FERARI

FERTILIZER RESEARCH & RESPONSIBLE IMPLEMENTATION

# Determination of Fertilizer Cost Components and Their Effect on Fertilizer Prices and the Fertilizer Value Chain in Ghana

## IFDC FERARI Research Report No. 4

N. Odionye, D. Saa, A. Laamari, W. Adzawla, I., Koffi, E. Afimia, W.K. Atakora, M. Jemo, P.S  Bindraban

MOHAMMED VI POLYTECHNIC UNIVERSITY

ESAFE

# Determination of Fertilizer Cost Components and Their Effect on Fertilizer Prices and the Fertilizer Value Chain in Ghana

N. Odionye[1,2,4], D. Saa[3], A. Laamari[1], W. Adzawla[2], I., Koffi[4], E. Afimia[4], W.K. Atakora[2], M. Jemo[1], P.S. Bindraban[2,*]

[1]*Mohammed VI Polytechnic University, Ben Guerir, Morocco*
[2]*International Fertilizer Development Center, USA*
[3]*University of Development Studies, Tamale, Northern Region, Ghana*
[4]*University of Ibadan, Nigeria*
[*]*Correspondence: pbindraban@ifdc.org*

This report is based on the thesis by N. Odionye, submitted to the Faculty of the School of Agriculture, Fertilization and Environmental Sciences (ESAFE) for obtaining the diploma of master's degree in "Fertilizer Science and Technology." This thesis research was conducted under the Fertilizer Research and Responsible Implementation (FERARI) program.

*Citation*:

Odionye N., Saa D., Laamari A., Adzawla W., Koffi I., Afimia E., Atakora W.K., Jemo M., Bindraban P.S., 2020. Determination of fertilizer cost components and their effect on fertilizer prices and the fertilizer value chain in Ghana. IFDC FERARI Research Report No. 4.

# ACKNOWLEDGMENTS

*Acknowledgements by Nnaemeka Odionye from his thesis.*

I would like to thank my family for their support throughout my master's program. Also, I would like to thank my supervisors, co-supervisors, and the entire IFDC staff for their hospitality and professionalism in guiding me through all the steps necessary in delivering this report. Finally, I would like to thank the School of Agriculture, Fertilization and Environmental Sciences (ESAFE) faculty members, UM6P lecturers, and students for their hospitality and OCP Foundation for the scholarship they provided for this master's program.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# ABBREVIATIONS

| | |
|---|---|
| ADF | Augmented Dickey-Fuller |
| AFO | AfricaFertilizer.org |
| AIC | Akaike Info Criterion |
| ARDL | Autoregressive Distributed Lag |
| C.V. | Critical Value |
| CNPK | Commercial Nitrogen, Phosphate, and Potassium |
| COVID-19 | Coronavirus Disease 2019 |
| CUREA | Commercial Urea |
| ECM | Error Correction Model |
| FAO | Food and Agricultural Organization of the United Nations |
| FMC | Forward Market Commission |
| FOB | Free on Board |
| FOT | Free on Truck |
| FPE | Final Prediction Error |
| FSP | Fertilizer Subsidy Program |
| GDP | Gross Domestic Product |
| GFEP | Ghana Fertilizer Expansion Program |
| GoG | Government of Ghana |
| GSS | Ghana Statistical Service |
| ha | hectares |
| HQ | Hannan-Quinn |
| ICT | Information and Communication Technology |
| IFDC | International Fertilizer Development Center |
| KASO | Kasoa Market |
| KOFO | Koforidua Market |
| LR | Likelihood Ratio |
| MANK | Mankessim Market |
| MCDM | Multi-Criterion Decision-Making |
| MoFA | Ministry of Food and Agriculture |
| mt | Metric Ton |
| NPK | Nitrogen, Phosphate, and Potassium |
| OLS | Ordinary Least Square |
| PBM | Parity Bound Model |
| PFJ | Planting for Food and Jobs |
| PP | Phillips-Perron |
| SEB | Security Exchange Board |
| SECK | Seckondi Market |
| SEECM | Single Equation Error Correction Model |
| SNPK | Subsidized NPK |
| SoA | Ammonium Sulfate |
| SUREA | Subsidized Urea |

| | |
|---|---|
| TAKO | Takoradi Market |
| TECH | Techiman Market |
| U.S. | United States |
| USD | United States Dollars |
| VAR | Vector Autoregression |
| VCR | Value:Cost Ratio |
| VECM | Vector Error Correction Model |
| WENC | Wenchi Market |

ABSTRACT

Fertilizer is a major input for crop production, especially in nutrient-depleted soils. In Ghana, consumption of fertilizers has been relatively low due to high prices, which has prompted the introduction of fertilizer subsidy programs to induce consumption and increase agricultural productivity. However, the externality effect of the subsidy program is eroding the profitability of the fertilizer sector downstream, especially the commercial fertilizer market, as margins are insufficient to encourage the expansion of retail distribution networks to remote agrarian communities. These externalities could compromise the gains made by the Planting for Food and Jobs (PFJ) program of the Government of Ghana (GoG).

This study establishes margins and profitability of value chain actors in the wake of the PFJ. A total of 394 respondents, comprising 153 agro-dealers (106 retailers, 42 distributors, and five importers) and 241 farmers, were interviewed through the aid of a questionnaire. Cointegration analyses were used to investigate price transmission within markets, while a vector auto regression (VAR) model was used to determine the relationship between subsidized and commercial fertilizers (NPK 15:15:15 and urea) for the period 2012-2019.

The results revealed weak market efficiency within the fertilizer markets investigated in Ghana while also establishing that prevailing prices of subsidized fertilizers influence the subsequent prices of commercial fertilizers for the period investigated. Furthermore, value chain cost and margin breakdown revealed fertilizer importers had a net positive margin (6.24%) when all costs were factored in, while distributors and retailers had net margins of -17.19% and -15.13%, respectively, for commercial urea. Farmers had the highest transportation cost (3 GH₵ per 50-kg bag) associated with the purchase of fertilizers, as a result of the poor fertilizer distribution network in Ghana. The report concludes with several recommendations, such as an inclusive subsidy negotiation and more research and development to address the identified externalities.

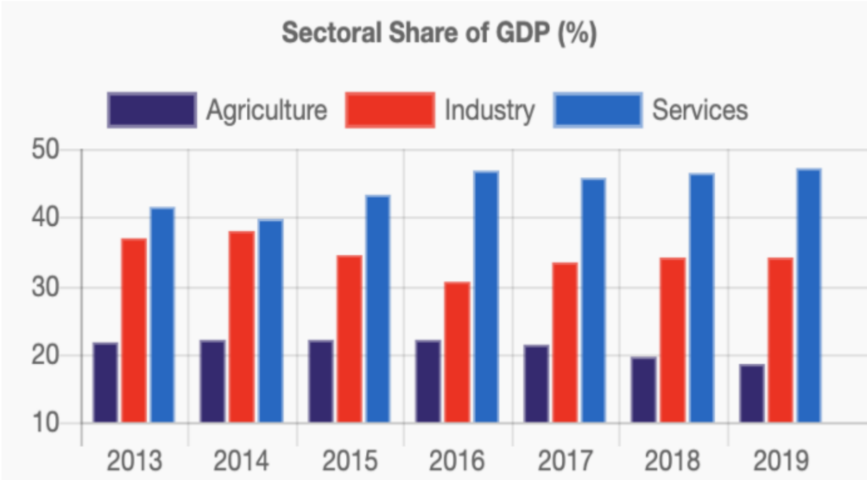
Keywords: Fertilizer value chain; fertilizer cost components; fertilizer price transmission; market integration; market inefficiency

# CHAPTER 1: INTRODUCTION

## 1.1 Ghana and Agriculture

Ghana has a population of over 29.7 million people and a gross domestic product (GDP) of $65.46 billion (World Bank, 2020). In 2019, the agriculture sector contributed 18.5% to Ghana's GDP (GSS, 2020), as shown in Figure 1, and employed 52% of the total labor force (FAO, 2020). Furthermore, it is a major source of foreign exchange, which is substantiated by Ghana's ranking as the second biggest cocoa exporter behind Côte d'Ivoire. Export crops occupy 60% of total cultivated area and consume 51% of total fertilizers, while staple crops occupy 40% of total cultivated area and consume 49% of total fertilizers (Fuentes et al., 2011; GFEP, 2018). Ghana constitutes about 10.6% of the Economic Community of West African States (ECOWAS) fertilizer market share, with an annual fertilizer consumption of 440,661 metric tons (mt) and 310,866 mt in 2017 and 2018, respectively, and is the region's third biggest fertilizer market after Nigeria and Mali (AFO, 2020).

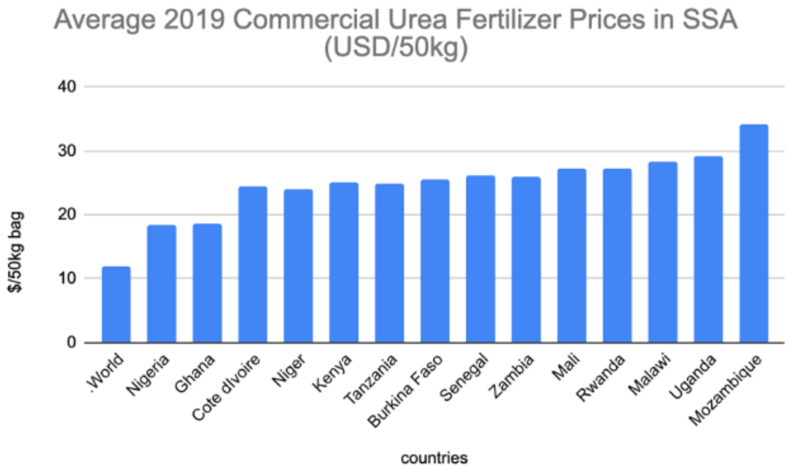
Due to the importance of agriculture in job creation and rural development, the Government of Ghana (GoG) has substantially invested in agricultural projects over the years. These projects include the Ghana Grains Development Project (1979-1997) and the Food Crops Development Project (2000-2008). Despite gains made by previous programs in the sector, the shortfalls of globalization were evident as effects of the 2008 global economic meltdown rippled across countries and continents. The agriculture sector was not spared as food prices soared. To enhance food security in line with the *Abuja Declaration on Fertilizer for an African Green Revolution*, the GoG introduced a Fertilizer Subsidy Program (FSP) in 2008 that was rolled out in 2009 (Fuentes et al., 2011). This ushered in a new era of FSP in Ghana and across sub-Saharan Africa (SSA). In 2017, the new administration in Ghana introduced a program called Planting for Food and Jobs (PFJ), with the objective of increasing agricultural productivity and creating employment opportunities within the sector. One of the pillars of the PFJ program is to provide fertilizers at 50% subsidy, targeted to smallholder farmers with 0.4-2 hectares (ha) of land and cultivating important staple crops (MoFA, 2017; Wiredu et al., 2019; Scheiterle et al., 2019; IFDC, 2019; Iddrisu et al., 2020).




