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Greenhouse Gas Emission Reduction in Agriculture: A Situation for Africa

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Abstract:

This work was analysed adopting a time series panel data analysis from the period 1995 to 2014. A unit root test was carried out on all the variables in order to ascertain its stationarity and it was found that the variables were integrated of order I(1) and I(0). After the cointegration test, it was discovered that the variables were cointegrated, so it became necessary to conduct a VECM analysis and affirmed that agriculture (AGRIC) was positive to food security (FPI).

Apart from AGRIC which had a causality running from AGRIC to FPI, it further affirmed from a causality test that there is bi-directional causality from the variables AGRIC, GHG, FPI GRANT. Bi-directional causality was found between AGRIC, GHG and GRANT.

The resilient nature of the sector is evident in its ability to offer food security quickly than other means, from shocks resulting from disruptive events e.g GRANT etc. We also found that incentive (GRANT) contributed little to AGRIC, but had a positive contribution to FPI in these countries. This shows the importance of GRANT to FPI and lack of attention or investment to the sector.

Therefore, increased efforts in creating more incentives which will contribute positively towards the reduction of gas emission in agriculture should be very important to all in Africa.

Keywords: Agriculture production (AGRIC), Food production index (Food security), Greenhouse gas emission (GHG), Grant (GRANT/Incentive), Gross capital formation (GCF), Response to shocks, Granger causality tests, unit root test, cointegration test, VECM.

1.1 Introduction

A lot of linkages have been found to exist between agriculture and climate change. On one hand, global agriculture is affected by climate change that could significantly impact productivity, especially in the tropics (Lobell et al 2011, Challinor et al 2014, Rosenzweig et al 2014). According to (Kreidenweis et al 2016, Popp et al 2017), large-scale afforestation and biomass for energy production as well as population and income growth will exacerbate the competition for land. This raises challenges for the sufficient provision of food and biomass for a growing and richer world population with different dietary and energy demands and requires adaptive action and climate change mitigation (Wheeler and von Braun 2013, Leclere ` et al 2014, Hertel 2015). On the other hand, agriculture is an important contributor to climate change, accounting directly for 10%–12% of anthropogenic greenhouse gas (GHG) emissions and also for around 70% of land use change emissions, mainly through deforestation (Hosonuma et al 2012, IPCC 2014, Tubiello et al 2015). Thus, the agricultural sector has to be an integral part of any global strategy to stabilize the climate.

Despite the need to stabilize the climate by achieving net negative emissions by the end of the century (IPCC 2014, Schleussner et al 2016), a major concern about implementing mitigation requirements in agriculture is that this could limit the potential for the increase of food and biomass supply and the continued support of rural livelihoods in the decades ahead (Smith et al 2013, Hasegawa et al 2015, Herrero et al 2016). Cost-efficient distribution of mitigation efforts across regions and sectors is typically calculated in integrated assessment models using a global uniform carbon price (IPCC 2014). However, such a uniform carbon price would, in reality, lead to substantial impacts on food availability (Golub et al 2013, Hasegawa et al

2015, Havl´ık et al 2015). A particular concern is the impact on food security if climate mitigation targets were also to encompass the agricultural sector in vulnerable regions of the world (FAO 2009). Mitigation requirements would affect food availability via (i) diversion of land from food to energy uses, (ii) limited land availability for agricultural expansion due to the need for avoided conversion of high carbon landscapes, (iii) shift towards less GHG-intensive agricultural commodities i.e. away from ruminant production, and (iv) adoption of GHG-efficient management practices that may either directly (i.e. reduced fertilizer application, reduced livestock density) or indirectly (i.e. increased production costs) impact product prices and food production (Smith et al 2013, Havl´ık et al 2014, Hertel 2015, Searchinger et al 2015, Kreidenweis et al 2016, Popp et al 2017).

Hence, to distribute efforts across sectors and regions, other aspects besides cost-efficiency i.e. equity should be considered (Hohne ¨ et al 2014, Tavoni et al 2015) to determine how to best meet policy objectives in addition to climate change mitigation. Proposed mechanisms for enabling development in Africa under mitigation include climate finance, low emissions development, exempting countries below a given emissions threshold from mitigation requirements (Chakravarty et al 2009, Wollenberg et al 2016) and 'win-win' mitigation options i.e. soil carbon (SOC) sequestration or sustainable intensification (Smith et al 2008, Tilman et al 2011, Valin et al 2013) that both reduce agricultural emissions and increase food production. SOC sequestration through improved crop- and grassland management offers the possibility to sequester significant amounts of carbon in the soil, while at the same time improving soil quality and productivity, and subsequently food security (Lal 2010, Smith et al 2013, Paustian et al 2016). For example, the French government proposed in the '4 per 1000, Soils for Food Security and Climate' initiative (www.4p1000.org) to offset global anthropogenic GHG emissions by increasing the SOC content of soils annually by 0.4% through improved farming and forestry practices. However, despite the potential for climate change mitigation, SOC sequestration is currently not considered in global climate stabilization scenarios (Fuss et al 2016, Smith 2016). Concerns about the length of time required building up SOC, the reversibility of sequestered carbon, competition for soil inputs and difficulties of detecting improvements have limited attention to SOC thus far.

