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Supply Response of Rice in Ghana: A Co-integration Analysis

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Abstract
This study presents an analysis of the responsiveness of rice production in Ghana over the period 1970-2008. Annual time series data of aggregate output, total land area cultivated, yield, real prices of rice and maize, and rainfall were used for the analysis. The Augmented-Dickey Fuller test was used to test the stationarity of the individual series, and Johansen maximum likelihood criterion was used to estimate the short-run and long-run elasticities. The land area cultivated of rice was significantly dependent on output, rainfall, real price of maize and real price of rice. The elasticity of lagged output (12.8) in the short run was significant at 1%, but the long run elasticity (4.6) was not significant. Rainfall had an elasticity of 0.004 and significant at 10%. Real price of maize had negative coefficient of -0.011 and significant at 10% significance level. This is consistent with theory since a rise in maize price will pull resources away from rice production into maize production. The real price of rice had an elasticity of 2.01 and significant at 5% in the short run and an elasticity of 3.11 in the long run. The error correction term had the expected negative coefficient of -0.434 which is significant at 1%. It was found that in the long run only real prices of maize and rice were significant with elasticities of -0.46 and 3.11 respectively. The empirical results also revealed that the aggregate output of rice in the short run was found to be dependent on the acreage cultivated, the real prices of rice, rainfall and previous output with elasticities of 0.018, 0.01, 0.003 and 0.52 respectively. Real price of rice and area cultivated are significant 10% level of significance while rainfall and lagged output are significant 5%. In the long run aggregate output was found to be dependent on acreage cultivated, real price of rice, and real price maize with elasticities of 0.218, 0.242 and -0.01 respectively at the 1% significance level. The analysis showed that short-run responses in rice production are lower than long-run response as indicated by the higher long-run elasticities. These results have Agricultural policy implications for Ghana.

Key Words: Supply response, Rice, Error Correction Model, Co-integration Analysis, Ghana

1. Introduction

One of the most influential policy prescriptions for low-income countries ever given by development economists has been to foster industrialization by withdrawing resources from agriculture (e.g., Lewis, 1954). There is robust evidence that the majority of policy makers followed this prescription at least until the mid-1980s. The results of a comprehensive World Bank study (Krueger et al., 1992), for example, show for the period 1960 –1985 that in most countries examined, agriculture was taxed both directly via

interventions in agricultural markets and indirectly via overvalued exchange rates and import substitution policies. It is not obvious whether the disincentives for agricultural production have continued to exist since the mid-1980s. On the one hand, most developing countries have adopted structural adjustment programs which explicitly aim at a removal of the direct and indirect discrimination against agriculture. But, on the other hand, it is known that many of these programs were not fully implemented, especially in Sub-Saharan Africa (Kherallah et al., 2000; Thiele and Wiebelt 2000; World Bank, 1997). Hence it can be concluded that a certain degree of discrimination still prevails.

One of the most important issues in agricultural development economics is supply response of crops. This is because the responsiveness of farmers to economic incentives determines agricultures' contribution to the economy especially where the sector is the largest employer of the labour force. This is often the case in third world low income countries. Agricultural pricing policy plays a key role in increasing farm production. Supply response is fundamental to an understanding of this price mechanism (Nerlove and Bachman, 1960).

There is a notion that farmers in less developed countries respond slowly to economic incentives such as price and income. Reasons cited for poor response vary from factors such as constraints on irrigation and infrastructure to a lack of complementary agricultural policies. The importance of non-price factors drew adequate attention in the literature: rainfall, irrigation, market access for both inputs and output, and literacy. The reason cited for a low response to prices in less developed economies is the limited access to input and product markets or high transaction costs associated with their use. Limited market access may be either due to physical constraints such as absence of proper road links or the distances involved between the roads and the markets, or institutional constraints like the presence of intermediaries (Mythili, 2008).

In Ghana, the goals of agricultural price policy are among others fair incomes for farmers, low food prices for urban consumers, cheap raw materials for manufacturing (Ministry of Food and Agriculture (MOFA), 2005). Price support was one policy that was used by government in targeting these goals. Price support has been used in many countries across the world. The prices of major commodities have been set below world prices using subsidies and trade barriers, guaranteed prices (act as floors) and domestic market forces determining actual prices (Food and Agriculture Organization (FAO), 1996). The effect of liberalization on the growth of agriculture crucially depends on how the farmers respond to various price incentives.

For many low-income countries, the impact of structural reforms on economic growth and poverty alleviation crucially depends on the response of aggregate agricultural supply to changing incentives. Despite its policy relevance, the size of this parameter is still largely unknown (Thiele, 2000).