*Source: GSS, 2020.*

***Figure 1. Sectoral contribution to GDP in Ghana***

In general, Ghana's FSP has successfully increased its domestic fertilizer consumption from 137,000 mt in 2006 to 425,110 mt in 2019 (AFO, 2020). The 2019 PFJ subsidized fertilizer prices were 12 USD/50 kg and 13 USD/50 kg for urea and NPK, respectively, while commercial fertilizer prices for the same period were around 19 USD/50 kg and 20 USD/50 kg for urea and NPK, respectively. Ghana fertilizer prices are the lowest in the region alongside Nigeria, as revealed in Figure 2 (AFO, 2020). Despite gains made by the FSP, the subsidy program has resulted in market distortion and market inefficiencies, including smuggling, uneven margins, and poor fertilizer market development. Bonilla et al. (2020) observed that fertilizer prices are lower in Northern Ghana as compared to Southern Ghana, which is an entry point for fertilizers as all the ports are located in the South. Low fertilizer prices farther north violate the law of one price, which stipulates the existence of a universal price for a defined commodity no matter the market as long as it has been adjusted for transaction costs and other associated taxes/levies (Baffes, 1991). It is also speculated that commercial fertilizer prices are kept as close as possible to subsidized fertilizer prices to remain competitive in the wake of the FSP. These low margins act as disincentives for the development of local distribution networks (IFDC, 2019), as actors claim commercial fertilizers are sold only to increase cash flow and maintain their existing customers. At the last rung of the fertilizer value chain, farmers are not left out and would have to travel long distances to acquire fertilizers due to the lack of local fertilizer retail outlets. The lack of local fertilizer retail networks acts as a disincentive for fertilizer use by farmers, as depicted by Obisesan et al. (2013). Furthermore, farmers are often faced with constraints, such as access to finance, asymmetric information, and fluctuating commodity prices, which exacerbates the entire process of fertilizer acquisition (Klutse et al., 2018). Previous studies by Fuentes et al. (2011) and IFDC (2019) revealed that financial cost is the biggest cost component associated with final fertilizer retail prices; however, the effects of cost components on market margins were not established. Also, the level of spatial fertilizer market integration is unknown, which is an important parameter in understanding the movement of fertilizer from surplus markets to deficit markets.




*Source: IFDC, 2019.*

***Figure 2. Average retail fertilizer price in SSA***

## 1.2 Research Questions

1. What are the costs and margins associated with commercial and subsidized fertilizers along the fertilizer value chain in Ghana?
2. How effective are fertilizer prices transmitted spatially in markets within Ghana?
3. What relationships exist between commercial and subsidized fertilizer prices in Ghana?

## 1.3 Objective of Research

The overall objective of this research is to determine the level of efficiency, distribution of costs, and margins in each segment of Ghana's fertilizer value chain and the effect of several cost components on stakeholder margins in the chain. The specific objectives are outlined below:

1. Assess fertilizer cost components and margins associated with stakeholders in each stratum of the value chain.
2. Determine the level of market integration in Ghana.
3. Determine the relationship between commercial and subsidized fertilizer prices.

## 1.4 Hypotheses

*Ho.* Stakeholder margins are below the Bank of Ghana's 365-day treasury bill rate.

*Ho.* Ghana's fertilizer market is not spatially integrated.

*Ho.* Commercial urea fertilizer price cause subsidized urea fertilizer price.

## 1.5 Scope and Limitation of Study

The scope of the study is to evaluate the level of efficiency within Ghana's fertilizer market and to give a breakdown of various cost components and their effect on stakeholders' margin. Cost components for the seven fertilizers captured under the PFJ and ammonium sulfate (SoA) are investigated in the major agricultural communities within the Savannah agroecological zone because of the region's role as the major food basket in Ghana.

Due to limited data on fertilizer market prices, spatial market integration analyses were conducted based on the price of NPK 15:15:15 from major markets in the Southern part of Ghana. Furthermore, due to restrictions caused by the COVID-19 pandemic, surveys were limited to urban and peri-urban communities.

## 1.6 Justification of Study

The essence of this study is to provide empirical evidence to inform policymakers and fertilizer stakeholders on Ghana's fertilizer spatial price transmission and the effects of market constraints on the final fertilizer price. This would enable the GoG and other allied institutions to provide appropriate policies to develop the domestic fertilizer market and incentivize more private sector involvement in the sector.

# CHAPTER 2: LITERATURE REVIEW

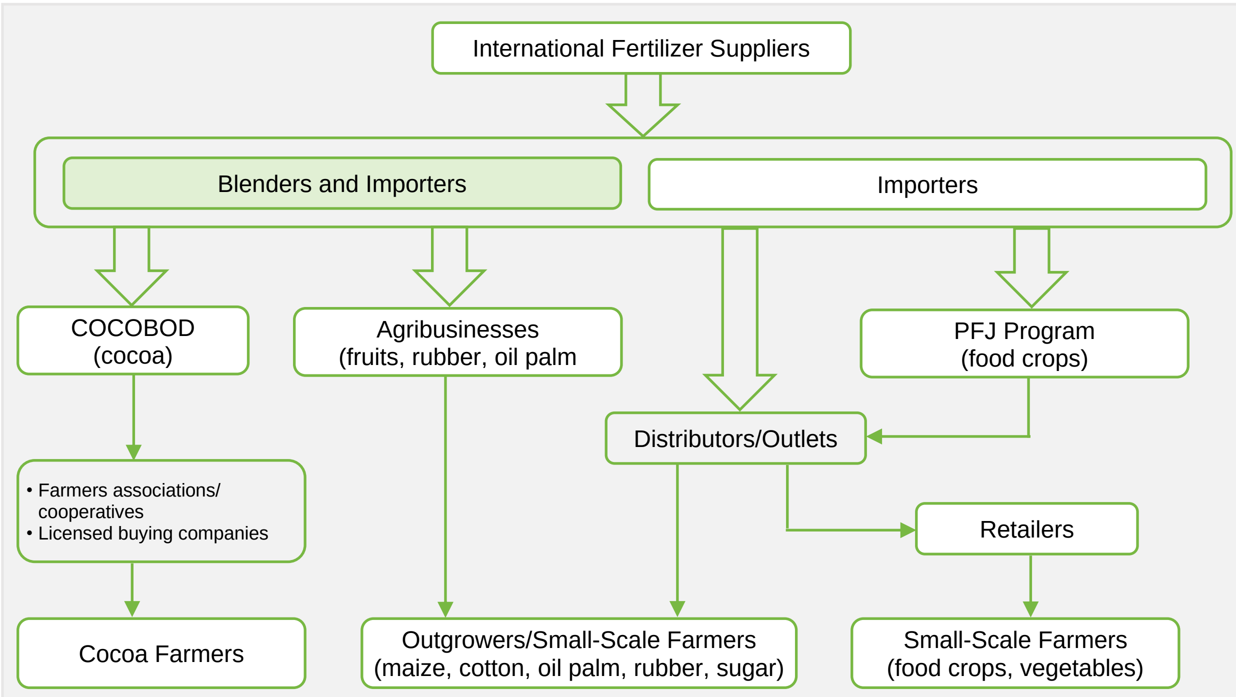
## 2.1 Ghana Fertilizer Trend

Ghana imports all its fertilizers with little domestic value addition in the form of blending. Pre-1980s, the total amount of fertilizers imported was below 60,000 mt per annum. Macroeconomic reforms in the 1980s made foreign exchange scarce, which led to currency devaluation; the effect of a devalued currency meant more money was needed to import same amount of goods and services. Faced with limited foreign currency and competing needs, the GoG eliminated FSPs. The effect was felt by farmers as fertilizer demand declined, which led to a spike in food prices (Jayne et al., 2003). The 1990s saw a rise in importation to 56,000 mt and a peak in 2003 at 93,000 mt, with a further decline to 56,000 mt in 2004; in 2006, it increased to 137,000 mt (Fuentes et al., 2011).

The 2008 global financial meltdown took a toll on Ghana's economy, as total fertilizer imports declined by 10%. In 2009, the GoG reintroduced fertilizer subsidies to cushion the effect of the financial crisis. The new subsidy program incorporated the use of coupons to target smallholder farmers and specific crops of interest. The effect of the subsidy program was instant, as total fertilizer imports increased to 218,000 mt (Fuentes et al., 2011). In order to create employment, reduce poverty, and increase agricultural productivity, the GoG introduced the PFJ program with a 50% subsidy rate for fertilizer in 2017 (MoFA, 2017; Ansah et al., 2020). The PFJ has five key components comprising seed promotion, fertilizer access, extension services, market development, and information and communication technology (ICT) (MoFA, 2017; FTWG, 2019). The PFJ's 50% FSP is the highest within the ECOWAS region, and the effect was an eminent increase in apparent fertilizer consumption (440,661 mt) in 2018 (AFO, 2020). Fluctuations in the domestic fertilizer market are attributed to the absence of local fertilizer production, which has left Ghana vulnerable to international commodity price shocks, especially when considering the small size of the market.

## 2.2 Fertilizer Distribution Channel

All imported fertilizers in Ghana are distributed to farmers through one of three of differentiated channels shown in Figure 3: (a) plantations and commercial/industrialized crops owners; (b) agricultural parastatals, such as PFJ and COCOBOD; and (c) smallholder farmers and producers of staple food crops. The plantations owners have large-scale farms for cultivating cash crops, such as sugarcane, oil palm, tobacco, and rubber. Due to their reliance on fertilizer for productivity and profitability, they import and distribute fertilizers to selected interest groups, such as outgrowers, under a contractual agreement to buy back output at a guaranteed price. Recently, due to logistics, limited financial resources, and time constraints, most plantations have abandoned fertilizer importation, leaving it to in-country importers, while maintaining their local distribution networks (IFDC, 2019). The GoG established COCOBOD as a government agency in 1947 to regulate the cocoa industry in order to increase value addition and generate foreign exchange. COCOBOD is responsible for the facilitation of production and processing of cocoa, coffee, and shea. It is also charged with the responsibility of formulating policies within the cocoa sub-sector. COCOBOD was responsible for fertilizer importation and distribution through its network of over 90% of cocoa farmers. Subsequent fertilizer market reforms made COCOBOD exit importation operations, leaving importation to private sector players, such as Yara-Wienco and Chemico. PFJ also distributes fertilizers to targeted farmers under the GoG subsidy program. Smallholder farmers not captured by the FSP rely on the open market for their fertilizer needs at commercial prices.




*Source: AFO, 2020.*

***Figure 3. Fertilizer distribution channels in Ghana***

## 2.3 Fertilizer Supply Chain Cost Analysis

Ghana relies solely on fertilizer importation; therefore, the fertilizer cost structure is divided into international and domestic cost. Importation cost is determined by international free on board (FOB) price, and domestic costs are influenced mainly by infrastructure, policies, and macroeconomic conditions (Fuentes et al., 2011). FOB prices are often controlled by global energy prices (Huang, 2009; Ripplinger and Miljkovic, 2017) and are beyond the control of any country. Domestic supply chain costs remain under the domain and influence of GoG. Hence, from an in-country perspective, cost analysis is premised on the domestic supply chain components. As shown in Table 1, the 2018 free on truck (FOT) cost of urea at the port of Tema was $394.20/mt; FOB was the highest cost constituent with 70.5% of total FOT bagged cost, followed by ports/shipping cost with 10%; insurance/freight, bagging, and tariffs/levies were 9.2%, 5.8%, and 5.3%, respectively. In summary, there is an additional 29.5% cost from FOB to FOT at the port level. Further costs are incurred along the value chain, as fertilizers are transported geographically and also vertically down the value chain, in the form of storage and financial costs.

***Table 1. FOT cost of importing urea at Tema port***

| Importer Costs/Charges | $/mt | GH₵/mt | FOT Bulk % | FOT Bagged % |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| FOB | 279.40 | 1341.10 | 74.8% | 70.5% |
| Cost, Insurance, and Freight | 305.10 | 1,464.30 | 81.7% | 77.0% |
| Total Taxes, Tariffs, and Levies | 326.10 | 1,565.10 | 87.3% | 82.3% |
| Port Charges | 365.10 | 1,753.80 | 97.8% | 92.2% |
| Shipping Charges | 366.10 | 1,754.80 | 97.9% | 92.3% |
| Total Forwarder Charges | 371.20 | 1,778.60 | 100% | 94.2% |
| **FOT Cost at Port of Tema** | **371.40** | **1,793.30** | **100%** | **94.2%** |
| Bagging | 394.20 | 1,902.30 | | 100% |
| **Total FOT Bagged at Tema Port** | **394.20** | **1,902.30** | | **100%** |

Note: Assumed exchange rate is GH₵ 4.8/$1, three-month average, up to September 2018.