In the light of the issues discussed, this paper seeks to explore the response of agriculture to shocks in investment, determine the response of food security to shock in agriculture and shocks in grant and finally the causality between gas emission and food security.

2.1 Review of Relevant Literature

According to (Rosenzweig et al. 1992), climate change is expected to result in long-term water and other resource shortages, worsening soil conditions, drought and desertification, disease and pest outbreaks on crops and livestock, sea-level rise and so on. Vulnerable areas are expected to experience losses in agricultural productivity, primarily due to reductions in crop yields. Increasing use of marginal land for agriculture (especially among smallholder farms) is anticipated as the availability and productivity potential of land begin to decline. In contrast, climate change is also expected to result in some beneficial effects, particularly in temperate regions (Mendelsohn et al. 1999). (Intergovernmental Panel on Climate Change (IPCC) 1996; Bindi and Olesen 2000) lengthening of growing seasons, carbon fertilization effects, and improved conditions for crop growth are forecast to stimulate gains in agricultural productivity in high-latitude regions, such as in northern China and many parts of northern America and Europe. Consequently, the likely impacts of climate change on the agricultural sector have prompted concern over the magnitude of future global food production. Early global estimates predict (without consideration of CO2 fertilization effects or adaptation) a 20–30 percent reduction in grain production (Darwin and others 1995). Based on agronomic research in low latitude countries, Reilly and others (1994, 1996) approximate global welfare changes in the agricultural sector (without adaptations) between losses of US$61.2 billion and gains of US$0.1 billion. This is in contrast to losses of US$37 billion to gains of US$70 billion with appropriate adaptations in place. In recent studies, CO2 fertilization impacts and adaptation suggest that global agricultural supply is likely to be robust in the face of moderate warming. Under the most severe scenarios of climate change, however, significant losses are expected worldwide (see also studies by Fischer and others (1993, 1996; see also Rosenzweig and others 1993; Rosenzweig and Parry 1994); Darwin and others (1995, 1996); Tsigas and others (1996); Adams and Hurd 1999; Reilly 1999; Rosenzweig 2000).

Given the range of warming predicted by the scientific community, regional and local variation in impacts on the agricultural production is likely to be high. However, a rapidly emerging consensus is that the worst impacts will be in tropical regions (Rosenzweig and others 1993; Mendelsohn 2000; IPCC 2001; Sachs 2003. As a result, experts predict a spatial shift of crops and agricultural practices away from the tropics toward the temperate and polar regions (IPCC 2001). Early estimates suggest 4–24 percent losses in production in the developed countries, and 14–16 percent losses in developing countries (IPCC 1996). In particular, it is anticipated that adverse impacts on the agricultural sector will exacerbate the incidence of rural poverty. Impacts on poverty are likely to be especially severe in developing countries where the agricultural sector is an important source of livelihood for a majority of the rural population. In Africa, estimates indicate that nearly 60–70 percent of the population is dependent on the agricultural sector for employment and the sector contributes on average nearly 34 percent to gross domestic product (GDP) per country. In the West African, more than 80 percent of the population is involved in agriculture and stock-farming in rural areas and the two sectors contribute approximately 35 percent of the countries' GDPs (Mohamed and others 2002). With lower technological and capital stocks, the agricultural sector in such poorer developing countries is unlikely to withstand the additional pressures imposed by climate change without a concerted response strategy (Crosson 1997). According to some estimates, the overall economic impact of climate change on the agricultural sector could be up to 10 percent of GDP (Hernes and others 1995; IPCC 2001).

As research on the spatial variation in climate change and its subsequent impacts mounts, it is becoming increasingly apparent that both across and within regions vulnerability to climate impacts will be diverse. Another expectation is the high cost of mal-adaptation, where policies to address climate change are not fully implemented or are poorly designed. In developing countries, the expansion of human settlements to marginal land and hazardous areas such as deltas and low-lying coastlines and other climate-sensitive areas has no doubt contributed to worsening the expected problems (Burton 2001). In short, it is apparent that some communities will be better equipped and positioned to deal with the many possible outcomes associated with sudden or gradual climate scenarios.