Rice is a very important crop especially for those areas where it is produced. Rice is gradually taking the position as the main staple food for the majority of families in Ghana especially in the urban centres. The growth in consumption of rice has been not been matched with a corresponding growth in local production of the crop. Per capita consumption of rice has steadily increased over the years since the 1980s from about 12.4kg/person /year in 1984 to about 20kg/person /year (Statistical Research and Information Division (SRID), 2005). It continued to rise to 38kg/person/year in 2008 (National Rice Development Policy (NRDP), 2009). Over the last decade rice per capita consumption has increased by more than 35%. This is attributed mainly to the rapid urbanization and changes in food consumption patterns. It is estimated based on population and demand growth rates that per capita consumption will reach 41.1kg by 2010 and 63.0kg by 2015 giving an aggregate demand of 1,680,000tons/year (Statistical Research and Information Division (SRID), 2005). Changes in population dynamics and the taste or preference for foreign products is contributing to this trend. These changes are significant considering the rate of population growth. Ghana's population has grown by about 70% from 12.3 million in 1984 to about 21 million in 2004. The population is now 24 million (Ghana Statistical Service (GSS), 2011).

The growing quantum of rice imports into the country has also been triggered partly by the fall in world market price. This is largely due to increased output levels in India and South Asia. Massive subsidies in rice exporting countries have also contributed to this phenomenon. Despite all these developments there seem to be a lack of coherent and comprehensive national policy for rice in Ghana. From the period of economic recovery and structural adjustment, the country has had to embark on trade liberalization and the removal of all forms of subsidies on agriculture. These policies no doubt have adversely affected rice production in the country. The smallholder rural farmer is faced with unfair competition from abroad. The

role of incentives to farmers has generally been sidelined or ignored in most developing countries due to conditions of trade liberalization and global trade integration. However, a number of empirical studies in other developing economies addressed the question of farmers' response to economic incentives and efficient allocation of resources (e.g. Chinyere, 2009). The agricultural sector in Ghana has undergone various policy regimes which has affected both the factor and product market resulting in changes in the structure of market incentives (prices) faced by farmers. Most of these policies have, however, not been crop specific and therefore has wide variations in the quantum of changes in the incentives. This study therefore follows the supply response framework of analysis to examine the dynamics of the supply of rice in Ghana. Effort in this direction will have to be preceded by a thorough analysis of the factors that affects the supply of rice. These teething problems lead to the following research questions;

How responsive is rice production to price and non-price factors? What are the long run and short run elasticities of rice production? What are the trends in area cultivated, output and real prices of output? Therefore, objective of the study is threefold: (a) Examine the acreage and output response of rice production in Ghana. (b) Estimate and compare the long run and short run elasticities of rice production.

(c) Analyze the trends in output, area cultivated and real prices.

The rest of the paper is structured as follows. Section 2 outlines the methodology. In section 3 we present the empirical applications and the results. Section 4 provides the conclusions.

2.0 Methodology

This section presents the methodology of the study.

2.1 *Linear Regression*

Linear regression was conducted to determine the growth rates of the variables over the study period. Time in years was regressed on acreage cultivated, aggregate output, real price of rice separately.

2.2 *Time series analysis*

In empirical analysis using time series data it is important that the presence or absence of unit root is established. This is because contemporary econometrics has indicated that regression analysis using time series data with unit root produce spurious or invalid regression results (e.g. Townsend, 2001). Most time series are trended over time and regressions between trended series may produce significant parameters with high R^2s, but may be spurious or meaningless (Granger and Newbold, 1974). When using the classical statistical inference to analyze time series data, the results are only stationary when the series are stationary. The solution to this problem was initially provided by Box and Jenkins (1976), by formulating regressions in which the variables were expressed in first difference. Their approach simply assumed that non-stationary data can be made stationary by repeated differencing until stationarity is achieved and then to perform the regression using these differenced variables. However, according to Davidson et al., (1978), this process of repeated differencing even though leads to stationarity of the series; it is achieved at the expense of losing valuable long run information. This posed a new challenge to time series econometrics. The concept of cointegration was introduced to solve these problems (Granger, 1981; Engle and Granger, 1987). By using the method of cointegration an equation can be specified in which all terms are stationary and so allow the use of classical statistical inference. It also retains information about the long run relationship between the levels of variables, which is captured in the stationary co-integrating vector. This vector will comprise the parameters of the long run equilibrium and corresponds to the parameters of the error correction term in the second stage regression (Mohammed, 2005). The cointegration approach takes into consideration the long-run information such that spurious results are avoided.

2.3 *Stationarity Tests*

A data series is said to be stationary if it has a constant mean and variance. That is the series fluctuates around its mean value within a finite range and does not show any distinct trend over time. In a stationary series displacement over time does not alter the characteristics of a series in the sense that the probability distribution remains constant over time. A stationary series is thus a series in which the mean, variance and covariance remain constant over time or in other words do not change or fluctuate over time. In a stationary

series the mean always has the tendency to return to its mean value and to fluctuate around it in a more or less constant range, while a non-stationary series has a changing mean at different points in time and its variance change with the sample size (Mohammed, 2005). The conditions of stationarity can be illustrated by the following:

$Y_t = \theta Y_{t-1} + \mu_t \qquad t=1\ldots\ldots T \qquad (1)$

Where μ_t is a random walk with mean zero and constant variance. If $\theta < 1$, the series Y_t stationary and if $\theta = 1$ then the series Y_t is non-stationary and is known as random walk. In other words the mean, variance and covariance of the series Y_t changes with time or have an infinite range. However Y_t can be made stationary by differencing. Differencing can be done multiple times on a series depending on the number of unit roots a series has. If a series becomes stationary after differencing d times, then the series contains d unit roots and hence integrated of order d denoted as *I* (d). Thus, in equation (1) where $\theta = 1$, Y_t has a unit root. A stationary series could also exhibit other properties such as when there are different kinds of time trends in the variable.