*Source: IFDC, 2019.*

## 2.4 Identifying Key Constraints and Bottlenecks

### *2.4.1 High Cost and Inefficiencies at the Port*

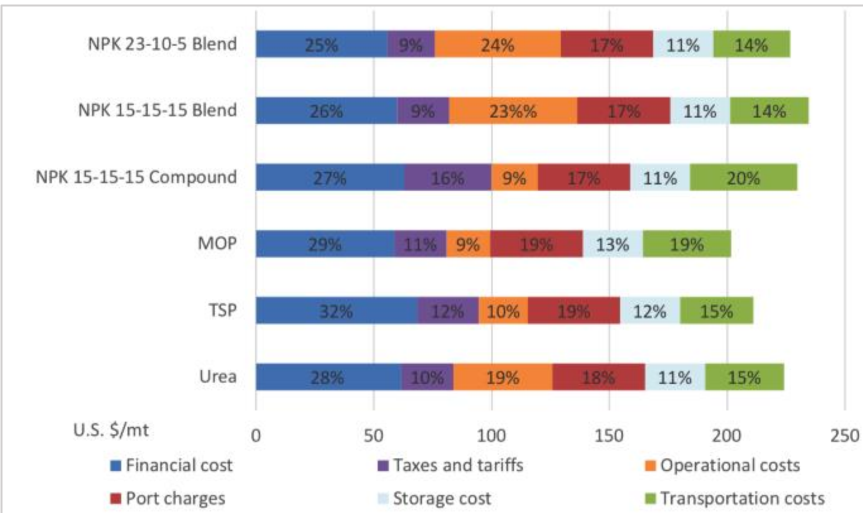
A plethora of operational inefficiencies, such as the exclusive regulation that permits only port employees (stevedores) to perform the loading and bagging of products, exist at the ports that culminate into the high cost of fertilizers; these often slow down the process and lead to additional demurrage (Fuentes et al., 2011). Limitations in port capacity and infrastructure further exacerbate the entire process. According to Fuentes et al. (2011), the port cost could be reduced if the exclusive rights to the stevedores was reversed and made competitive. Furthermore, the labor cost for unloading and bagging, which is pre-established by the port authority at an hourly cost, is not reflective of competitive market rates and does not provide enough incentive for workers to increase their productivity. Also, shallow drafts prevent the docking of vessels larger than 15,000 mt, hence eliminating the potential for economies of scale.

### *2.4.2 Uneven Distribution of Market Margins*

The newly introduced FSP price negotiation only involves importers (IFDC, 2019). The exclusion of distributors and other downstream players has led to market distortion, and margins are unevenly distributed among actors. Negotiation leaves the importers better off when they hedge against international price fluctuation, currency devaluation, and high-interest rates. Distributors take whatever price is offered by importers and, in most cases, are responsible for the transportation of these fertilizers to the point of sale. Distributors are also faced with harsh macroeconomic conditions, such as high domestic interest rates, currency devaluation, and other risks associated with fertilizer logistics (Fuentes et al., 2011; IFDC, 2019). Furthermore, the same burden is passed down from distributors to retailers, who in most cases face harsher conditions, such as poor access to credit associated with over-collateralization of loans and high-interest rates. The FSP price capping erodes whatever profit margins that would have been made in a competitive market. Therefore, the entire system does not induce value chain actors to expand their distribution networks into the most remote parts of Ghana.

### 2.4.3 Financial Constraint

Access to credit is a challenge to domestic fertilizer distributors and retailers; loan over collateralization makes it difficult for downstream players to access credit. In situations where credit is available, it is mostly given out at an exorbitant interest rate of 30-35% per annum. Hence, for businesses to write off their debts, they would require a profit margin higher than 30-35% (Fuentes et al., 2011). IFDC (2019) also confirmed high financial cost is a major contributor to the high margins in fertilizer retail prices and requires urgent intervention, as depicted in Figure 4. Fuentes et al. (2011) stated that fertilizer distributors and retailers face the same credit constraints as farmers as a result of lenders' perceived risk and uncertainty in agricultural businesses. Generally, financial institutions prefer to invest in low-risk government bonds with higher returns rather than increasing their agricultural loan portfolio.




*Source: IFDC, 2019.*

***Figure 4. Fertilizer importers cost breakdown in Ghana***

### 2.4.4 Poor Infrastructure

Poor road networks and a lack of rail services in transporting fertilizers to farming communities also influence fertilizer pricing and adoption by farmers, especially in isolated communities. This is substantiated by higher retail fertilizer prices in remote regions, as revealed in Table 2. The distance to fertilizer retail shops or cost of transportation influences a farmer's decision to use fertilizer, as they often would have to travel a long distance to purchase them (Fuentes et al., 2011; Obisesan et al., 2013).

*Table 2. 2009 fertilizer price and coupon value in Ghana*

| Region | Fertilizer Product and Prices | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Urea | | AS | | N-P-K/T-15 | | N-P-K Blend | |
| | Market Price | Coupon Value* | Market Price | Coupon Value* | Market Price | Coupon Value* | Market Price | Coupon Value* |
| | (US $/50-kg bag) | | | | | | | |
| Northern | 27.88 | 9.20 | 23.56 | 10.60 | 38.87 | 20.60 | 36.23 | 19.20 |
| Upper East | 28.29 | 9.90 | 24.26 | 11.40 | 40.38 | 21.40 | 36.85 | 19.90 |
| Upper West | 27.65 | 9.40 | 23.48 | 10.80 | 39.25 | 20.80 | 36.60 | 19.40 |
| Central | 26.77 | 8.30 | 22.79 | 9.80 | 38.08 | 19.80 | 35.19 | 18.30 |
| Eastern | 27.81 | 8.90 | 23.41 | 10.30 | 39.04 | 20.30 | 36.35 | 18.90 |
| Brong Ahafo | 27.81 | 8.90 | 23.41 | 10.30 | 39.04 | 20.30 | 36.35 | 18.90 |
| Western | 26.88 | 8.60 | 22.95 | 10.10 | 38.65 | 20.10 | 35.77 | 18.60 |
| Greater Accra | 26.33 | 7.90 | 22.38 | 9.40 | 38.04 | 19.40 | 35.10 | 17.90 |
| Volta | 27.81 | 8.90 | 23.11 | 10.40 | 39.23 | 20.40 | 36.35 | 18.90 |
| Ashanti | 27.10 | 8.40 | 23.02 | 9.90 | 38.27 | 19.90 | 35.38 | 18.40 |
| Averages | 27.50 | 8.80 | 23.41 | 10.30 | 39.04 | 20.30 | 36.15 | 18.80 |

*The exchange rate considered for estimating the coupon value and the product price is 1.4 GHC to US $1.00.

*Source: IFDC, 2019.*

### 2.4.5 Underdeveloped Fertilizer Market and Low Fertilizer Demand

The incorporation of coupons for subsidy in the new FSP is intended to help the program achieve its objective of targeting smallholder farmers (0.4-2 ha) and specific crops. However, the use of these coupons simply means the fertilizer market is defined and disincentivizes the expansion of retail and distribution networks to remote areas in order to capture more farmers. Houssou et al. (2017) revealed that fertilizer subsidies can crowd out private sector activities in areas with well-developed distribution channels. Furthermore, low crop productivity, attributed to blanket recommendations, lack of extension services, and farmers' technical know-how, is responsible for low fertilizer productivity, which has reduced the volume of fertilizer demand in Ghana (Fuentes et al., 2011; IFDC, 2019). For retailers to be profitable and remain in business, they must increase their margin to make up for the volume deficit, since revenue is a function of price and quantity.

In summary, Figure 4 highlights the various constraints in Ghana's fertilizer value chain pertaining to fertilizer costs and prices.

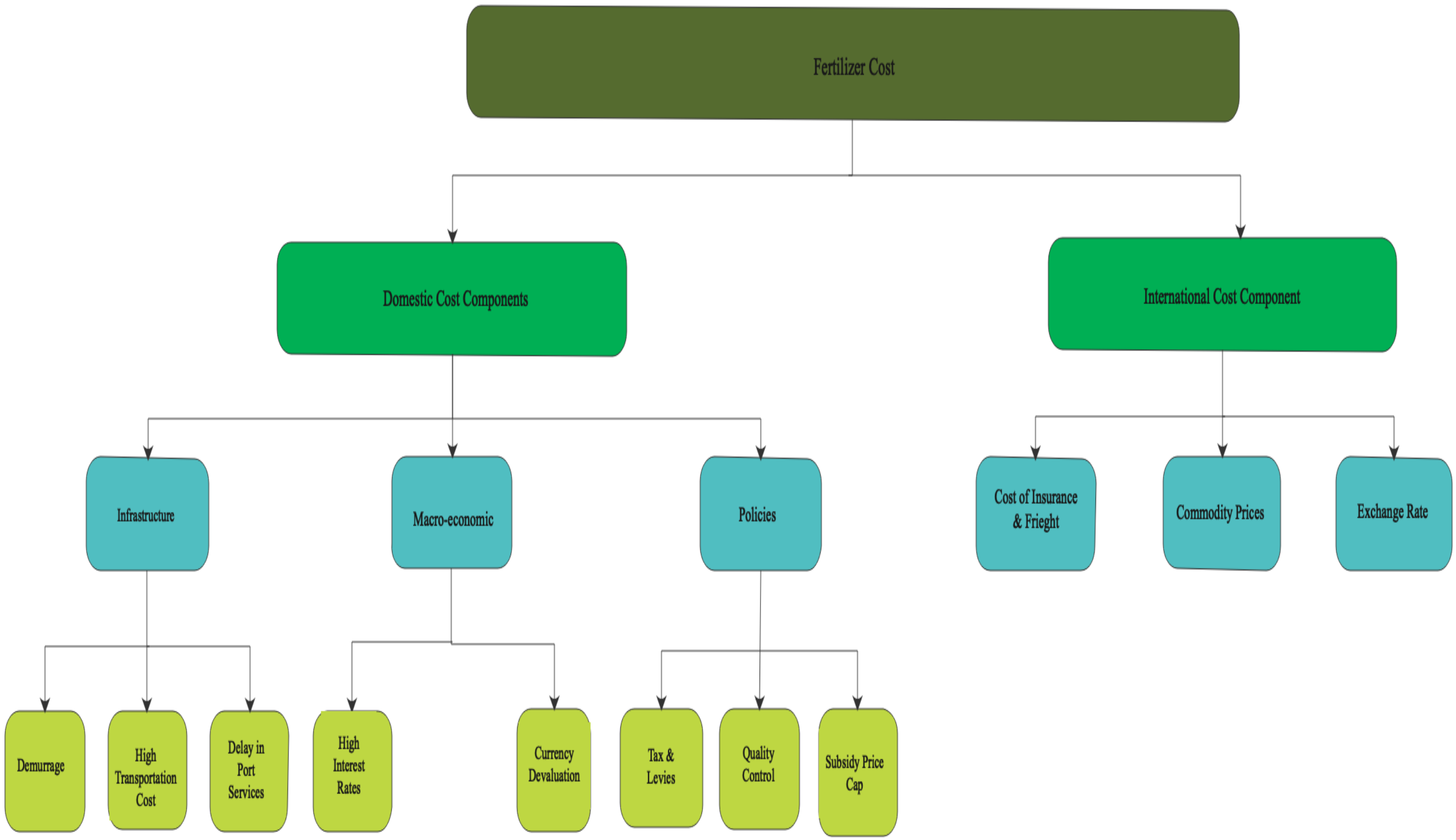



***Figure 4. Problem tree associated with the fertilizer value chain in Ghana***

## 2.5 Empirical Review

Most agricultural market integration studies have focused on agricultural commodity prices. For instance, Galang (2014) examined the spatial fertilizer market in the Philippines through cointegration analyses and established that prices in regional markets cause or influence prices in other markets. This indicates market integration, whereby shocks in one market would ripple across other markets. The author explained that causal determination was essential in identifying price leaders and price takers in the region. Also, Rufino (2008) studied the existence of partial market integration in the Philippine rice market. The presence of stationarity was determined through an Augmented Dickey-Fuller (ADF) test, while Engel Granger cointegration and Granger causality tests were used to determine long-run and causal relationships. The study concluded that market price transmission was efficient despite the existence of market segregation and poor distribution networks.