In order to address the expected pressures on the agricultural as well as other economic sectors, policymakers have thus far largely focused on addressing climate change through mitigation of human-induced emissions of greenhouse gases and sequestration of carbon. However, it is becoming widely accepted that mitigation alone is unlikely to be sufficient as a climate policy (Pielke 1998). As understanding improves of the workings of ecosystems and socioeconomic systems function and the extent of their likely resilience to climatic stimuli, there is an intensive push for contemporary policy dialogue to complement mitigation initiatives with adaptation policies as another key defence against climate change. The recognition that some countries (especially the developing countries and particularly, the poorest segments of society within countries), will not be able to avoid the impacts of climate change, has added impetus to promoting adaptation (Burton 2001). In addition, under-preparedness to increased frequency or lengthening of periods of drought, higher temperatures and climate variability (for example, extreme events) can be prohibitively costly and can severely undermine expensive long-term investments.

A lot of studies have consequently emphasized the need to pursue adaptation in addition to mitigation strategies. The Intergovernmental Panel on Climate Change (IPCC) notes that adaptability through changes in “processes, practices or structures” is a crucial element in reducing potential adverse impacts or enhancing beneficial impacts of climate change (IPCC 2001). Adaptation is regarded as a vital component of climate change impacts and vulnerability assessment (Skinner and others 2001). In the context of development, Burton (1996) asserts that a practical response strategy is to improve adaptation to climate variability, including extreme events. Smith (1997) maintains that adaptation is necessary to avoid impacts that can otherwise occur gradually and may be irreversible. That is, increasing the robustness of infrastructure designs and investments can reap immediate benefits through improved resilience to climate variability and extreme atmospheric events. Adaptation is viewed as a crucial step to strengthen local capacity to deal with forecasted and unexpected climatic conditions (Smith and others 1996; Smith and others 1999).

3.1 Data and Methodology

It became necessary to examine this research by using Solow–Swan model which is an exogenous growth model, an economic model of long-run growth set within the framework of neoclassical economics. It attempts to explain long-run growth by looking at increases in productivity. At its core, it is a neoclassical aggregate production function, usually of a Cobb–Douglas type, which enables the model "to make contact with microeconomic variables.

In line with the objectives of the study, a single equation is inadequate to capture the simultaneous interaction between agriculture, greenhouse gas emission, food security and grant, a simultaneous model will be used which will capture adequately the interactions among the variables. However, simultaneous equation models have been criticized for the difficulty in separating the endogenous variables and exogenous variables. Thus, Sims (1982) developed the Vector autoregressive model (VAR) which is an improvement on the simultaneous equation models as it treats all variables in the model as endogenous with each equation in the VAR system corresponding to each of the endogenous variables. This study will adopt the VAR framework by Sims (1982) to capture the lead-lag interactions between agriculture, greenhouse gas emission, food security and grant in Africa.

3.1.1 Model 1:

For the purpose of analyses, the model is generally specified as follows:

$$AGR_t = \beta_0 + \beta_1 FPI_t + GRANT + \beta_3 GHG_t + u_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

AGRIC = Agriculture production

FPI = Food production index (food security)

GRANT= Incentive

GHG = Greenhouse gas emission

In order to capture the first objective of the study, a VAR is econometrically specified following Pesaran et. al. (2001) as:

3.1.2 Model 2

In order to capture objective two of the study, the impulse response function (IRF) will be used. The reason is because the IRF is used to show how a variable known as the dependent variable responds to shocks in the impulse variable in a particular equation. Thus, the IRF Graph will be used to capture the response on agriculture to shocks in investment.

3.1.3 Model 3

The Granger Causality Test will be used to determine the direction of causality between gas emission and food security for objective 3. The regression for the Granger Causality test is specified as follow:

$$GHG_t = \sum_{i=1}^{m} \alpha_i GHG_{t-i} + \sum_{i=1}^{m} \beta_j FPI_{t-j} + u_{1t} \text{...(6)}$$

$$FPI_t = \sum_{i=1}^{m} \gamma_i FPI_{t-i} + \sum_{j=1}^{m} \delta_j GHG_{t-j} + u_{2t} \text{...(7)}$$

Equation (6) and (7) will be used to determine if the direction of causality runs from gas emission to food security or from food security to gas emission under the critical assumption that GHG and FPI are stationary.

3.14 Estimation Technique

The VAR Technique will be used to estimate model (1) while the impulse response function and Granger Causality test will be applied to model (2) and Model (3). The VAR as developed by Christopher Sims is an improvement on the simultaneous model. It is used to capture the simultaneous interactions among variables. However it is applied under the condition that the variables are I (1) and I (0) processes. The impulse response function (IRF) will be used to show the response to shocks in the impulse variables, while, the Granger Causality will be used to show the direction of causality under the assumption that the variables are stationary.

4.1 Empirical Results

Table 4.1 Unit Root Test

Panel unit root test: Summary
Series: D(FPI)
Date: 08/23/18 Time: 12:15
Sample: 1995 2014
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 3
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-9.74184	0.0000	10	177
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-8.84941	0.0000	10	177
ADF - Fisher Chi-square	105.243	0.0000	10	177
PP - Fisher Chi-square	133.864	0.0000	10	180

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.
Source: Eview 8.

