vector $\beta_2'X$ was prominent and the highest compared to the other speed of adjustments in the two identified cointegration (CI) equations. This indicates that the cointegration was between world crude oil price, maize, rice, soybeans, beans, cocoa and exchange rate. Also, in the first CI equation, the speed adjustment for world crude oil was α_6 = 1.822, $\beta_1'X$ which was the second highest in the first CI equation. This showed a cointegration between world crude oil prices, exchange rate, prices of maize, soybeans, rice, beans and cocoa respectively in the long-run. The first CI equation witnessed a speed of adjustment following the long run deviation for soybeans and beans at α_3=0.302, α_4= 0.612, as the two strongest in the equation. This was the cointegration equation for soybeans, crude oil price, exchange rate, maize, rice, beans and cocoa. The other cointegrating equation was beans, crude oil price, exchange rate, maize, rice, soybeans and cocoa. This explains that, among the two cointegrating equations, the first CI equation is better and fast towards equilibrium than the second CI equation since the long-run speed of adjustments for the first equation has two insignificant parameter estimates at α_1 = 0.0485 (maize) and α_7 = 0.00025 (effective exchange rate) compared to three insignificant parameter estimates at α_1= 0.0324 (maize), α_4= 0.00054 (beans) and α_7=0.00339 (effective exchange rate) for the second equation.

Restrictions, that is $\beta_{i,j} = \beta_{j,i}$ = 0, were placed on the two cointegrating vectors on the assumption that one or either macroeconomic variables or food prices had no effect on the two cointegrating vectors. This restriction will enhance economic theory against intuitive deductions (Moosa and Vaz, 2016). Two scenarios were observed, indicating diagnostic tests on the exclusion of both food prices and macroeconomic variables **(**Table 5b**)** and the exclusion of food prices in the two cointegration systems. This was to access which of the variables was weakly exogenous and Granger-cause the other.

Table 5b. Diagnostic test on exclusion of food prices and crude oil prices, and exchange rates from cointegration system

[$\beta_{i,j} = 0, \beta_{j,i} = 0$ **]**

Variable	**Chi-Square**	**Pr > ChiSq**	**Decision**
Maize	28.1891	0.0000	Reject
Rice	7.7468	0.0208	Reject
Soybeans	2.4296	0.2950	F.T.R
Beans	16.0964	0.0003	Reject
Cocoa	0.3528	0.8382	F.T.R
World Crude Oil	2.1607	0.3394	F.T.R
Exchange Rates	7.4921	0.0236	Reject

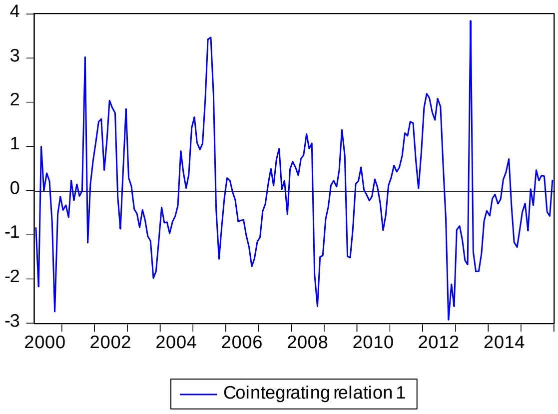
Note: critical value of χ^2 is 5.991. F.T.R= "Fail to Reject"

A normalization process was undertaken for the two scenarios. In that case, $\beta_{i,j}$ in the long-run equilibrium, restrictions on agricultural product prices was equal to -1 against the null hypothesis that is different from 1. Each variable (macroeconomic or food price) was excluded from the cointegration system. A null hypothesis that macroeconomic variables and food prices are not part of the cointegrating system based on a 2 degrees of freedom. We failed to reject the null hypothesis for crude oil price, prices of cocoa and soybeans in scenario 1, that both food prices and macroeconomic variables were excluded from the cointegration system. This explains that prices of crude oil, cocoa and soybeans are not part of the two cointegrating vectors and hence weakly exogenous. This further shows that monthly soybean and beans prices as well as crude oil price influences food prices in Ghana. Results are shown in Table 5b below.