Gupta et al. (2018) and Inan (2018) investigated market efficiency and price discovery in India's agricultural commodity market. They utilized a unit root analysis to investigate whether price series exhibited random walk, while Johansen cointegration was used to assert the existence of a long-run relationship. Mohanty and Mishra (2020) also investigated the impact of Indian regulatory reform and market efficiency on domestic agricultural commodity markets through intraday prices (pre-merger and post-merger) between the Forwarding Market Commission (FMC) and Securities Exchange Board (SEB). The study utilized an intraday predictability return model based on past order flows via Ordinary Least Square (OLS), in line with Rosch et al. (2017), and a multiple various ratio test to evaluate weak market efficiency. The investigation revealed the presence of short-term inefficiency during the pre- and post-merger period. Furthermore, Baquedano and Liefert (2014) utilized a Single Equation Error Correction Model (SEECM) to investigate market integration and price transmission in developing countries. SEECM, unlike the Error Correction Model (ECM), does not necessarily require the presence of unit root to determine the long-run relationship of a time series.

In the global North, Daly et al. (2017) utilized ADF and Johansen cointegration tests to determine the long-run relationship between corn, fertilizer, and natural gas spot prices in the United States (U.S.), while VECM was used to re-estimate the relationship among ammonia, natural gas, and corn prices. Hu and Brorsen (2017) investigated spatial transmission of urea prices in the U.S.; the study utilized a VECM and a Parity Bound Model (PBM), as outlined by Baulch (1997). PBM was introduced by Baulch (1997) as a more accurate procedure to test for spatial price transmission when the cost of transaction data is available.

There also have been numerous investigations on market integration in Africa, especially on commodity market prices. Delgado (1986) utilized a variance component model to evaluate 18 months of weekly grain prices from 22 villages in Northern Nigeria, which revealed the absence of market integration. In Kenya, Gitau and Meyer (2018) studied the spatial linkages in maize markets (surplus and deficit) in the presence of transaction cost and policy interventions through a cointegration and a causality test. The study revealed close market pairs were integrated, which could be a result of low transaction costs; therefore, price differences were easily adjusted as compared to further isolated markets with high transaction cost. Zungol and Kilima (2019) investigated the price transmission between maize and rice prices in Tanzania (1987-2012) with a cointegration analysis; the study revealed a long-term relationship existed between maize and rice prices for the period observed.

Previous studies on the fertilizer market had focused on the demand side; Manos et al. (2007) investigated the effect of fertilizer price policy on farm behaviors such as income and employment through a Multi-Criterion Decision-making Model (MCDM) in Bangladesh. A utility function was used to analyze farmers' behavior under alternative fertilizer prices while trying to maximize gross margin and minimize variance of gross margin and labor. Their findings revealed that minimization of labor was significantly higher than others, which implies that, in the wake of higher fertilizer prices, farmers are more inclined to cut down on farm labor or switch to less labor-intensive crops to maximize their utility function. Chakraborty (2016) investigated the determinants of fertilizer demand in India. He utilized time series data and estimated a demand function for fertilizer through an OLS regression model. He revealed that non-price factors are more important than the price of fertilizers in determining fertilizer use by farmers. Investigation to understand the supply and demand for nitrogen fertilizers among smallholder farmers in Malawi was conducted through a two-step procedure in which a Hicksian and Marshallian price elasticity were estimated. The findings revealed that fertilizer price and agricultural commodities, such as maize and tobacco, were crucial for farmers in making fertilizer decisions (Chembezi, 1990). Huang (2009) further identified energy cost, transportation cost, feedstock cost, exchange rate, unions, and the number of industry participants as the major factors responsible for supply-side fertilizer price variation. Meanwhile, factors that affect fertilizer prices from the demand side include population, economic growth, foreign trade policies, commodity prices, and the presence or absence of subsidies.

Rashid et al. (2014) assessed fertilizer policies, value chain, and profitability in Ethiopia, and the findings revealed that specific household characteristics, such as geographic location, entrepreneurial skills, access to market, and credit availability, influence demand for fertilizer. Furthermore, fertilizer profitability to farmers is a function of value:cost ratio (VCR), and a high VCR of at least 2 is needed for fertilizer use to be profitable in Africa. Petrick and Latruffe (2003) investigated Polish farmers' credit access and borrowing cost through a hedonic pricing model to estimate the effect of various loan attributes and their impact on financial cost. This revealed that young farm owners with updated bookkeeping practices had a higher likelihood of accessing loans while household size also influenced the amount of loan applied by farmers, as these tend to smoothen consumption. Although these studies provided a guide to understand the fertilizer value chain, empirical evidence that examines the fertilizer value chain of Ghana with analysis of the market integration possibilities is limited.

## 2.6 Theoretical Review

### *2.6.1 Market Efficiency*

A market can be defined quantitatively or qualitatively (Carlton, 2007), but for this research, a market is defined as a platform where goods and services are traded. An efficient market is a market in which all costs and benefits are reflected in the commodity price. The absence of this condition can lead to market failure, as a result of the presence of externalities, asymmetric information, and lack of market competition (Dowding and Taylor, 2020). Externality, information asymmetry, and noncompetitive markets are inextricably linked, and they affect the transaction cost of products when left unregulated. It is, therefore, imperative for governments, policymakers, and private sector actors to understand the concept of agricultural market efficiency due to the sensitive nature of the sector and its macroeconomic impact, especially in SSA.

Market efficiency is divided into: (a) weak efficiency, which occurs when commodity prices reflect all publicly captured information; (b) medium efficiency, when commodity prices adjust to prevalent market information as quickly as possible, thereby eliminating the possibility of abnormal profit; and (c) strong efficiency, when all private and public information is captured in the commodity (Mohanty and Mishra, 2020).

### 2.6.2 Market Integration

Market integration is defined by Barrett (1996) as the movement of goods and underlying information, such as price, over time, space, and form. It emphasizes the traceability of goods from one market to another (Rapsomanikis et al., 2006; Barrett, 2008). It is on this premise that arbitrageurs move goods from surplus markets to deficit markets (Balch, 1997), which also ensures the stability of market prices. Galang and Myka (2014) indicated that market integration is a necessary but not sufficient condition for an efficient market, as other factors that characterize a perfectly competitive market need to be in place. Hence, market integration can be used to understand the level of competitiveness in a market (Rufino, 2008). Recently, market integration has been an area of interest for governments and development organizations, especially in developing countries. It provides a basis to understand the depth and spread of policies and market shocks within a value chain or across regional markets. Therefore, information on market integration may provide specific evidence on the extent of the competitiveness of a market (Alexander and Wyeth, 1994).

### 2.6.3 Law of One Price

The law of one price is predicated on the assumption that there is a prevailing market price for a homogenous commodity at every point in time, as long as it has been adjusted for all transaction costs, such as transportation and tariffs (Baffes, 1991; Lutz et al., 1995; Baquedano and Liefert, 2014; Hu and Brorsen, 2017). It is on this principle that the Big Mac Index was invented as an unofficial measurement of real exchange rate when all other factors have been factored in. For instance, Richardson's (1978) model on commodity arbitrage between U.S. and Canada was modified by Fackler and Godwin (2001) in a bivariate linear model, as indicated below:

$$P_{it} = \beta_0 + \beta_1 P_{jt} + e_t \qquad (1)$$

$P_i$ is the price of a homogenous commodity at a point in time ($t$), $P_j$ is the price of the same commodity in another market at the same time ($t$), while $\beta_0$ is the intercept, $\beta_1$ and $e_t$ are the coefficient of regression and the error term, respectively. When $\beta_0 = 0$ and $\beta_1 = 1$, both are assumed to be perfectly integrated as they exhibit perfect price transmission.

# CHAPTER 3: EMPIRICAL METHODOLOGY

## 3.1 Data

The study utilized primary and secondary data to investigate the objectives outlined. Primary data for Objective 1 was obtained through the administration of questionnaires to farmers, retailers, and distributors in urban and peri-urban communities within Kumasi, Tamale, Yendi, Techiman, Wa, Kintampo, Walewale, and Bolgatanga; importers were interviewed in Greater Accra, which is the point of entry for most fertilizers consumed in Ghana. Secondary data for Objectives 2 and 3, such as FOB prices, average national fertilizer prices, and local fertilizer market prices, were obtained from IFDC, AfricaFertilizer.org (AFO), MoFA, and Esoko for the period 2012-2019.

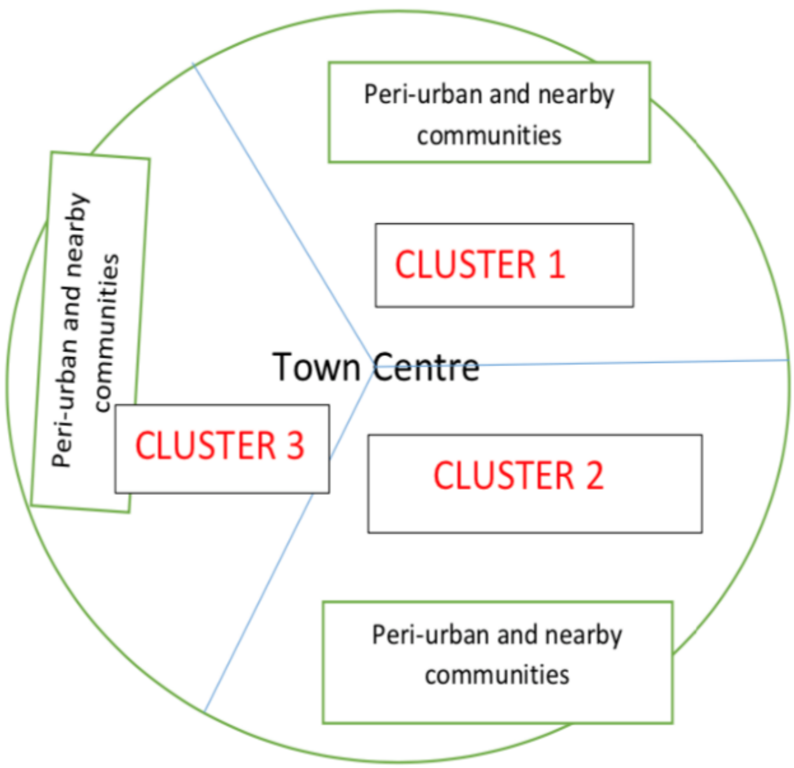



***Figure 5. Sampling technique in each surveyed community***

Based on Figure 5, seven retailers, three distributors, and 10 farmers were selected from each cluster by snowballing, due to COVID-19 restrictions, totaling 10 agro-dealers and 10 farmers per community. The survey regions (Greater Accra, Ashanti, Bono, Northern, North-East, and Upper-West region), highlighted in Figure 6 were selected by purposeful sampling, in line with Maxwell (1996). Prices were collected for the seven PFJ fertilizers and SoA (a non-PFJ fertilizer). Greater Accra and Ashanti regions are major fertilizer supply routes, as most fertilizers in Ghana are imported through the port of Tema, while Bono, Northern, North-East, and Upper-West regions, which are agricultural communities and consume a substantial amount of the national fertilizer quota in Ghana, make up the Guinea Savannah agroecological zone. Price transmission for NPK

15:15:15 within markets was investigated in Kasoa, Koforidua, Takoradi, Techiman, Mankessim, Seckondi, and Wench due to data availability.