The result of the test presented above (Table 4.1) shows that FPI is stationary after first difference, as its test statistics is smaller than 5% critical value for rejection of the hypotheses of the unit root. We can therefore conclude that the variable is integrated of order 1(*1*).

Table 4.2 Unit Root Test

Panel unit root test: Summary
Series: GRANTS
Date: 08/23/18 Time: 12:19
Sample: 1995 2014
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 4
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.68653	0.0001	10	185
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-3.78927	0.0001	10	185

ADF - Fisher Chi-square	49.7455	0.0002	10	185
PP - Fisher Chi-square	47.1524	0.0006	10	190

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

The result of the test presented above (Table 4.2) shows that GRANT is stationary at level form, hence, null hypotheses of no unit root was rejected at level form, implying that it is integrated of order I(0).

Table 4.3 Unit Root Test

Panel unit root test: Summary
Series: D(GHG)
Date: 08/23/18 Time: 12:18
Sample: 1995 2014
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 2
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-8.28550	0.0000	10	176
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-7.24721	0.0000	10	176
ADF - Fisher Chi-square	88.6099	0.0000	10	176
PP - Fisher Chi-square	93.4994	0.0000	10	180

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.
Source: Eview 8

The result of the test presented above (Table 4.3) shows that GHG is stationary at first difference as the test statistics is smaller than 5% critical value.

Table 4.4 Unit Root Test

Panel unit root test: Summary
Series: AGRIC
Date: 08/23/18 Time: 12:14
Sample: 1995 2014
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.66468	0.0001	10	189
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-0.08802	0.4649	10	189
ADF - Fisher Chi-square	29.4565	0.0792	10	189
PP - Fisher Chi-square	39.5179	0.0057	10	190

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

The result of the test presented above (Table 4.2) shows that AGRIC is stationary at level form, hence, null hypotheses of no unit root was rejected at level form, implying that it is integrated of order I(0).

Table 4.5 VAR Lag Order Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: AGRIC FPI GHG GRANTS
Exogenous variables: C
Date: 08/23/18 Time: 12:34
Sample: 1995 2014
Included observations: 120

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-5334.531	NA	5.15e+33	88.97552	89.06844	89.01326
1	-4516.741	1567.431	8.09e+27	75.61236	76.07694*	75.80102*
2	-4509.150	14.04307	9.32e+27	75.75251	76.58876	76.09211
3	-4466.992	75.18292	6.04e+27*	75.31653*	76.52444	75.80707
4	-4461.404	9.591713	7.22e+27	75.49007	77.06965	76.13155
5	-4454.084	12.07932	8.40e+27	75.63473	77.58597	76.42714
6	-4431.352	35.99113	7.58e+27	75.52254	77.84545	76.46588
7	-4406.221	38.11624*	6.61e+27	75.37035	78.06492	76.46463
8	-4390.365	22.99107	6.75e+27	75.37275	78.43899	76.61796

* 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
Source: Eview 8.

It can be seen from the table 4.5 of VAR lag order selection criteria. LR was selected of lag order seven (7), FPE and AIC lag three (3), while, SC and HQ criteria suggests selection of lag two (2). To run the VAR model and granger causality test for the period of 1995-2014, this study takes 2 lags to estimate the VAR and granger causality test.

Table 4.6 Unrestricted Cointegration

Date: 08/24/18 Time: 20:37
Sample (adjusted): 1998 2014
Included observations: 170 after adjustments
Trend assumption: Linear deterministic trend
Series: AGRIC FPI GHG GRANTS
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.201407	62.43649	47.85613	0.0012
At most 1	0.089511	24.20280	29.79707	0.1920
At most 2	0.042008	8.261310	15.49471	0.4379
At most 3	0.005664	0.965561	3.841466	0.3258

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.201407	38.23369	27.58434	0.0015
At most 1	0.089511	15.94149	21.13162	0.2283
At most 2	0.042008	7.295749	14.26460	0.4548
At most 3	0.005664	0.965561	3.841466	0.3258

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

AGRIC	FPI	GHG	GRANTS
-0.014073	-0.005578	1.26E-07	1.11E-09
0.002505	-0.024721	-7.33E-06	2.79E-11
-0.036905	0.027440	-2.58E-07	-3.06E-10
0.042522	0.030536	-6.60E-06	-1.35E-10

Unrestricted Adjustment Coefficients (alpha):

D(AGRIC)	-0.128660	0.123679	-0.093052	0.017424
D(FPI)	0.171630	1.258740	0.287876	-0.523555
D(GHG)	-1618.473	-1366.715	-849.5326	-287.8270
D(GRANTS)	-4.65E+08	50733317	1.19E+08	6522979.