The DF (Dickey-Fuller)-statistic used in testing for unit root is based on the assumption that μ_t is white noise. If this assumption does not hold, it leads to autocorrelation in the residuals of the OLS regressions and this can make invalid the use of the DF-statistic for testing unit root. There are two approaches to solve this problem (Towsend, 2001). In the first instance the equations to be tested can be generalized. Secondly the DF-statistics can be adjusted. The most commonly used is the first approach which is the Augmented Dickey-Fuller (ADF) test. μ_t is made white noise by adding lagged values of the dependent variable to the equations being tested, thus:

$\Delta Y_t = (\theta_1 - 1) Y_{t-1} + \sum_{i=1}^{k} \Phi_I Y_{t-I} + \mu_t \qquad (2)$

$\Delta Y_t = \alpha_2 + (\theta_2 - 1) Y_{t-1} + \sum_{i=1}^{k} \Phi_I \Delta Y_{t-I} + \mu_t \qquad (3)$

$\Delta Y_t = \alpha_3 + \beta_3 t(\theta_3 - 1) Y_{t-1} + \sum_{i=1}^{k} \Phi_I \Delta Y_{t-I} + \mu_t \qquad (4)$

The ADF test uses the same critical values with DF. The results of the ADF test for unit roots for each of the data series used in this study are presented in in the next section using equation (4) where Y_t is the series under investigation, t is the time trend, α_3 is the constant term and μ_t are white noise residuals. Eviews was used in the analysis, all the data series was tested for stationarity and the results are presented in section three.

2.4 *Cointegration*

Cointegration is founded on the principle of identifying equilibrium or long run relationships between variables. If two data series have a long run equilibrium relationship it implies their divergence from the equilibrium are bounded, that is they move together and are cointegrated. Generally for two or more series to be co-integrated two conditions have to be met. One is that the series must all be integrated to the same order and secondly a linear combination of the variables exist which is integrated to an order lower than that of the individual series. If in a regression equation the variables become stationary after first differencing, that is *I* (1), then the error term from the cointegration regression is stationary, *I* (0) (Hansen and Juselius, 1995). If the cointegration regression is presented as:

$Y_t = \alpha + \beta X_t + \mu_t \qquad (5)$

where Y_t and X_t are both *I* (1) and the error term is *I* (0), then the series are co-integrated of order *I* (1,0) and β measures the equilibrium relationship between the series Y_t and X_t and μ_t is the deviation from the long-run equilibrium path. An equilibrium relationship between the variables implies that even though Y_t and X_t series may have trends, or cyclical seasonal variations, the movement in one are matched by movements in the other. The concept of cointegration has implications for economists. The economic interpretation that is accepted is that if in the long-run two or more series Y_t and X_t themselves are non-stationary, they will move together closely over time and the difference between them is constant (stationary) (Mohammed 2005).

2.4.1 *Testing for Cointegration*

There are two most commonly used methods for testing cointegration. The Augmented Dickey-Fuller residual based test by Engle and Granger (1987), and the Johansen Full Information Maximum Likelihood (FIML) test (Johansen and Juselius, 1990). For the purpose of this study the Johansen Full Information Maximum Likelihood test is used due to its advantages. The major disadvantage of the residual based test is

that it assumes a single co-integrating vector. But if the regression has more than one co-integrating vector this method becomes inappropriate (Johansen and Juselius, 1990). The Johansen method allows for all possible co-integrating relationships and allows the number of co-integrating vectors to be determined empirically.

2.4.2 *Johansen Full Information Maximum Likelihood Approach*

The Johansen approach is based on the following Vector Autoregression

$$Z_t = A_t Z_{t-1} + \ldots + A_k Z_{t-k} + \mu_t \quad (6)$$

Where Z_t is an (n×1) vector of *I*(1) variables (containing both endogenous and exogenous variables), A_t is (n×n) matrix of parameters and μ_t is (n×1) vector of white noise errors. Z_t is assumed to be nonstationary hence equation (6) can be rewritten in first difference or error correction form as;

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \pi Z_{t-k} + \mu_t \quad (7)$$

where $\Gamma_1 = -(1 - A_1 - A_2 - \ldots - A_i)$, (i = 1, …, k-1) and $\pi = -(1 - A_1 - A_2 - \ldots - A_k)$.

Γ_1 gives the short run estimates while π gives the long run estimates. Information on the number of co-integrating relationships among variables in Z_t is given by the rank of the matrix π. If the rank of π matrix r, is $0 < r > n$, there are r linear combinations of the variables in Z_t that are stationary. Thus π can be decomposed into two matrices α and β where α is the error correction term and measures the speed of adjustment in ΔZ_t and β contains r co-integrating vectors, that is the cointegration relationship between non-stationary variables. If there are variables which are *I*(0) and are significant in the long run co-integrating space but affect the short run model then equation (7) can be rewritten as:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \pi Z_{t-k} + vD_t + \mu_t \quad (8)$$

where D_t represents the *I*(0) variables.