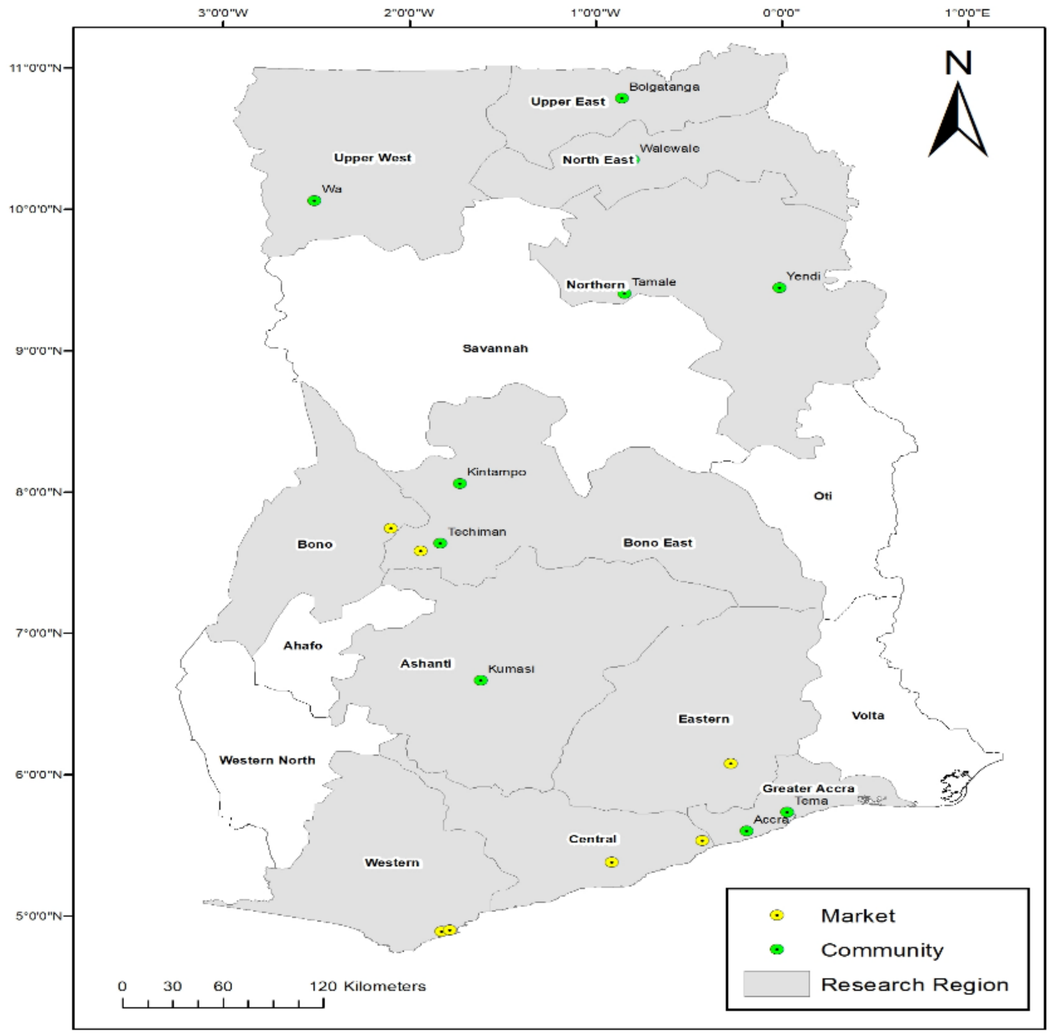



*Figure 6. Study regions in Ghana*

## 3.2 Data Analysis

### 3.2.1 Unit Root

Most time-series data possess unit root (non-stationarity), which makes the time series unfit for stochastic analysis. The absence of unit root, also known as stationarity, indicates that: (a) time series data is mean revolving or has a constant mean: $\mu(t) = \mu$; (b) the variance of the distribution is constant over time: $\sigma^2 (t) = \sigma^2$; and (c) the time series distribution is not dependent on time (Priebe, 2019). Hence, if all of these conditions are violated, the series is said to be non-stationary and is likely to produce a spurious result when utilized for statistical analysis without correction (Obayelu and Salau, 2010; Mahmood et al., 2017). A non-stationary time series can be made stationary by differentiation; when a distribution achieves stationarity at the first difference it is denoted as I(1), while stationarity achieved at the second difference is denoted by I(2). Statistically, unit root is often determined by ADF (Dickey and Fuller, 1979) and Phillips-Perron (PP) tests. The ADF test is given as:

$$\Delta Xt = \alpha 0 + \beta\, \gamma\, Xt\text{-}1 \;\sum_{i=1}^{\rho} \boldsymbol{\beta_i X_{t-1}} \; + \varepsilon t \tag{2}$$

where $X_t$ is the stationary series, $\alpha_0$ is the intercept, $\rho$ is the lag operator, and $t$ is the time, while $\varepsilon$ is the error term. Akaike Information Criterion (AIC) is used to determine the lag length of the equation (Hu and Brorsen, 2017).

### 3.2.2 Cointegration

Cointegration analysis was first introduced by Granger in 1981 and further modified by Engel Granger, as well as Engel and Yoo, in 1987. The Johansen and Juselius (1994) cointegration technique is used in a multivariate analysis that is all integrated in the same order, while ARDL is used for a bivariate analysis integrated of order I(0) (Otieno, 2017). The essence is to determine if a long-run relationship exists between the variables of interest; this information enables the analyst to decide on the use of VAR or an Error Correction Model (ECM)/Vector Error Correction Model (VECM) (Ripplinger et al., 2017; Obayelu and Salau, 2010). Studies (Endera, 2010; Shaik and Miljkovic, 2010; Daly et al., 2017; Mahmood et al., 2017) show that, in the presence of cointegration and stationarity on the order I(1), a VECM or ECM is preferable depending on the stipulated objective.

### 3.2.3 Vector Autoregressive Model (VAR)

The VAR model is a general framework used to describe the dynamic interrelationship among non-stationary variables. In time-series analysis, the first step is to determine whether the levels of the data are stationary; if not, the first difference of the series is verified. Usually, if the levels or log-levels of the time-series are not stationary, the first difference will be stationary. If the time series are not stationary, then the VAR framework needs to be modified to allow consistent estimation of the relationships among the series.

The VAR is one of the most successful, flexible models for the analysis of multivariate time series. It is a natural extension of the univariate autoregressive model to dynamic multivariate time series. It has proven to be especially useful for describing the dynamic behavior of economic and financial time series and for forecasting. It often provides superior forecasts to those from univariate time series models and elaborate theory-based simultaneous equations models. The VAR model fits this study in the sense that vector estimates of the series are generated and the causal effects are assessed simultaneously.

This study adapts VAR as earlier used by Hamilton (1983) and Bjørnland (1996) to analyze the effect of price shocks to verify the causality between commercial fertilizer price and subsidized fertilizer price. The theoretical methodological framework is represented as follows:

$$\begin{pmatrix} \Delta COMp \\ \Delta SUBp \end{pmatrix} \begin{pmatrix} b_{11i} & b_{12i} \\ b_{21i} & b_{22i} \end{pmatrix} \begin{pmatrix} \phi_{1t} \\ \phi_{2t} \end{pmatrix} \tag{3}$$

Where ΔCOMp, ΔSUBp represents the first difference of commercial fertilizer prices in time ($t$), $\phi_{1t}$, and $\phi_{2t}$ are the uncorrelated white noise disturbances and $b_{11i}$, $b_{12i}$, $b_{21i}$, and $b_{22i}$ are polynomials in the lag operator where the individual coefficients are denoted as $b_i$. The series in equation (4) can be endogenized in a VAR model system as follows:

$$\Delta COMp_t = \alpha_0 + \sum_{t-1}^{n} \beta_{11i}\, \Delta COMp_{t-1} + \sum_{t-1}^{n} \beta_{12i}\, \Delta SUB_{t-1} + \varepsilon_t \tag{4}$$

$$\Delta SUB\ p_t = \alpha_0 + \sum_{t-1}^{n} \beta_{12i}\, \Delta SUBp_{t-1} + \sum_{t-1}^{n} \beta_{11i}\, \Delta COMp_{t-1} + \varepsilon_t \tag{5}$$

# CHAPTER 4: RESULTS

## 4.1 Cost Components and Distribution of Margins

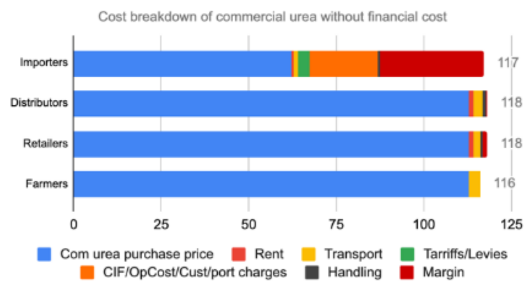
A total of 394 respondents, comprising of 153 agro-dealers (5 importers 42 distributors, 106 retailers) and 241 farmers, were surveyed. Table 3 shows the cost breakdown and margins for value chain actors from point of purchase to point of sale. The results revealed that NPK fertilizer prices were relatively higher than straight fertilizer prices, such as urea and ammonium sulfate (SoA). This price difference is to be expected, as NPK contains more essential nutrients compared to urea and SoA. However, some price inconsistencies were observed within the value chain, as some retail fertilizer prices were lower than the prices offered by distributors (wholesalers); for example, the average price for which retailers purchased commercial NPK 12:22:21 was 98 GH₵ and sold for 137 GH₵, while distributors' (wholesalers') average purchase price for the same fertilizer was 121 GH₵ and sold for 133 GH₵ (Appendix Table 1A). In some cases, there was no difference between the retail price and the distribution price; this can be attributed to non-stratification of the downstream fertilizer market, as most distributors also retail fertilizers. Furthermore, the highest cost associated with fertilizers is the purchase price followed by financial cost, transportation cost, and cost of rent. Margins are unevenly distributed and highly skewed toward fertilizer importers, especially when margins are adjusted for financial cost. For example, when financial cost is factored into the total cost of commercial urea, only the importers have positive margins while distributors and retailers make negative margins.