1 Cointegrating Equation(s): Log likelihood -6329.073

Normalized cointegrating coefficients (standard error in parentheses)

AGRIC	FPI	GHG	GRANTS
1.000000	0.396370	-8.92E-06	-7.88E-08
	(0.53653)	(9.5E-05)	(1.3E-08)

Adjustment coefficients (standard error in parentheses)

D(AGRIC)	0.001811
	(0.00078)
D(FPI)	-0.002415
	(0.00919)
D(GHG)	22.77677
	(8.83506)
D(GRANTS)	6542404.
	(1234005)

2 Cointegrating Equation(s): Log likelihood -6321.103

Normalized cointegrating coefficients (standard error in parentheses)

AGRIC	FPI	GHG	GRANTS
1.000000	0.000000	-0.000122	-7.53E-08
		(9.7E-05)	(1.2E-08)
0.000000	1.000000	0.000284	-8.76E-09
		(8.4E-05)	(1.1E-08)

Adjustment coefficients (standard error in parentheses)

D(AGRIC)	0.002120	-0.002340
	(0.00078)	(0.00139)
D(FPI)	0.000738	-0.032075
	(0.00922)	(0.01635)
D(GHG)	19.35341	42.81503
	(8.84001)	(15.6729)
D(GRANTS)	6669482.	1339019.
	(1252087)	(2219886)

3 Cointegrating Equation(s): Log likelihood -6317.455

Normalized cointegrating coefficients (standard error in parentheses)

AGRIC	FPI	GHG	GRANTS
1.000000	0.000000	0.000000	-4.78E-08
			(8.7E-09)
0.000000	1.000000	0.000000	-7.32E-08
			(1.4E-08)
0.000000	0.000000	1.000000	0.000227
			(5.8E-05)

Adjustment coefficients (standard error in parentheses)

D(AGRIC)	0.005554	-0.004893	-8.99E-07
	(0.00215)	(0.00203)	(4.0E-07)
D(FPI)	-0.009886	-0.024176	-9.28E-06
	(0.02552)	(0.02408)	(4.7E-06)
D(GHG)	50.70512	19.50386	0.010036
	(24.3305)	(22.9635)	(0.00451)
D(GRANTS)	2278458.	4603909.	-461.0141
	(3446602)	(3252947)	(638.924)

Source: Eview 8

The variables were found to be integrated of order I(*1*), and I(0) and thus, we examined whether there is the presence or non-presence of cointegration among the variables. When a cointegration relationship is present, it means that the variables share a common trend and have a long-run interaction. We started the cointegration analysis by employing the unrestricted cointegration test. The result in table 4.6 presents the unrestricted cointegration test base on the "Trace test and Maximum Eigen value". Starting with the "Trace test at 62.43649, it indicates 1 cointegrating variable at 0.05 level in the model, which denotes rejection of the null hypothesis at the 5% level of significance according to Mackinno-Haug-Michelis (1999) p-values. The maximum eigenvalue test at 38.23369 indicates 1 cointegrating variable at 5% level in the model, which denotes rejection of the null hypothesis at the 5% level of significance. It therefore suggests that there is a long run relationship in the model.

Table 4.7 Vector Error Correction

Vector Error Correction Estimates
Date: 08/24/18 Time: 20:36
Sample (adjusted): 1998 2014
Included observations: 170 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
AGRIC(-1)	1.000000
FPI(-1)	0.396370 (0.53653) [0.73876]
GHG(-1)	-8.92E-06 (9.5E-05) [-0.09384]
GRANTS(-1)	-7.88E-08 (1.3E-08) [-6.14902]
C	-27.62997

Error Correction:	D(AGRIC)	D(FPI)	D(GHG)	D(GRANTS)
CointEq1	0.001811 (0.00078) [2.31022]	-0.002415 (0.00919) [-0.26290]	22.77677 (8.83506) [2.57800]	6542404. (1234005) [5.30177]
D(AGRIC(-1))	0.134940 (0.06425) [2.10038]	-2.672575 (0.75310) [-3.54878]	-424.7886 (724.232) [-0.58654]	-40818321 (1.0E+08) [-0.40352]
D(AGRIC(-2))	0.029842 (0.06532) [0.45683]	0.293714 (0.76573) [0.38357]	-364.4765 (736.384) [-0.49495]	77810133 (1.0E+08) [0.75653]
D(FPI(-1))	0.014824 (0.00674) [2.19913]	-0.242856 (0.07901) [-3.07355]	-39.88670 (75.9862) [-0.52492]	-9145267. (1.1E+07) [-0.86170]
D(FPI(-2))	0.053163 (0.00683) [7.78075]	-0.057518 (0.08009) [-0.71815]	5.538707 (77.0226) [0.07191]	4857071. (1.1E+07) [0.45149]
D(GHG(-1))	-8.60E-06 (6.9E-06) [-1.25494]	-6.62E-05 (8.0E-05) [-0.82468]	-0.006336 (0.07724) [-0.08203]	712.9239 (10787.8) [0.06609]
D(GHG(-2))	-2.69E-06 (6.9E-06) [-0.39031]	2.09E-05 (8.1E-05) [0.25920]	-0.183213 (0.07769) [-2.35841]	-1675.887 (10850.4) [-0.15445]
D(GRANTS(-1))	2.06E-10 (5.9E-11) [3.48770]	-4.00E-10 (6.9E-10) [-0.57708]	1.19E-06 (6.7E-07) [1.79298]	-0.052847 (0.09303) [-0.56804]
D(GRANTS(-2))	2.21E-10 (5.1E-11)	7.68E-10 (6.0E-10)	1.30E-06 (5.7E-07)	-0.064529 (0.07997)