To test for co-integrating vector two likelihood ratio (LR) tests are used. The first is the trace test statistic;

$$\Lambda_{trace} = -2\ln Q = -T\sum_{i=r+1}^{p} \ln(1 - \lambda_i) \quad (9)$$

Which test the null hypothesis of r co-integrating vectors against the alternative that it is greater than r. The second test is known as the maximal-eigen value test:

$$\Lambda_{max} = -2\ln(Q: r\ 1\ r+1 = -T\ln(1-\lambda_{r+1}) \quad (10)$$

which test the null hypothesis of r co-integrating vectors against the alternative of r+1 co-integrating vectors. The trace test shows more robustness to both skewness and excess kurtosis in the residuals than the maximal eigen value test (Harris, 1995). The error correction formulation in (7) includes both the difference and level of the series hence there is no loss of long run relationship between variables which is a characteristic feature of error correction modeling.

It should be noted that in using this method, the endogenous variables included in the Vector Autoregression (VAR) are all *I*(1), also the additional exogenous variables which explain the short run effect are *I*(0). The choice of lag length is also important and the Akaike Information Criterion (AIC), the Scharz Bayesian Criterion (SBC) and the Hannan-Quin Information Criterion (HQ) are used for the selection.

According to Hall (1991) since the process might be sensitive to lag length, different lag orders should be used starting from an arbitrary high order. The correct order is where a restriction on the lag length is rejected and the results are consistent with theory.

2.5 *Error Correction Models (ECMs)*

The idea behind the mechanism of error correction is that a proportion of disequilibrium from one period is corrected in the next period in an economic system (Engle and Granger, 1987). The process of making a data series stationary is either done by differencing or inclusion of a trend. A series that is made stationary by including a trend is trend stationary and a series that is made stationary by differencing is difference stationary. The process of transforming a data series into stationary series leads to loss of valuable long run information (Engle and Granger, 1987). Error correction models helps to solve this problem.

The Granger representation theorem is the basis for the error correction model which indicates that if the variables are cointegrated, there is a long-run relationship between them and can be described by the error correction model. The following equation shows an ECM of agricultural supply response involving the variables Y and X in its simplest form:

$\Delta Y_t = \alpha \Delta X_t - \theta(Y_{t-1} - \gamma X_{t-1}) + \mu_t$ (11)

Where μ_t is the disturbance term with zero mean, constant variance and zero covariance. Parameter α takes into account the short run effect on Y of the changes in X, while γ measures the long-run equilibrium relationship between Y and X that is:

$Y_t = \gamma X_t + \mu_t$ (12)

Where $Y_{t-1} - \gamma Y_{t-1} + \mu_{t-1}$ measures the divergence (errors) from long-run equilibrium. Also θ measures the extent of error correction by adjustment in Y and its negative sign indicates that the adjustment is in the direction which restores the long-run relationship (Hallam and Zanoli, 1993). In order to estimate equation (5), Engle and Granger (1987) proposed a two stage process. Firstly the static long run cointegration regression (6) is estimated to test cointegration between the two variables. If cointegration exists the lagged residuals from equation (5) are used as error correction term in the Error Correction Model (in equation 6) to estimate the short run equilibrium relationship between the variables in the second stage. The validity of the Error Correction Models (ECMs) depends upon the existence of a long-run or equilibrium relationship among the variables (Mohammed, 2005).

The Error Correction Model (ECM) has several advantages. It contains a well-behaved error term and avoids the problem of autocorrelation. It allows consistent estimation of the parameters by incorporating both short-run and long-run effects. Most importantly all terms in the ECM are stationary. It ensures that no information on the levels of the variables is lost or ignored by the inclusion of the disequilibrium terms (Mohammed, 2005). ECM solves the problems of spurious correlation because ECMs are formulated in terms of first difference which eliminates trends from the variables (Ganger and Newbold, 1974). It avoids the unrealistic assumption of fixed supply based on stationary expectations in the partial adjustment model.

2.6 *Supply Response Models*

This study estimated the total area cultivated and aggregate output of rice in Ghana using double logarithmic regression models.

Area cultivated of rice (lgarea) is a function of own price (Lrp), rainfall (lgrain), aggregate output (lgoutput) and price of maize (lmp). The equation used for the regression is:

$Lgarea = f_1 (Lgoutput, Lrp, Lgrain, Lmp)$ (13)

Aggregate output of rice (lgoutput) is a function of the area cultivated (lgarea), the price of rice (Lrp), price of maize (Lmp), rainfall (lgrain). The estimating equation is:

$Lgoutput = f_2 (lgrain, Lrp, Lmp, Lgarea)$[1]. (14)

3. Empirical Application and Results

3.1 *Results for linear regression*

Table 1: The results of the regression analysis for the trend of the variables against time

Variable	Coefficient	Std error	t-statistic	R^2	F-statistic	Prob
Lgarea	1.334274	1.149167	1.61079	0.035154	0.253046	0.2530
Lgoutput	-13.86625	68.09380	-0.20364	0.005889	0.844432	0.8444
lgyield	-25.99348	35.51112	-0.73198	0.071100	0.487957	0.4880
Lrp	2.588941	5.221601	4.956136	0.399186	24.58311	**0.0000**

As can be seen from table 1 the results indicated that the regression for area, output and yield turned out insignificant. Only the trend of real price of rice was significant at 1% significance level. Real rice price yielded a positive coefficient of 2.589 which implies that for each year the real price of rice grew by 2.589 units.