*Table 3. Cost and margin breakdown of three fertilizer types per 50-kg bag*

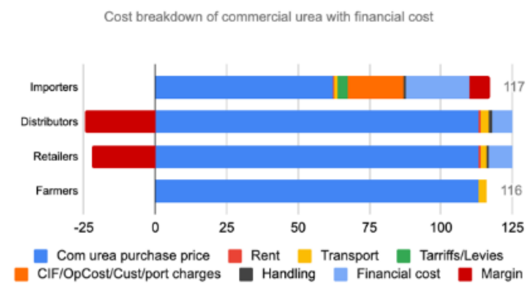
| **Commercial Urea** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Actor** | **Urea Purchase Price/50kg** | **Rent/50kg** | **Transport/50kg** | **Tariffs/Levies/50kg** | **CIF/OpCost/Cust/Port Charges** | **Handling/50kg** | **Financial Cost/50kg** | **Selling** | **Margin** | **%Margin with Finance/50kg** | **% Margin without Finance Cost/50kg** |
| **Importer** | 62.21 | 0.58 | 1.15 | 3.5 | 19.33 | 0.86 | 22.5 | 117 | 6.87 | 6.24% | 33.52% |
| **Distributor** | 113 | 1 | 2.83 | 0 | 0 | 0.96 | 24.7 | 118 | -24.49 | -17.19% | 0.18% |
| **Retailer** | 113 | 1 | 2 | 0 | 0 | 0.86 | 23.51 | 118 | -22.36 | -15.93% | 0.98% |
| **Farmer** | 113 | 0 | 3 | | | | | | | | |

| **Subsidized Urea** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Actor** | **Urea Purchase Price/50kg** | **Rent/50kg** | **Transport/50kg** | **Tariffs/Levies/50kg** | **CIF/OpCost/Cust/Port Charges** | **Handling/50kg** | **Financial Cost/50kg** | **Selling/50kg** | **Margin/50kg** | **%Margin with Finance/50kg** | **% Margin without Finance Cost/50kg** |
| **Importer** | 62.21 | 0.58 | 1.15 | 3.5 | 19.33 | 0.86 | 22.5 | 117 | 6.87 | 6.24% | 33.52% |
| **Distributor** | 72 | 1 | 2.83 | 0 | 0 | 0.96 | 18.9 | 79 | -16.69 | -17.44% | 2.88% |
| **Retailer** | 71 | 1 | 2 | 0 | 0 | 0.86 | 17.66 | 80 | -12.52 | -13.53% | 6.87% |
| **Farmer** | 80 | 0 | 3 | | | | | | | | |

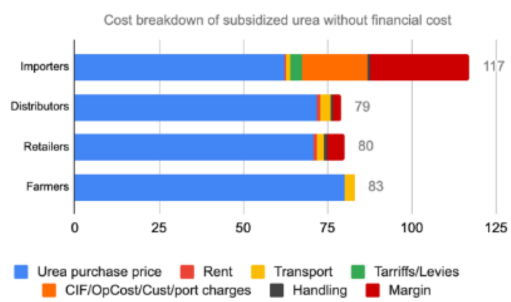
| **Commercial SoA** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Actor** | **SoA Purchase Price/50kg** | **Rent/50kg** | **Transport/50kg** | **Tariffs/Levies/50kg** | **CIF/OpCost/Cust/Port Charges/50kg** | **Handling/50kg** | **Financial Cost/50kg** | **Selling/50kg** | **Margin/50kg** | **%Margin with Finance/50kg** | **% Margin without Finance Cost/50kg** |
| **Importer** | 40.32 | 0.58 | 1.15 | 3.5 | 19.33 | 0.86 | 13.15 | 85 | 6.11 | 7.75% | 29.30% |
| **Distributor** | 87 | 1 | 3 | 0 | 0 | 1 | 22.65 | 94 | -20.65 | -18.01% | 2.17% |
| **Retailer** | 89 | 1 | 2 | 0 | 0 | 1 | 21.94 | 100 | -14.94 | -13.00% | 7.53% |



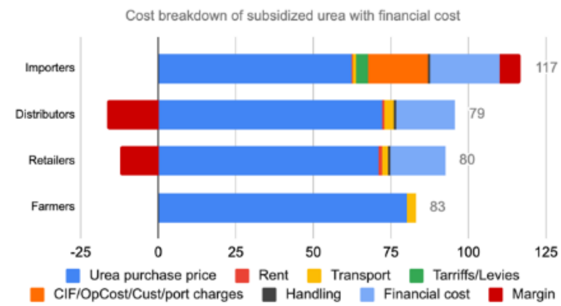

(a)



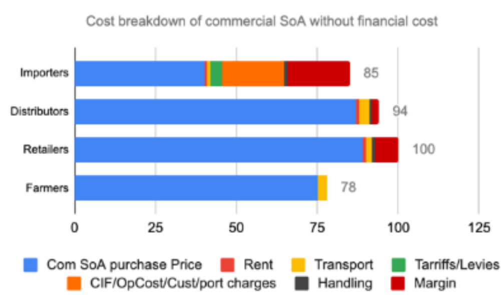

(b)



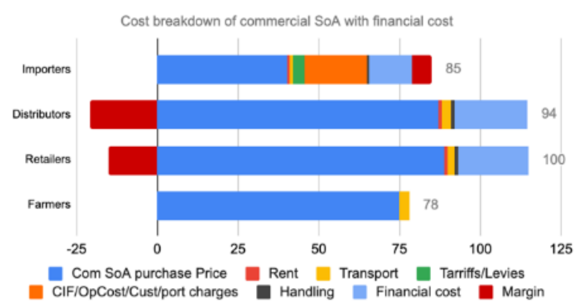

(c)




(d)




(e)




(f)

***Figure 7.*** ***Cost breakdown and margin distribution along the value chain for a 50-kg bag of commercial urea, subsidized urea, and SoA***

Figure 7 shows the distribution of margins and cost breakdown among value chain actors. For commercial urea, importers had a net positive margin (with and without the adjustment of financial cost), while distributors and retailers had low margins without factoring in financial cost. Meanwhile, when financial costs are factored in, distributors and retailers both made negative margins of -17.19% and -15.13%, respectively. This was the case for all three fertilizers investigated in this survey. Therefore, since all stakeholders' margins after factoring in financial costs were below 14.46%, which is the 365-day treasury bill rate in Ghana, we accept our null hypothesis, which states that stakeholder margins for commercial fertilizers are below the Bank of Ghana's 365-day treasury bill rate of 14.46% (BoG, 2020). The uneven distribution of margins is consistent with the observation by Fuentes et al. (2011) and IFDC (2019) that the exclusion of agro-dealers from subsidy price negotiation erodes their profitability, since they cannot hedge against risk and other macroeconomic fluctuations enjoyed by fertilizer importers. Also, farmers on average experienced a 3.75% increase in the retail price of fertilizers as a result of transportation cost. In addition, Figure 8 reveals that some agro-dealers seemed to be adjusting to market constraint, as 14% of distributors and 19% of retailers collected grains during harvest in exchange for fertilizers.

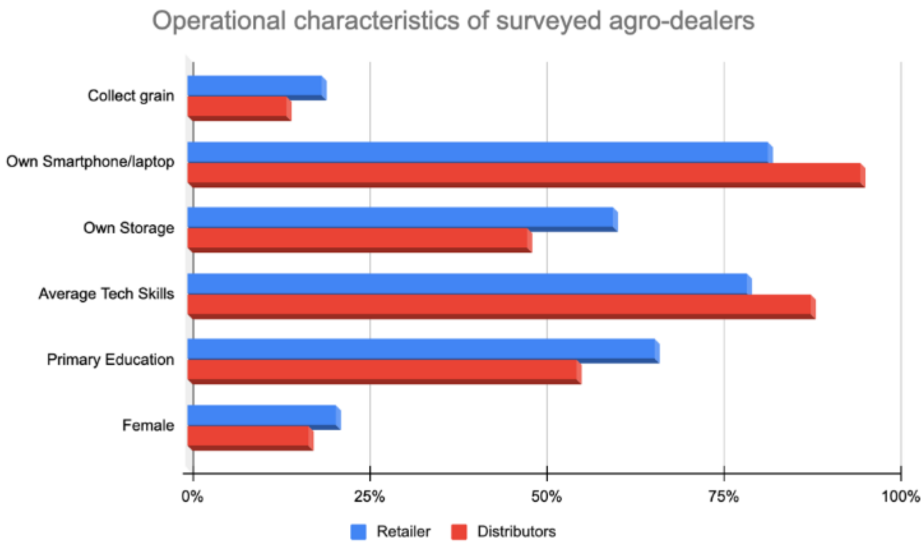
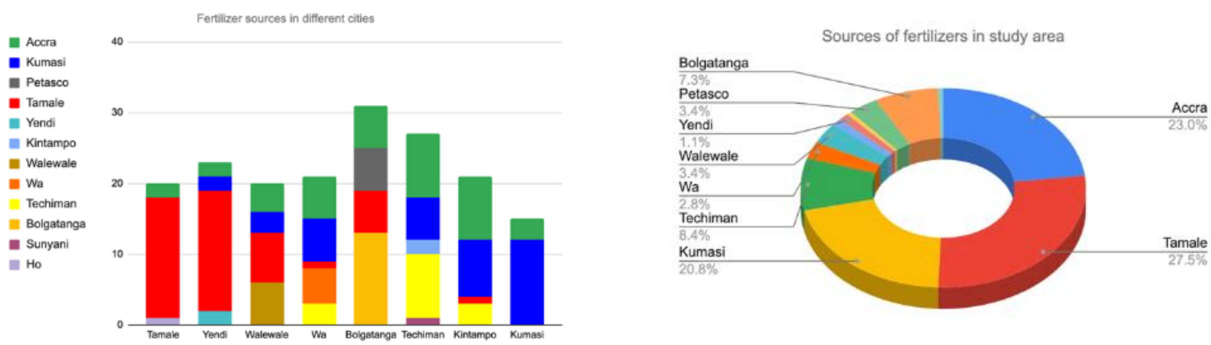



*Figure 8. Operational characteristics of surveyed agro-dealers in percentage*




(a) (b)

*Figure 9. (a) Total fertilizer sources in cities by agro-dealers and (b) percentage share of fertilizer source in study area*

Figure 9 (a and b) highlights the sources of fertilizers in individual cities surveyed, with Tamale, Accra, and Kumasi being the major source of fertilizers in the study regions. Accra is the point of entry for most fertilizers due to the port at Tema, while Tamale is a major fertilizer hub in the north and hosts some fertilizer importers. It was observed that fertilizer retail prices increased with transaction cost, as seen in Ashanti, Bono East, and Northern regions. However, Figure 10 revealed fertilizer retail prices were highest in the Northern region but lowest in the North-East region, which is in line with the observation of Bonilla et al. (2020) that commercial fertilizer prices were lower farther north in Ghana.

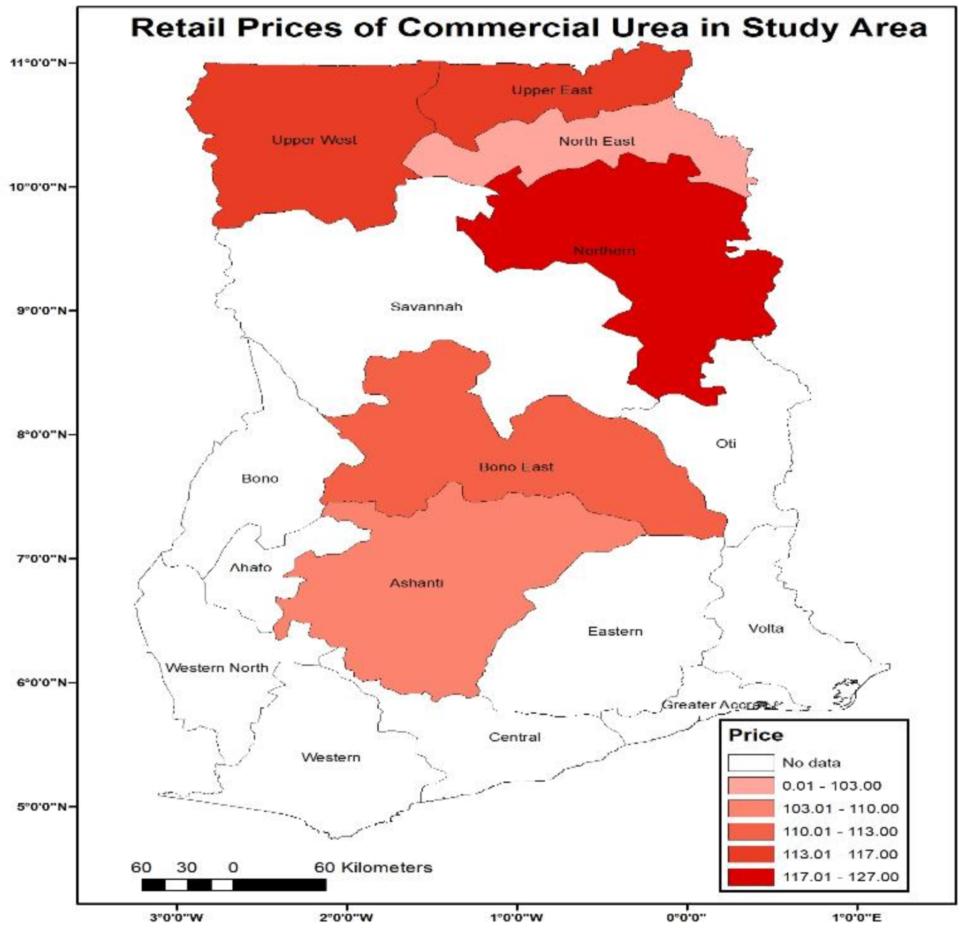



*Figure 10. Map presenting fertilizer retail prices within the study areas*

## 4.2 Market Integration

### 4.2.1 Unit Root Analyses

Market integration was investigated to understand spatial price transmission between Kasoa, Koforidua, Takoradi, Techiman, Mankessim, Seckondi, and Wench markets. Unit root analyses were conducted using the ADF test based on Akaike Info Criterion (AIC). The unit root analyses in Table 4 revealed all markets had unit root at level and were stationary only at first difference. Therefore, they are integrated at I(1).