	[4.35133]	[1.28924]	[2.27544]	[-0.80688]
C	-0.059327	5.098573	1604.548	58858586
	(0.07782)	(0.91226)	(877.294)	(1.2E+08)
	[-0.76233]	[5.58896]	[1.82897]	[0.48035]
R-squared	0.359114	0.140427	0.076416	0.292826
Adj. R-squared	0.323065	0.092076	0.024464	0.253048
Sum sq. resids	84.36208	11592.03	1.07E+10	2.09E+20
S.E. equation	0.726129	8.511766	8185.536	1.14E+09
F-statistic	9.961618	2.904329	1.470899	7.361409
Log likelihood	-181.6617	-600.1129	-1767.788	-3781.786
Akaike AIC	2.254844	7.177798	20.91515	44.60924
Schwarz SC	2.439302	7.362257	21.09961	44.79370
Mean dependent	0.247104	3.274588	1145.247	46926471
S.D. dependent	0.882552	8.932952	8287.537	1.32E+09

Determinant resid covariance (dof adj.)	3.26E+27
Determinant resid covariance	2.56E+27
Log likelihood	-6329.073
Akaike information criterion	74.97733
Schwarz criterion	75.78895

Source: Eview 8

The result above shows the presence of cointegration among the variables in the in the model. Trace test and Maximum Eigenvalue test were used to come to such conclusions. This led us to conduct a Vector Error Correction model and the result can be seen in Table 4.7.

Table 4.8 Granger Causality Test

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 08/23/18 Time: 14:09
Sample: 1995 2014
Included observations: 180

Dependent variable: AGRIC

Excluded	Chi-sq	df	Prob.
FPI	0.532741	2	0.7662
GHG	4.102324	2	0.1286
GRANTS	0.570809	2	0.7517
All	5.436829	6	0.4891

Dependent variable: FPI

Excluded	Chi-sq	df	Prob.
AGRIC	13.78869	2	0.0010
GHG	1.113198	2	0.5732
GRANTS	2.180874	2	0.3361

All	17.80190	6	0.0067

Dependent variable: GHG

Excluded	Chi-sq	Df	Prob.
AGRIC	0.614176	2	0.7356
FPI	0.068082	2	0.9665
GRANTS	1.559470	2	0.4585
All	2.188741	6	0.9015