Table 5c. Diagnostic test on exclusion of food prices from cointegration system [$\beta_{i,j}=0,\beta_{j,i}=0$]

Variables	Maize		Rice		Soybean		Beans		Cocoa	
	CI1	**CI2**	**CI1**	**CI2**	**CI1**	**CI2**	**CI1**	**CI2**	**CI1**	**CI2**
Crude Oil $_{t-1}$	4.75E-06	0.00035	0.00176	0.00014	0.002	0.00131	0.001555	0.00094	0.00226	0.00074
Exchange $_{t-1}$	2.76007	-16.982	9.15741	-0.5819	9.1324	-15.021	-2.979	-5.3411	6.21328	-15.519
Chi-Square Statistic ($\chi2$)	28.18909		7.7468		2.42955		16.6096		0.35282	
Prob.	0.000		0.020700		0.296776		0.000247		0.83827	
Decision	Reject		Reject		FTR		Reject		FTR	

Note: CI 1, CI2 represents cointegration equation 1 and cointegration equation 2, respectively



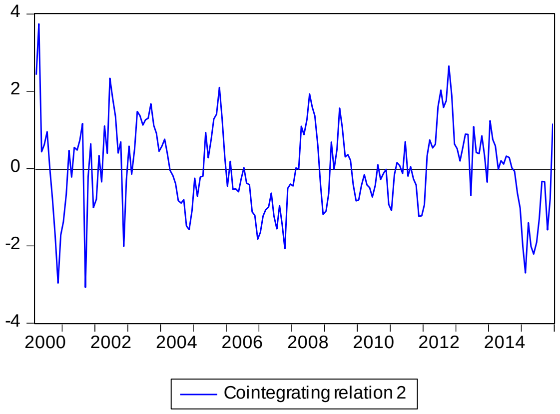


Fig. 3. Cointegration relation graphs

Also, Table 5c showed a rejection of all the macroeconomic variables and showed that except for soybean and cocoa prices, world crude oil price and exchange rate do not directly cause shocks in maize, rice and beans markets but indirectly through close substitutes and complements in Ghana. This is attributed to the international demand for soybeans and cocoa for industrial need. This further explains that, world crude oil price and exchange rate were part of the cointegrating system in the Ghana's grain and cereal markets during 2000 to 2015. The diagnostic test results for weak exogeneity presented in Table 5d failed to reject the null hypothesis for maize, soybean, cocoa, crude oil prices and Ghana's monthly reel effective exchange rate at 5% significance level. This shows that prices of maize, soybean, cocoa, crude oil and effective exchange rate in Ghana were weakly exogenous. It indicates that each of these prices and rate, transmits shocks to prices of rice and rice in Ghana but not otherwise. The result further shows that during 2000 to 2015, prices of maize, soybean, cocoa, crude oil and exchange rate Granger-caused prices of beans and rice in Ghana. This result echoes with the effect of crude oil price and exchange rate on grain prices in the world (Ahmadi, Behmiri and Manera, 2016).

Table 5d. Diagnostic test for weak exogeneity of each variable in long run cointegration [$\alpha_{i,j}=0$]

Variable	Chi-Square	Pr>ChiSq	Decision
Maize	2.4317	0.2965	F.T.R
Rice	8.0524	0.0178	Reject
Soybeans	1.6053	0.4482	F.T.R
Beans	22.1171	0.0000	Reject
Cocoa	3.6492	0.1613	F.T.R
Crude Oil	5.8339	0.0541	F.T.R
Exchange Rate	1.2249	0.5420	F.T.R

Note: critical value of χ_2 is 5.991. F.T.R= "Fail to Reject"

With a 5% level of significance, both crude oil price and effective exchange rate in Ghana restored their long-run equilibrium in an event of speculation, market regulations and externalities. This confirms that macroeconomic variables are exogenous and transmits shocks to food prices in Ghana but food prices except beans and rice do not transmit shocks to macroeconomic variables. This result is in line with finding of Yu, Bessler and Fuller (2006b) that crude oil price is not dependent on food prices. Among food prices, price of beans and rice were identified as exogenous which confirms that most of beans and local rice produced for national nutrition programs, livestock feed and household consumption. Table 5e also displayed parameter estimate results for $\Pi = \alpha\beta'$ in the long run.