*Table 4. Unit root analyses*

| Variables | 5% C.V. | Level | 1st Diff | Order |
|---|---|---|---|---|
| Seckondi Market | -2.896779 | -1.975771 | -7.221907 | I(1) |
| Takoradi Market | -2.896346 | -2.346104 | -7.365407 | I(1) |
| Techiman Market | -2.896346 | -2.088279 | -7.115513 | I(1) |
| Wench Market | -2.896346 | -2.176433 | 7.340624 | I(1) |
| Kasoa Market | -2.896779 | -0.461549 | -7.786163 | I(1) |
| Koforidua Market | -2.899115 | -1.633092 | -3.241306 | I(1) |
| Mankessim Market | -2.899619 | -1.53923 | -6.081129 | I(1) |

*Note: C.V. means critical value, 1st Diff is first difference, and Order means order of integration.*

### 4.2.2 Market Cointegration

Following the observed non-stationarity of the markets at level, cointegration analyses were carried out to investigate whether the markets have a long-run relationship. The Johansen (1991) cointegration technique was adopted. The trace and maximum eigenvalue test results in Table 5 reveal that there are two cointegrating equations among the markets investigated.

*Table 5. Result of trace and eigenvalue cointegration test*

| No. of CE(s) | Eigenvalue | Trace Stat | 5% C.V. | Prob. |
|---|---|---|---|---|
| None * | 0.515405 | 155.2104 | 125.6154 | 0.0002 |
| At most 1 * | 0.472945 | 103.0506 | 95.75366 | 0.0143 |
| At most 2 | 0.319450 | 56.93817 | 69.81889 | 0.3412 |
| At most 3 | 0.186705 | 29.22870 | 47.85613 | 0.7574 |
| At most 4 | 0.110963 | 14.34905 | 29.79707 | 0.8204 |
| At most 5 | 0.058011 | 5.880675 | 15.49471 | 0.7096 |
| At most 6 | 0.021676 | 1.577857 | 3.841466 | 0.2091 |

*Result of cointegration (maximum eigenvalue)*

| No. of CE(s) | Eigenvalue | Max-Eigen | 5% C.V. | Prob. |
|---|---|---|---|---|
| None * | 0.515405 | 52.15984 | 46.23142 | 0.0104 |
| At most 1 * | 0.472945 | 46.11241 | 40.07757 | 0.0093 |
| At most 2 | 0.319450 | 27.70947 | 33.87687 | 0.2272 |
| At most 3 | 0.186705 | 14.87965 | 27.58434 | 0.7577 |
| At most 4 | 0.110963 | 8.468371 | 21.13162 | 0.8728 |
| At most 5 | 0.058011 | 4.302818 | 14.26460 | 0.8261 |
| At most 6 | 0.021676 | 1.577857 | 3.841466 | 0.2091 |

*Note: Trace and maximum eigenvalue tests indicate two cointegrating eqn(s) at the 0.05 level; C.V. means critical value while * denotes rejection of the hypothesis at the 0.05 level.*

Following the result of two cointegrating equations in Table 5, a bivariate analysis was investigated to identify market pairs that are convergent in the long run. A converging market implies that current inefficiencies within the markets can be addressed in the future by policies and restructuring. The results revealed only three market pairs exhibited long-run relationship with each other. The co-integrating markets in Table 6 include: **Seckondi and Takoradi** markets; **Techiman and Takoradi** markets; and **Wench and Takoradi** markets. About 86% of the market pairs failed to show a long-run relationship. Based on results in Table 5 and 6, it can be inferred that, for the markets investigated, Ghana's fertilizer markets are not spatially integrated; therefore, the research null hypothesis is accepted.

*Table 6. Bivariate market cointegration results*

| MARKET | SECK__ | TAKO_ | TECH_ | WENC | KASO | KOFO | MANK_ |
|---|---|---|---|---|---|---|---|
| SECK_ | | YES | NO | NO | NO | NO | NO |
| TAKO_ | YES | | YES | YES | NO | NO | NO |
| TECH_ | NO | YES | | NO | NO | NO | NO |
| WENC_ | NO | YES | NO | | NO | NO | NO |
| KASO_ | NO | NO | NO | NO | | NO | NO |
| KOFO_ | NO | NO | NO | NO | NO | | NO |
| MANK__ | NO | NO | NO | NO | NO | NO | |

## 4.3 Relationship Between Commercial and Subsidized Fertilizers

### 4.3.1 Unit Root

In order to investigate the price relationship between commercial and subsidized fertilizers, a unit root analysis was conducted through an ADF test based on AIC to observe whether the variables are mean reverting and can be utilized for statistical analyses at level. The subsidized fertilizers investigated include subsidized urea (SUREA), subsidized NPK 15:15:15 (SNPK), commercial urea (CUREA), and commercial NPK 15:15:15 (CNPK). The ADF test revealed the presence of unit root at level for all variables; however, the variables became stationary at first difference. Table 7 revealed all the variables are integrated on the order of I(1). The unit root analysis verified the convergent capacity of the prices in the long run. Therefore, the properties of the data series of all the variables indicate that this study can proceed to carrying out a cointegration test between the variables in order I(1), using the Johansen (1991) techniques.

***Table 7. Subsidized and commercial fertilizers Unit root analyses***

| Variables | 5% C.V. | Level | 1st Diff. | Order |
|---|---|---|---|---|
| CNPK | -2.90621 | -1.556696 | 4.503577 | I(1) |
| SNPK | -2.921175 | 0.930954 | -6.238303 | I(1) |
| CUREA | -2.903566 | -1.049207 | -8.547421 | I(1) |
| SUREA | -2.919952 | 0.818019 | -6.382652 | I(1) |

*Note: C.V. means critical value; 1st Diff. means first difference, and Order means the order of integration.*

### *4.3.2 Subsidized and Commercial Fertilizers Price Cointegration Analysis (2012-2019)*

In conducting a cointegration test between the variables with the aim of estimating the relationship between the prices of the different types of fertilizers in Ghana, this study adopted the Johansen (1991) method, which is less restrictive to cointegration. The results of the cointegration test are shown in Table 8. In this test, the null hypothesis, which stipulates that there is no relationship between the variables, is accepted because the coefficients of trace and maximum eigenvalue of 36.32 and 20.78, respectively, are less than their corresponding critical values. Also, their *p*-values are higher than the 5% level of significance. Specifically, the results by trace and maximum eigenvalue tests found no cointegrating equations. The results imply that there is no long-run relationship between the variables; in essence, there is no long-run relationship between the prices of the different types of fertilizers (SUREA, SNPK, CUREA, and CNPK) investigated in this study in Ghana. In view of this, it is imperative to conduct a short-run analysis to examine whether a short-run relationship exists between these variables through a VAR analysis.

*Table 8. Unrestricted cointegration rank test*

*Trace eigenvalue*

| No. of CE(s) | Eigenvalue | Trace | 5% C.V. | Prob.** |
|---|---|---|---|---|
| None | 0.511619 | 36.32105 | 47.85613 | 0.3804 |
| At most 1 | 0.335510 | 15.53794 | 29.79707 | 0.7443 |
| At most 2 | 0.109776 | 3.684591 | 15.49471 | 0.9273 |
| At most 3 | 0.010715 | 0.312412 | 3.841466 | 0.5762 |

*Maximum eigenvalue*

| No. of CE(s) | Eigenvalue | Max-Eigen | 5% C.V. | Prob.** |
|---|---|---|---|---|
| None | 0.511619 | 20.78311 | 27.58434 | 0.2896 |
| At most 1 | 0.335510 | 11.85335 | 21.13162 | 0.5622 |
| At most 2 | 0.109776 | 3.372180 | 14.26460 | 0.9189 |
| At most 3 | 0.010715 | 0.312412 | 3.841466 | 0.5762 |

*Note: Trace and maximum eigenvalue tests indicates no cointegrating eqn(s) at the 0.05 level; C.V. means critical value, while * denotes rejection of the hypothesis at the 0.05 level.*

## 4.4 Vector Auto Regressive Model for Subsidized and Commercial Fertilizer Monthly Prices (2012-2019)

The VAR model begins with the VAR Lag Order Selection. The results of the Likelihood Ratio (LR), sequential modified LR test statistic, final prediction error (FPE), AIC, Schwarz information criterion (SC); and Hannan-Quinn information criterion (HQ) all supported a lag length of 2 for the variables. Consequently, the VAR model was estimated based on lag 2, and the results are presented in Table 9.

*Table 9. VAR result on commercial NPK and subsidized NPK*

| | CNPK | SNPK |
|---|---|---|
| CNPK(-1) | 0.496028 | -0.036943 |
| | (0.15358) | (0.05980) |
| | [ 3.22978] | [-0.61778] |
| CNPK(-2) | 0.337847 | -0.041173 |
| | (0.15379) | (0.05988) |
| | [ 2.19684] | [-0.68757] |
| SNPK(-1) | 1.035798 | 0.928045 |
| | (0.42843) | (0.16682) |
| | [ 2.41766] | [ 5.56312] |
| SNPK(-2) | -0.976656 | 0.121003 |

| | CNPK | SNPK |
|---|---|---|
| | (0.44772) | (0.17433) |
| | [-2.18139] | [ 0.69409] |
| C | 55.66948 | 19.96889 |
| | (37.1883) | (14.4802) |
| | [ 1.49696] | [ 1.37904] |
| R-squared | 0.795973 | 0.986912 |
| Adj. R-squared | 0.774496 | 0.985534 |
| Sum sq. residuals | 36166.80 | 5483.397 |
| S.E. equation | 30.85058 | 12.01249 |
| F-statistic | 37.06242 | 716.3421 |
| Log likelihood | -205.8103 | -165.2524 |
| Akaike AIC | 9.805132 | 7.918715 |
| Schwarz SC | 10.00992 | 8.123506 |
| Mean dependent | 495.4419 | 392.6512 |
| S.D. dependent | 64.96604 | 99.87561 |

Table 9 shows a VAR estimate with two models. The R-squared coefficients of 0.80 and 0.99 for CNPK and SNPK, respectively, indicate that the independent variables of the models explain the up to 80% and 99% variations in the dependent variables of the respective models. In the CNPK model, the coefficients of lagged CNPK and SNPK are statistically insignificant. This means that there is no relationship between the lagged CNPK prices and SNPK prices on CNPK prices. In the same vein, the coefficients of lagged CNPK and two-year lagged CNPK are not statistically significant in the SNPK model. To understand the causality, however, the bounds or Wald's test was performed on individual variables in the models. The bounds test output is documented in Appendix 3J.