Dependent variable: GRANTS

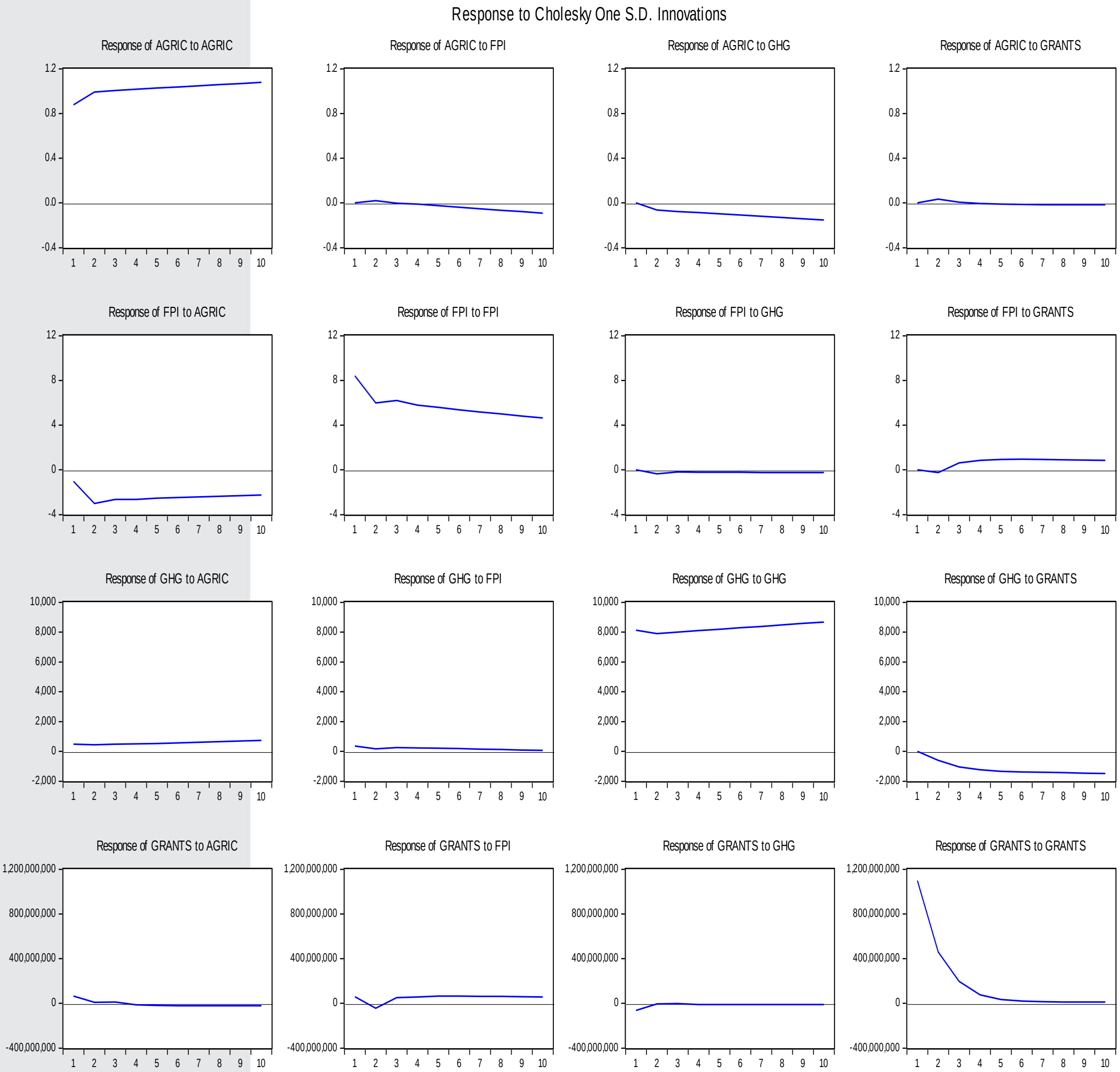
Excluded	Chi-sq	Df	Prob.
AGRIC	0.653177	2	0.7214
FPI	3.846170	2	0.1462
GHG	0.731878	2	0.6935
All	4.460933	6	0.6146

Source: Eview 8

The result shows that FPI, GHG and GRANT does not granger cause AGRIC. The result further shows a causality running from AGRIC to FPI. However, we reject the null hypothesis on FPI, since the probability value is less than 5% level of significant.

Therefore, we conclude that AGRIC granger cause FPI. On the other hand, we accept the null hypothesis that FPI, GHG and GRANT does not granger cause AGRIC, which means that they have a bi-directional causality. It also shows that AGRIC, FPI and GRANT does not granger cause GHG and AGRIC. FPI and GHG does not granger cause GRANT, it as well means that there is a bi-directional causality among these variables.

Figure 4.1 Impulse Response Function



Source: Eview 8

The response of FPI to GHG was slightly negative meaning GHG did not distort FPI (Food security) in these countries during these periods. AGRIC had a negative response to GHG, while GHG was positive to AGRIC, meaning GHG had no influence on AGRIC (agriculture production) in these countries. At the early periods (point 1 to 3) GRANT and AGRIC shocks were positive and became slightly negative (point 4 to 10) on each other in these countries. This means that during the early periods GRANT (incentives) contributed positively to increases in AGRIC (agriculture production), while later (point 4 to 10) had no positive impact on AGRIC (agriculture production).

5.1 Conclusion and Policy Recommendation

In this paper, a series of tests were conducted in line with the objective of that work and the following results were obtained in the analysis. A Unit root test was conducted on the series to determine whether the series were stationary, and the results show that, AGRIC and GRANT were integrated of 1(*0*). However, GHG and FPI were found to be integrated of order I(I). Moreover, Johansen cointegration test was employed to know the cointegration status of the series in the model. It was found that there exists cointegration relationship among variables in the model. The VEC estimation result shows that AGRIC (our variable of interest) is statistically insignificant to GHG and GRANT, also was established that FPI was positively related to AGRIC and the relationship was significant. Moreover, the trend in GRANT was positive at the early periods and later became negative to AGRIC output, while AGRIC was positive to FPI. Meaning, despite the no impart of GRANT to AGRIC, AGRIC yielded more increases, which translates into enhanced food security in these countries.