3.2 *Unit Root Test Results*

As a requirement for cointegration analysis the data was tested for series stationarity and to determine the order of integration of the individual variables. For cointegration analysis to be valid all series must be integrated of the same order usually of order one (Towsend, 2001). Eviews was used to perform these tests.

[1] Price of maize is included because we assume that the same resources (land type, fertilizer etc.) can be used to produce both maize and rice. Hence, a rise in the price of maize will pull resources away from rice production to maize production.

The data series on annual acreage cultivated (Lgarea), aggregate output (Lgoutput), aggregate yield (Lgyield), real price of rice (Lrp), real price of maize (Lmp), rainfall (Lgrain) was tested for unit root for the study period 1970 - 2008. The Augmented Dickey-Fuller test was used for this test. The results are presented below.

Table 2: Results of unit root test at levels

Series	ADF test statistic	Mackinnon critical value	Lag-length	Prob	Conclusion
Lgarea	2.221125	3.615588	2	0.2024	Non-stationary
Lgoutput	1.519278	5.119808	2	0.4582	Non-stationary
Lgyield	0.103318	4.580648	2	0.9419	Non-stationary
Lmp	0.378290	3.621023	2	0.9026	Non-stationary
Lrp	1.429037	3.615588	2	0.5579	Non-stationary
Lgrain	3.006033	2.963972	7	0.0457	Stationary

The results of the unit root test after first differencing are presented in table 3.

Table 3: Results of unit root test at first differences

Series	ADF test statistic	Mackinnon critical value	Lag-length	Prob	Conclusion
Lgarea	7.517047	3.621023	2	0.0000	I(1)
Lgoutput	9.577098	3.621023	2	0.0000	I(1)
Lgyield	7.517047	3.621023	2	0.0000	I(1)
Lmp	10.02189	3.621023	2	0.0000	I(1)
Lrp	6.346392	3.626784	2	0.0000	I(1)

Note; All variables are in log form. The ADF method test the hypothesis that $H_0 : X \sim I(1)$, that is, has unit root (non-stationary) against $H_1 : X \sim I(0)$, that is, no unit root (stationary). The Mackinnon critical values for the rejection of the null hypothesis of unit root are all significant at 1%. Lgarea denotes log of area cultivated, Lgoutput denotes log total output, Lgyield denotes log of yield, Lmp denotes log of maize price, Lrp denotes log of rice price and Lgrain denotes log of rainfall.

The results of the unit root tests showed that all the series are non-stationary at levels except for rainfall which is stationary at levels as shown in table 2 above. However as expected all the non-stationary series became stationary after first differencing. From table 2 the null hypothesis of unit root could not be rejected at levels since none except rainfall of the ADF test statistics was greater than the relevant Mackinnon Critical values. Hence the null of the presence of unit root is accepted.

However the hypothesis of unit root in all series was rejected at 1% level of significance for all series after first difference since the ADF test statistics are greater than the respective Mackinnon critical values as shown in table 3 above.

3.3 *Cointegration Results*

When the order of integration of the data series have been established, the next step in the process of analysis is to determine the existence or otherwise of cointegration in the series. This is to establish the existence of valid long-run relationships between variables. Basically there are two most commonly used methods to test for cointegration. These were suggested by Engle and Granger (1987) and Johansen and Juselius (1990). This study applies the Johansen approach which provides likelihood ratio tests for the presence of number of co-integrating vectors among the series and produces long-run elasticities. The Error correction model was then used to estimate short-run elasticities.

3.3.1 *Supply Response of Rice Output*

Firstly, the Vector Error Correction Modeling (VECM) procedure using the Johansen method involves defining an unrestricted Vector Autoregression (VAR) using the following equation.

$$Z_t=A_tZ_{t-1}+\ldots+A_kZ_{t-1}+\mu_t \quad (15)$$

Likelihood Ratio (LR) tests were conducted with maximum of three lags due to the short time series. The results are shown in table 4.

Table 4: Results for lag selection output model

VAR Lag Order Selection Criteria
Endogenous variables: OUTPUT AREA MP RP
Exogenous variables: C RAIN

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1208.968	NA	6.64e+32	86.92626	87.30689*	87.04262
1	-1184.928	37.77692	3.84e+32	86.35198	87.49387	86.70107
2	-1174.563	13.32579	6.37e+32	86.75452	88.65766	87.33633
3	-1138.068	36.49514*	1.92e+32*	85.29058*	87.95499	86.10511*

* 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
LogL: Log-likelihood

The results indicate that the Akaike Information Criterion (AIC) and the Hannan-Quin information criterion (HQ) selected lag order three while the Scharz Bayesian Criterion (SBC) selected the lag order zero. Thus, this study selects the lag order three as the order for the VAR models. The next step in the Johansen method is to test for the number of co-integrating vectors among the series in the model.