Table 5e. Long run parameter estimates $\Pi = \alpha\beta'$

Parameter estimates

	ΔMaize	**ΔRice**	**Δsoybean**	**ΔBeans**	**ΔCocoa**	**ΔCrude Oil**	**ΔExcahnge**
Maize_{t-1}	0.284	-0.153	0.273	-0.405	0.216	1.082	0.001
Rice_{t-1}	-0.146	-0.113	0.162	0.140	-0.171	9.971	0.004
Soybeans_{t-1}	0.015	0.011	-0.337	0.034	-0.005	4.089	0.000
Beans_{t-1}	-0.071	-0.107	-0.242	-0.246	-0.253	-3.639	-0.001
Cocoa_{t-1}	-0.021	0.003	-0.057	-0.006	-0.199	0.331	-0.001
Crude Oil_{t-1}	0.001	0.000	0.000	'0.000	-0.003	0.337	-0.000
Exchange_{t-1}	-0.300	-2.453	2.662	-4.110	-19.74	179.4	-0.153

Furthermore, short run parameter estimates were also reported in Table 5f. These estimates showed a short run relationship between maize, rice, soybeans, beans, cocoa and macroeconomic variables, which is, crude oil price and exchange rates. In the short run, a relationship existed between first lag maize price and current maize price.

Table 5f. Short run parameter estimates

	ΔMaize	**ΔRice**	**ΔSoybeans**	**ΔBeans**	**ΔCocoa**	**ΔCrude Oil**	**ΔExcahngeRate**
ΔMaize_{t-1}	0.3379 (0.0998)***	-0.1151 (0.0731)	0.0128 (0.0309)	-0.1380 (0.0505)**	-0.0243 (0.0162)	0.0017 (0.0006)**	0.1129 (2.0234)
ΔRice_{t-1}	-0.0311 (0.1653)	-0.1705 (0.1212)	-0.0592 (0.0512)	-0.1966 (0.0837)*	-0.0109 (0.0269)	0.0013 (0.0010)	-1.8703 (3.3528)
$\Delta\text{Soybeans}_{t-1}$	0.3681 (0.2646)	-0.0253 (0.1940)	-0.3874 (0.0819)***	-0.1258 (0.1340)	-0.0579 (0.0430)	0.0011 (0.0017)	4.6223 (5.3663)
ΔBeans_{t-1}	-0.2852 (0.2334)	0.1181 (0.1711)	-0.0247 (0.0723)	-0.4519 (0.1182)***	-0.0150 (0.0379)	0.0020 (0.0015)	-4.0783 (4.7335)
ΔCocoa_{t-1}	0.4470 (0.5981)	-0.4132 (0.4385)	-0.1107 (0.1852)	-0.3155 (0.3030)	-0.2481 (0.0972)*	-0.0006 (0.0038)	-19.7616 (12.1324)
$\Delta\text{crude Oil}_{t-1}$	3.2347 (11.7783)	0.8841 (8.6351)	6.2222 (3.6473)	-1.5910 (5.9657)	0.1492 (1.9146)	0.3370 (0.0744)***	249.8225 (238.9130)

Table 5f (Continuous)

ΔExchange Rate $_{t-1}$	0.0008 (0.0040)	0.0011 (0.0029)	0.0016 (0.0012)	0.0016 (0.0020)	-0.0011 (0.0006)	-4.6e-05 (2.5e-05)	-0.1519 (0.0803)
ΔMaize $_{t-2}$	-0.0528 (0.1064)	'0.0133 (0.0757)	-0.0100 (0.0296)	-0.0676 (0.0487)	0.0003 (0.0164)	-0.0007 (0.0006)	0.4530 (2.0193)
ΔRice $_{t-2}$	0.0393 (0.1763)	-0.1491 (0.1254)	-0.0440 (0.0490)	-0.0789 (0.0807)	-0.0039 (0.0272)	-0.0008 (0.0011)	-1.5462 (3.3460)
ΔSoybeans $_{t-2}$	0.3441 (0.2822)	-0.3024 (0.2007)	-0.1351 (0.0784)	0.1804 (0.1291)	-0.0173 (0.0436)	0.0025 (0.0017)	3.7148 (5.3555)
ΔBeans $_{t-2}$	0.1100 (0.2490)	0.0173 (0.1771)	-0.0131 (0.0692)	-0.3171 (0.1139)**	0.0167 (0.0384)	0.0002 (0.0015)	-3.3483 (4.7239)
ΔCocoa $_{t-2}$	0.7566 (0.6381)	-0.4151 (0.4538)	-0.0527 (0.1773)	-0.0870 (0.2919)	-0.1275 (0.0985)	0.0002 (0.0039)	-2.3103 (12.1078)
ΔCrude Oil $_{t-2}$	16.4440 (12.5658)	-25.3793 (8.9365)**	4.0225 (3.4916)	3.2661 (5.7489)	2.8292 (1.9389)	0.1198 (0.0762)	-294.6827 (238.4289)
ΔExchange Rate $_{t-2}$	-0.0015 (0.0042)	-0.0042 (0.0030)	0.0026 (0.0012)*	0.0047 (0.0019)*	-0.0010 (0.0007)	2.3e-06 (2.6e-05)	0.1085 (0.0801)