It is recommended that agricultural policies on more GRANT should be designed and implemented towards gas emission reduction in AGRIC and this should be centred on climate change mitigation, in order to enhance the African economy, so that the benefits of economic growth will trickle down to the agro-based rural population that constitute a larger proportion of the population of Africa. Therefore, all tiers of government and the private sector should be fully involved in pursuing the course of greenhouse gas emission reduction through agricultural productivity for the growth of this region (Africa) economy.

The VECM estimation method of impulse response was adopted to analysis the response of food security to shock in agriculture and shocks in grant

AGRIC which lead to the key finding of this study. The result shows a large negative impact of GRANT on AGRIC, which contributed negatively to FPI (food security). This entails that FPI responded negatively when there is a shock on AGRIC in these countries within the period under review. The result also indicated that a shock on GRANT may increase or decreases FPI. The research further examines the causal relationship between GHG (Greenhouse gas emission) and FPI (Food security).

5.1 Policy Implication and Recommendation

This study has a number of policy implications. The presence of cointegration between AGRIC, FPI and other variables in the model, implies the effectiveness of one of the variables influencing the long run behaviour of the other variables. If this interpretation holds and given the significance of long run relationship between AGRIC, FPI, GHG and GRANT, then policy makers should adopt policies that will enable diversification of the African economy through greenhouse gas emission reduction in the agricultural sector.

As far as the policy implications are concern, agriculture plays an important role either directly or indirectly to food security in Africa. The sector fulfils all demands in terms of food and raw material for domestic industry and also a source of foreign exchange earnings. The findings that AGRIC does not granger-cause GHG is not a surprising result. This is because, despite agricultural gas emission, the sector is neglected in term of incentives (GRANT), both at policy level and at social reforms level. Moreover, the negative response of GRANT to AGRIC, implies that a shock on GRANT and AGRIC does not have a significant impact on FPI (Food security). This could be as a result of government expenditure, which falls heavily on non-agricultural production and defence purposes.

If the government increases its spending (grants/incentives) towards gas emission reduction in agricultural, then, the food security will more have a significant impact on the economic growth of these African nations.

Base on the findings above, this study therefore recommends the following:

The African governments should increase its budgetary allocation towards issuing grants to farmers as an incentive to encourage the reduction of gas emission in agriculture in order to mitigate climate change and boost food security in Africa. Similarly, African governments are advised to avoid inconsistency in its agriculture policy and programmes, rather it should embrace stable, consistent and sustainable agricultural policies, as that would help to improve food security. The study further recommends that African nations should strengthen agricultural credit agencies in order to ensure efficient disbursement of funds to farmers. In that, diversion and mismanagement of agricultural funds in these region would be discouraged and hence improve food security and the economy of Africa.

5.2 Conclusion

Africa's strategy for reducing agricultural emission is: (i) to stabilise GHG emissions, particularly methane, by enhancing efficiency measures. (ii) to further reduce emissions, particularly nitrous oxide. (iii) to offset GHG emission with carbon sequestration from afforestation and agricultural land management and (iv) displace fossil fuel emission with wood fuel and biogas.

If Africa can produce food with fewer inputs, then this reduces emission to the atmosphere and cost to the farmer. This will be achieved through adoption of measures such as dairy Economic Breeding index (i.e. improve the genetics of our dairy cow), beef genomics (to improve the genetics of our beef herd), improved animal health and extending the grazing season. These efficiencies will reduce the footprint of dairy, beef and stabilise methane emission via increased product per head. Improved nutrient management planning in combination with optimal use of slurry and legumes will help increase nitrogen efficiency and reduce nitrous oxide emission. Other strategies can reduce greenhouse gas emissions even further. Examples include the development of novel, low-emission fertilizers, reducing crude protein in bovine and pig diets, fatty acid supplementation to reduce methane, drainage of poorly drained mineral soils and adding amendment to manures during storage. In addition, enhancing carbon sequestration and reducing soil losses are key strategies to reducing sectoral emission. This will principally be achieved through increased afforestation, reducing losses on organic soil and enhancing pasture sequestration.

As both the 2020 and 2030 GHG reduction target are multi-year targets, the total GHG reduction will be highly dependent on rate of uptake. This means that the role of knowledge transfer and education will be more important than ever. Research of itself will not lead to emission reductions without strong linkage to advisory, education and the involvement of farmers. Initiatives, such as educative programmes, social media, and agricultural agencies/boards will all play vital role in getting the message out to farmers.

In summary, CO2, methane and nitrous oxide all contribute to climate change. There is potential to reduce the more long-lived nitrous oxide and CO2, whilst stabilising methane in the short term. Ultimately, achieving timely and substantial levels of mitigation will require the whole sector including farmers, industry, research, advisory/education and policymakers working in concert,. Effective large scale mitigation will only occur if best practices can be communicated on the ground. This will involve a closer linkage between research/analysis to the development of relevant policies and affective translation on the ground via knowledge transfer.

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