The results for the cointegration test imply that both the trace test and the maximum eigen value test selects the presence of one co-integrating vector, thus it can be concluded that the variables in the model are co-integrated. The Johansen model is a form of Error Correction Model. When only one co-integrating vector is established its parameters can be interpreted as estimates of long run co-integrating relationship between the variables (Hallam and Zanoli, 1993). This implies that the estimated parameter values from this equation when normalized on output are the long run elasticities for the model. Eviews automatically produces the normalized estimates. These coefficients represent estimates of long-run elasticities with respect to area cultivated, real price of rice and real price of maize. The normalized cointegration equation for rice output is given below;

$$Output=0.216748area+0.241522rp-0.009975mp-12841.69 \quad (16)$$

Since cointegration has been established among the variables, then the dynamic ECM can be used for supply response analysis since it provides information about the speed of adjustment to long run equilibrium and avoids the spurious regression problem between the variables (Engle and Granger, 1987).

The ECM for rice output is presented as;

$$\Delta output = \alpha_0+\sum_1^3 \alpha_{1i}\Delta output_{t-i} + \sum_1^3 \alpha_{2i}\Delta area_{t-i} + \sum_1^3 \alpha_{3i}\Delta rp_{t-I} + \sum_1^3 \alpha_{4i}\Delta mp_{t-I} + \alpha_5 rain - \theta EC_{t-I} \quad (17)$$

Where $\theta EC_{t-I} = \alpha (\beta_1 output_{t-I} - \beta_2 area_{t-I} - \beta_3 rp_{t-I} - \beta_4 mp_{t-I})$

In the ECM model above, the α's explain the short run effect of changes in the explanatory variables on the dependent variable whereas β's represent the long run equilibrium effect. θEC_{t-I} is the error correction term and correspond to the residuals of the long run cointegration relationship, that is the normalized equation (16). The negative sign on the error correction term indicates that adjustments are made towards restoring long run equilibrium. This representation ensures that short run adjustments are guided by and consistent with the long run equilibrium relationship. This method provides estimates for the short run elasticities, that is the coefficients of the difference terms and, whereas the parameters from the Johansen cointegration regression are estimates of the long run elasticities (Townsend and Thirtle, 1994). In selecting the best ECM estimates, models with lag lengths are estimated and those with insignificant parameters are eliminated.
Note that the estimates presented above represent the short run effect of the explanatory variables on the dependent variable. The long run effect is captured by the estimates of the normalised Johansen regression results presented in equation (16). The diagnostic tests are the t-ratio test of the coefficients, LM test for autocorrelation and the Jarque Berra test for normality of residuals.

Table 5: ECM results for rice output

Variable	Coefficient	t-statistic	Prob
Δlgarea	**0.017611**	0.668907	**0.0510**
Δlgoutput(-1)	**0.523393**	2.283959	**0.0319**
lgRain	**0.003740**	0.997918	**0.0328**
Δlgmp	-0.001107	-0.298174	0.7683
Δlgrp	**0.009922**	0.307758	**0.0761**
Residual	**-0.174253**	-1.321005	**0.0043**
R^2 (0.754242)	F-statistic (2.523411)	Prob(F-stat) **0.058261**	

It indicates that aggregate rice output is dependent on area cultivated, previous year's output, and previous year's price of rice. The coefficient of maize price was not significant.
An R^2 of 0.754 indicates that 75% of the variation in the dependent variable can be accounted for by variation in the explanatory variables. The results indicate that area cultivated was significant at 10%, with elasticity of 0.0176, which implies that a one percent increase in area cultivated of rice will lead to a 0.018 % increase in output in the short run. This is rather on the low side. This can be attributed to the fact that an increase in the land cultivated without a necessary increase in the resources of the farmer will increase adverse effect on the minimal resources available to the farmer hence resulting in this marginal increase in output. This result also indicates that the productivity of the farmer reduces with increase in farm size. The long run elasticity of area cultivated is 0.2167 (in equation (16)) is higher than the 0.0176 for the short run. This indicates that over the long run farmers adjust their farm sizes more to output than in the short run. That is, a 1% increase in area cultivated will lead to 0.217% increase in output in the long run.
Lagged output has elasticity of 0.523393 in the short run and is significant at the 5% significance level implying that a one percent increase in output in a year will lead to a 0.52% increase in output the subsequent year. This simply means that an increase in output will make capital available for the farmer to invest in the subsequent year's rice production activities. This is only true if the additional resource is invested into the following year's rice production activities.
Rainfall is significant at 5%. An elasticity of 0.003740 for rainfall indicates that a 1% increase in rainfall will result in a 0.004% rise in output. This low impact of rainfall can be explained by the fact that a large proportion of total rice output is produced under the irrigation projects across the country. This makes the response of output to rainfall highly inelastic.
A coefficient of 0.009922 which is significant at 10% for real price of rice indicates that a 1% rise in real

prices will lead to 0.01% increase in output the subsequent year in the short run. This makes prices also inelastic. This low rice price elasticity suggests that farmers do not always necessarily benefit from increasing prices due to the structure of the marketing system. Middlemen and other marketing channel members purchase the rice from farmers at the farm gate and thereafter transport it to market centres to be sold. Hence when there is a rise in prices a little fraction of it is transmitted to the famer. The low price elasticity could also be attributed to the fact that farmers are hindered by an array of constraints such as land tenure issues, rainfall variability, lack of capital resources and credit facilities which limits their capacity to respond to price incentives. The long run coefficient of 0.2415 indicates that 1% percent increase in real prices will lead to a 0.24% increase in output. The long run elasticity far exceeds the short run. This is because over the long run when prices show a continual rise, farmers are able to accumulate capital enough to enhance production.