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

This showed that news, information or speculation from previous month's price of maize transmits shocks to current maize price in Ghana (Amikuzuno, 2010; Isaac, 2012). Also, a short run, a negative relationship was observed between current price of rice and second lag price of crude oil price at 10% indicating that shocks from the previous month's crude oil price transferred negative shocks to current rice price. Current soybean price had negative short run relationships with its own first lag but a positive relationship with second lag exchange rate. That is, news from past soybean price transmits negative shock to current soybean price but news from last two month's value of Ghana cedi against the dollar caused positive shock to current soybean price. This is attributed to the demand for Ghana's soybean on the international market which requires the US dollar. Beans had negative short run relationship with the first lag of maize, rice and its own at 10%, 5% and 1% significant levels respectively. Also, a negative short run relationships were observed between beans and its second lag but positively with the second lag of effective exchange rate at 10% and 5% significance levels, respectively. This confirms the domestic demand for beans as protein supplements in national programs such as the National School Feeding program and hence a strategic food commodity in Ghana.

Cocoa as the key contributor to Ghana's economy (ISSER, 2012) had a negative short run relationship with its own lag price in Ghana. This situation has resulted in an illegal exportation of Ghana's cocoa to neighboring Cote D'Ivoire where cocoa prices are higher than Ghana (Anderson and McTernan, 2014) depending on the previous month's Ghana cocoa price. Monthly crude oil price had a positive short run relationship with the first lag of maize and its first lag at 10% and 1% significance levels. News and information from the previous month's maize and crude oil prices transmits positive shocks to current crude oil prices. Also, only rice price had a short run relationship with crude oil prices and this can be attributed to production and processing of rice which requires crude-related inputs, as such, a change in crude oil price sends negative shocks to rice price in Ghana. Also, importation of agricultural inputs depends on the rate of the Ghanaian cedi against the US$ and this is confirmed by the positive short run relationship between current prices of soybean and beans with second lag exchange rate during 2000 to 2015. This has shifted focus from maize price to close substitutes like beans for domestic consumption and soybean for industrial needs due to biofuel discovery. Biofuel discovery caused demand for maize for ethanol production causing rising food prices (Abbot, Hurt and Tyner, 2011). This confirms a notion that oil prices have effect on food prices in developing countries (Dillion and Barret, 2015). Also, short run relationships are common between food prices in Ghana due to free flow of market information among traders and also due to speculations in the grains and cereals markets. Test results failed to reject a normality assumption and the absence of autocorrelation as a feature for most time series data in the eight equations.

CONCLUSIONS

A weak and indirect relationship exist between world crude oil price, exchange rate and food prices in Ghana in the both long-run and short-run except rice, soybeans and beans. This is attributed to industrial and nutritional demand for soybeans, beans and rice and the labor-demand processing and handling. Past Ghana cedi-US$ exchange rates had direct effect on soybeans and beans and attributed to the importation of production and processing inputs of these commodities. The speculation in prices are partly caused by the discovery of biofuels as alternative source of energy. The indirect shocks from world oil prices, and exchange rates cause by its own lag confirms speculations based on economic theory. The speculations in the past are transmitted to current food prices through processing, handling and transportation cost. The long run relationship among cereals such as rice, soybeans and beans confirms that labor intensive agricultural commodities are indirectly affected by changes in macroeconomic variables. It is also evident that, food prices in Ghana except beans, soybeans and cocoa transmits shocks to other cereals and grain and the reverse. Also, the instability of Ghana's currency against the US$ causes hikes in food prices resulting in inflation. And the most affected is importers of agricultural inputs.

Based on this, government should expand the national food buffer stock policy as an option to minimizing indirect shock from crude oil prices. Also, government should build capacities of producer groups to withhold produce in an event of unstable food prices as short term measure. Subsidy on crude-related products such as fertilizer should be provided to reduce effect of cost of production. Major food commodities such as maize, rice, beans and soybeans are alternative source of ethanol for biofuels, and these commodities should be considered as "sensitive products" to avoid competition between household and domestic usage for biofuel production.

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