The residual which is the error correction term is significant at 1% and has the expected negative sign. It measures the adjustment to equilibrium. Its coefficient of -0.174 indicates that the 17.4% deviation of rice output from long run equilibrium is corrected for in the current period. This slow adjustment can be attributed to the fact that famers in the short run are constrained by technical factors as mentioned earlier which limits their ability to adjust immediately to price incentives.

In the long run maize price is significant at 1%. With a negative coefficient of 0.009975 it implies that a 1% increase in the price of maize will lead to 0.01% reduction in the output of rice. This is to say that resources will be diverted to maize production relative to rice production leading to the fall in rice output. However, Maize price was not significant in the short run. The results of the LM test of serial correlation for up to fifth order show that there is no serial correlation in the data set.

3.3.2 *Supply Response of Area Cultivated*

Testing for the selection of lag length yielded the same results for both the acreage and output models. Hence the same lag order three is therefore used for the Vector Error Correction model (VEC).

The trace test selects one co-integrating vector while the eigen value test selects two co-integrating vectors. But since the trace test is the more powerful test (Mohammed, 2005), the result from the trace test is used here. Thus the acreage model has one co-integrating vector. The normalised cointegration equation for area cultivated is given as;

$$\text{lgarea} = 4.613649\text{lgoutput} + 3.11429\text{lrp} - 0.46020\text{lmp} - 59247 \quad (18)$$

The ECM for area cultivated is presented as;

$$\Delta\text{lgarea} = \alpha_0 + \sum_1^3 \alpha_{1i}\, \Delta\text{lgoutput}_{t\text{-}i} + \sum_1^3 \alpha_{2i}\, \Delta\text{lgarea}_{t\text{-}i} + \sum_1^3 \alpha_{3i}\, \Delta\text{lgrp}_{t\text{-}I} + \sum_1^3 \alpha_{4i}\, \Delta\text{lgmp}_{t\text{-}I} + \alpha_{5l}\, \text{lgrain} - \theta EC_{t\text{-}I} \quad (19)$$

Where $\theta EC_{t\text{-}I} = \alpha(\beta_1 \text{area}_{t\text{-}I} - \beta_2 \text{output}_{t\text{-}I} - \beta_3 \text{rp}_{t\text{-}I} - \beta_4 \text{mp}_{t\text{-}I})$

The result of the estimated ECM is given in table 6 below.

Table 6: ECM results for area cultivated

Variable	Coefficient	t-statistic	Prob
Δlgarea(-1)	0.169747	1.343021	0.1192
Δlgoutput(-1)	**12.80810**	1.816372	**0.0824**
lgRain	**0.003984**	0.138622	**0.0891**
Δlmp(-1)	**-0.011350**	-0.401819	**0.0691**
Δlrp(-1)	**2.016747**	1.440683	**0.0265**
Residual	**-0.435411**	-1.043641	**0.0047**
R^2 (0.770669)	F-statistic (1.707148)	Prob(F-stat) **0.017301**	

An R^2 of 0.77067 indicates that 77% 0f the variation in the dependent variable is accounted for by variation in the explanatory variables. Output is significant at 10% with an elasticity of 12.80 indicating that a 1% increase in output this year will increase land cultivated in the subsequent year by 12.8% in the short run. Thus acreage cultivated is highly elastic with respect to output. An increase output level gives the farmers an opportunity to acquire necessary resources and equipment to put more land under cultivation. Output

elasticity is even higher than that for real prices. This can be attributed to the fact that a large proportion of output is for household consumption and thus is independent of prices. Increased output alone is enough motivation to increase acreage under cultivation. In the long run output is insignificant. This because in the long run land will get exhausted and output will be dependent on productivity (and not the area of land cultivated).

Rainfall is significant at 10% with a coefficient of 0.003984; this implies a 1% increase in rainfall leads to 0.004% increase in area cultivated. This low response to rain can be attributed to the fact that large areas under rice cultivation are in irrigated fields which depends less on rainfall for cultivation. Rainfall is an exogenous variable ($I(0)$), hence it measures short run effect.

Maize price is significant at 10% with a negative coefficient of -0.011350 in the short run and -0.460 in the long run. This means over the long run if maize prices are continually increasing farmers will commit more resources into maize farming relative to rice farming. Thus as the price of maize rises area under rice cultivation reduces both in the short and long run. In the short run a 1% increase in maize price reduces area cultivated of rice by 0.0114% and by 0.46% in the long run.

Real price of rice was significant at 5% with elasticities of 2.017 and 3.11 in the short run and long run respectively, thus price is elastic. This implies a 1% percent increase in real price of rice will result 2.017% and 3.11% increase in acreage cultivated in the short run and long run respectively. This is expected since in the long run farmers are able to adjust to overcome some the major challenges of production and hence are able to adjust more to price incentives.

The error correction term has the expected negative sign and with a coefficient of 0.4354 indicating that 43.54% of the deviation from long run equilibrium is corrected for in the current period.

The results of the test for serial correlation show that is no autocorrelation in the series. The Jarque-Berra test statistic of 10.18 with probability value of 0.25 implies that the residuals are normally distributed.

4. Conclusions

Economic theory in the past had been based on the assumption that time series data is stationary and hence standard statistical techniques (Ordinary Least Squares regression (OLS)) designed for stationary series was used. However, it is now known that many time series data are non-stationary and therefore using traditional OLS methods will lead to invalid or spurious results. To address this problem, the method of differencing was introduced. Differencing according to Granger however leads to loss of valuable long-run information. Granger and Newbold (1974) introduced the technique of cointegration which takes into account long-run information therefore avoiding spurious results while maintaining long-run information.

This study presents an analysis of the responsiveness of rice production in Ghana over the period 1970-2008. Annual time series data of aggregate output, total land area cultivated, yield, real prices of rice and maize, and rainfall were used for the analysis.

The Augmented-Dickey Fuller test was used to test the stationarity of the individual series. The Johansen maximum likelihood criterion is used to estimate the short-run and long-run elasticities.

The trend analysis for rice output, rice price, acreage cultivated, and yield revealed that only rice price is significant at 1% significance level. The results imply that for each year, the price of rice will increase by 2.589 units.

All the time series data that was used were tested for unit root. They were found to be non-stationary at levels but stationary after first differencing at the one percent significance level except for rainfall which was stationary at levels at the 5% significance level. The Likelihood Ratio tests selection of lag order selected order three by the AIC and HQ criteria for both models. The Johansen cointegration test selected one cointegration vector (in both rice output and rice price models) indicating that the variables are co-integrated. The diagnostic tests of serial correlation and normality test was done using the Lagrange Multiplier test for autocorrelation and the Jarque-Berra test for normality of residuals. The results indicate no serial correlation and normally distributed residuals.

The land area cultivated of rice was significantly dependent on output, rainfall, real price of maize and real price of rice. The elasticity of lagged output was 12.8 in the short run and was significant at 1%. However, this elasticity was not significant in the long run.

Rainfall had an elasticity of 0.004 and significant at 10%. Also real price of maize had negative coefficient of -0.011 which was significant at 10%. This is consistent with theory since a rise in maize price will pull

resources away from rice production into maize production. The coefficient of the real price of maize estimated by Chinere (2009) was -0.066 for rice farming in Nigeria. This is higher than the -0.011 estimated for Ghana (in this study).

The real price of rice had an elasticity of 2.01 and significant at 5% in the short run and an elasticity of 3.11 in the long run. The error correction term had the expected negative coefficient of -0.434 which is significant at 1%. It was found that in the long run only real prices of maize and rice were significant with elasticities of -0.46 and 3.11 respectively. The error correction estimated by Chinere (2009) was -0.575. This indicates that adjustment to long run equilibrium is faster in Nigeria. This could be attributed to better agricultural infrastructure in Nigeria compared to Ghana. The error correction for Indian rice in the rice zone as estimated by Mohammed (2005) was -0.415. This could be attributed to the fact that Indian agriculture was highly constrained by land problems hence leaving room for little adjustments in terms of increasing acreage cultivated.

The aggregate output of rice in the short run was found to be dependent on the acreage cultivated, the real prices of rice, rainfall and previous output with elasticities of 0.018, 0.01, 0.004 and 0.52 respectively. Real price of rice and area cultivated are significant 10% level of significance while rainfall and lagged output are significant 5%. In the long run aggregate output was found to be dependent on acreage cultivated and the real price of rice and real price maize with elasticities of 0.218, 0.242 and -0.01 respectively at the 1% significance level.

Mythili (2008) used panel data to estimate the supply response of Indian farmers. His findings also support the view that farmers' response to price is low in the short-run and their adjustment to reaching desired levels is low for food grains.

The analysis showed that short-run response in rice production is lower than long-run response as indicated by the higher long-run elasticities. This is because in the short run the farmers are constrained by the lack of resources needed to respond appropriately to incentives. In the short-run inputs such as land, labour, and capital are fixed. To address these concerns government should devise policies to make land available to farmers so that prospective farmers could increase acreage cultivated. More irrigation facilities should be constructed to put more land under cultivation.

It was also observed that the acreage model had higher elasticities than the output model. Thus farmers tend to increase acreage cultivated in response to incentives. This implies that farmers have more control over land than the other factors that influence output.

Efforts should be put in place to make the acquisition of inputs such as tractors and fertilizer more accessible and affordable to farmers, and to improve the road network linking farming communities and the urban centres.

Price control policy should be introduced and enforced to address the problem of frequent price fluctuation which is the main reason for the low response to prices. Since farmers are aware of these price fluctuations they are reluctant to immediately respond positively to price rises.

Though there is a market for rice in Ghana, recent developments have shown that consumers prefer foreign polished rice; therefore, government should put in place the needed infrastructure to process the locally produced rice to ensure the sustainability of local rice production.

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