### 4.4.1 Model 1: Causality from Subsidized NPK to Commercial NPK

For subsidized NPK, the VAR estimates show a positive relationship with commercial fertilizer in the first period but a negative one in the second period. However, the joint test by the Wald statistics indicates that the lag variable of subsidized NPK fertilizer prices jointly does cause the price of the commercial NPK fertilizer prices. The F-statistic is 4.71. When compared to the upper bound Pesaran table (4.85), it does refute the null hypothesis of no causality. This implies that lags of subsidized NPK cause commercial NPK, which means the price of subsidized NPK influences future prices of commercial NPK.

### 4.4.2 Model 2: Causality from Commercial NPK to Subsidized NPK

For the commercial NPK price, the VAR estimates showed a negative relationship with commercial NPK fertilizer price in both first and second periods. However, the joint test by the Wald statistics indicates that the lag variable of commercial NPK fertilizer prices jointly does not significantly cause the current price of the subsidized NPK fertilizer. The F-statistic is 2.44, and when compared to the upper bound Pesaran table (4.85), it does confirm the null hypothesis of no causality. This implies that lags of commercial NPK fertilizer price does not cause current subsidized NPK fertilizer price.

### 4.4.3 Commercial Urea Prices and Subsidized Urea Prices

The VAR model begins with the VAR Lag Order Selection. The result of LR, sequential modified LR test statistic, FPE, AIC, SC, and HQ all supported a lag length of 2 for the variables in Appendix Table 3B. Consequently, the VAR model was estimated based on lag 2. The results of the VAR analyses between CUREA and SUREA are presented in Table 10.

***Table 10. VAR result on commercial and subsidized urea fertilizer***

| | CUREA | SUREA |
|---|---|---|
| CUREA(-1) | 0.842581 | -0.025104 |
| | (0.14514) | (0.04489) |
| | [ 5.80537] | [-0.55928] |
| CUREA(-2) | 0.103051 | -0.022035 |
| | (0.14926) | (0.04616) |
| | [ 0.69041] | [-0.47735] |
| SUREA(-1) | 1.872830 | 0.944375 |
| | (0.51432) | (0.15906) |
| | [ 3.64139] | [ 5.93723] |
| SUREA(-2) | -1.827219 | 0.097235 |
| | (0.53850) | (0.16654) |
| | [-3.39315] | [ 0.58385] |
| C | 10.40678 | 7.863733 |
| | (35.3121) | (10.9208) |
| | [ 0.29471] | [ 0.72007] |
| R-squared | 0.846167 | 0.987822 |
| Adj. R-squared | 0.830390 | 0.986573 |
| Sum sq. resids | 63417.84 | 6065.554 |
| S.E. equation | 40.32491 | 12.47105 |
| F-statistic | 53.63056 | 790.8832 |
| Log likelihood | -222.4461 | -170.8095 |
| Akaike AIC | 10.33846 | 7.991341 |
| Schwarz SC | 10.54121 | 8.194090 |
| Mean dependent | 485.3636 | 370.8864 |
| S.D. dependent | 97.91455 | 107.6256 |

Table 10 shows VAR estimates with two models. The adjusted R-square results show that the models explained 84% and 98% of variations in commercial and subsidized urea prices, respectively, over the time periods considered in this study. The model infers causality between commercial and subsidized urea fertilizer prices. The inclusion of lags causes insignificant variables; interpreting the output may offer no economic sense. To understand the joint causality effect of these variables, the bounds or Wald test was performed and the results are presented in Appendix 3K.

### 4.4.4 Model 1: Causality from Subsidized Urea to Commercial Urea

The VAR estimates for SUREA showed a positive relationship with commercial urea fertilizer in the first period but negatively varied in the second lag. However, the joint test by the Wald statistics indicate that the lag variable of subsidized urea fertilizer prices jointly does cause the price of the commercial urea fertilizer. The F-statistic is 8.75. When compared to the upper bound Pesaran table (4.85), it does refute the null hypothesis of no causality. This implies that lags of subsidized urea prices cause commercial urea prices. Hence, it is confirmed that the prevailing price of subsidized urea influences the future price of commercial urea fertilizers. Since the subsidy price is lower than the commercial market fertilizer price, commercial agro-dealers tend to reduce their prices in order to remain competitive. This can be further substantiated by the distribution of margins in Figure 7, which indicates commercial urea had the lowest margins when compared to subsidized urea. Hence, the PFJ FSP's externality effect is likely to be eroding the profitability of commercial fertilizers in Ghana.

### 4.4.5 Model 2: Causality from Commercial Urea to Subsidized Urea

For the commercial urea price, the VAR estimates showed a negative relationship with the commercial urea fertilizer price in both first and second lags. However, the joint test (Wald test result) indicates that the lag variable of commercial urea fertilizer prices jointly does not cause the price of the subsidized urea fertilizer. The F-statistic is 1.316; when compared to the upper bound Pesaran table (4.85), it confirms the null hypothesis of no causality. This implies that lags of commercial urea fertilizer price do not cause the price of subsidized urea fertilizer. Hence, the research's null hypothesis of commercial fertilizer price causing subsidized fertilizer price is rejected.

# CHAPTER 5: DISCUSSION

## 5.1 Discussion

Findings reveal that Ghana's fertilizer value chain is inefficient, as fertilizer prices are lower in the North-East, Upper-West, and Upper-East regions compared to fertilizer retail prices in the Northern region, which is a major hub for fertilizer trade; most importers interviewed have warehouses in Tamale, the capital of Northern region. While looking at the value chain vertically, prices between distributors and retailers are not consistent, as some fertilizers had higher prices in distribution outlets (wholesale) when compared to retail outlets. Second, price transmissions between fertilizer markets are weak, since only three market pairs were observed to exhibit a long-run relationship. This weak fertilizer market could be a result of asymmetric information, trade barriers, externality effects, or a lack of competition, as stipulated by Dowding and Taylor (2020). However, it cannot be concluded that the observed inefficiency is caused by the FSP, even with the analyses confirming that the price of subsidized fertilizers for both NPK and urea influences the price of subsequent commercial NPK and urea prices, respectively. Further research on fertilizer price transmission is needed on a broader scale, especially for SoA which is not captured under the FSP, to better understand the effect of the FSP on the fertilizer market.

Furthermore, there is optimism in the value chain as the FSP program, through its fertilizer quota, has transformed some distributors to importers as observed in Tamale, which could be why the city is a major fertilizer trading hub.

Also observed was that 14% of distributors and 19% of retailers surveyed collected grains, ranging from soybean, rice, and maize, in place of cash from farmers. Since access to markets and credit are constraints faced by farmers, the exchange of farm commodities for fertilizers seems to be a good alternative for both farmers and fertilizer retailers. Thus, fertilizers are given as credit to be repaid with grains after harvest, which is likely to yield more value with time for these retailers. This provides a lot of opportunities for private sector investment and even for the GoG as a way of providing market-based solutions for farmers and to increase fertilizer consumption. However, more research is needed in the area to establish whether grains for fertilizers induces fertilizer consumption between farmers and whether the farmers get a fair price for their commodities.

It was also observed that 95% of distributors and 82% of retailers own a smartphone or a laptop; 88% of distributors and 79% of retailers rate their skills in using these gadgets above average. This finding encourages the use of ICT in coordinating the fertilizer value chain for smart subsidy programs with more efficiency, which would increase the timeliness along the chain and the quality of information accessed by these agro-dealers (AGRA, 2019).

Finally, gender participation in the value chain is relatively skewed against women and worsens up the chain, as only 21% of retailers and 17% of distributors are women. The low female participation could be a result of gender-based impediments associated with starting a business, such as poor access to finance, low level of education, and cultural disenfranchisement (Aristei and Gallo, 2016; Sauer and Wiesemeyer, 2018; Morsy, 2020).

## 5.2 Conclusion and Recommendation

In summary, the FSP has successfully increased competition in the fertilizer value chain upstream through its subsidy quota and by making sure importers get appropriate return on investment (ROI) through subsidy negotiations. However, the fertilizer value chain downstream is stifled by low margins that have disincentivized the expansion of distribution and retail networks to remote regions. The effect of a poor distribution network, as highlighted in Figure 7, implies that farmers have the highest average transportation cost per 50-kg bag (GH₵ 3) in the entire value chain. This could discourage fertilizer use among farmers and further jeopardize the effort of the entire subsidy program. However daunting, these challenges are not insurmountable as the GoG, through MoFA, has continually improved the FSP for greater impact. Examples include the introduction of a new fertilizer formulation for higher productivity and the introduction of designated retailers in border towns to curb fertilizer smuggling to neighboring countries. In light of the challenges outlined, the following are recommended for optimal performance of the fertilizer value-chain.

### *5.2.1 Inclusive Subsidy Negotiation*

An inclusive subsidy negotiation in line with the IFDC optimization study (2019) in which the challenges and cost components of value chain actors until the last mile will guarantee all costs encountered until the fertilizers are delivered to targeted farmers are captured in subsequent negotiations, as depicted in Figure 11. Inclusiveness would also ensure appropriate ROI and galvanize private sector involvement. This can be achieved through a multi-stakeholder platform backed by MoFA and supported by civil society organizations (CSOs), such as the International Fertilizer Development Center (IFDC) and African Fertilizer and Agribusiness Partnership (AFAP). The role of the public sector in the multi-stakeholder platform cannot be overemphasized, as it is the responsibility of the government to provide a conducive environment for the private sector to thrive. However, the role of fertilizers in crop productivity, rural development, and food security makes the platform a top priority for the GoG. An elaborate fertilizer distribution network would reduce farmers' travel time and cost associated with the purchase of fertilizers and induce fertilizer consumption in remote communities.

### *5.2.2 Cost-Benefit Analyses of the Subsidy Program*

The GoG should conduct a cost-benefit analyses of its FSP in order to channel resources into alternative investments with high ROI and social impacts. Alternative subsidy options might provide an exit plan for subsidy interventions.

### *5.2.3 Subsidized Credit Mechanism*

An in-country financial mechanism in line with the *Abuja Declaration* Resolution 7 should be introduced (FAO 2015). A national fertilizer financing mechanism would ensure value chain actors have access to low-interest loans when needed. These would unlock opportunities of economies of scale and lead to upward mobilization, as seen in Tamale where distributors transformed to importers.

### *5.2.4 Stimulate Private Sector Agtech Companies*

Start-up agricultural technology (agtech) companies in SSA, such as Farmcrowdy and Thrive Agric in Nigeria and One Acre Fund in East Africa, are known to provide micro-credit in the form of inputs for farmers in exchange for money or commodities after harvest. In Nigeria, Farmcrowdy has increased the income of enrolled farmers enrolled by 80% (Farmcrowdy, 2020). In Ghana, agro-dealers are adjusting to market constraints, such as farmers' poor access to finance and commodity markets. These agro-dealers already collect farm commodities in place of cash for fertilizers. However, this provides an opportunity for private sector participation in providing inputs in exchange for farm commodities. This would not only solve the input challenge of farmers but would also address the poor commodity market challenges faced by farmers. The GoG, through policies and financial interventions, can stimulate private sector agtech companies to fill in the gap and reduce the subsidy burden.

### *5.2.5 Increase Research and Development (R&D)*

Agricultural R&D has proven to be integral in agricultural transformation (FAO, 2009). The GoG would need reliable evidence-based research to guide policymaking and implementation in order to fast-track agricultural transformation in Ghana (Shakhovskoy et al., 2020). Due to the profiteering nature of the private sector and the small size of Ghana's fertilizer market, the GoG would have to take the lead in R&D in order to adequately disseminate findings for higher impact.

## 5.3 Research Perspective

It is possible that some agro-dealers did not provide accurate prices. However, based on the law of large numbers, the more a sample increases, the closer the sample mean moves to the real mean. Hence, our average fertilizer prices, as collated in this survey, are in line with the average fertilizer prices across Ghana, as reported by AfricaFertilizer.org. Furthermore, the VAR model utilized in this study is apt in respect to the non-cointegrating data sets. The price transmission in Ghana fertilizer markets might be different in other market clusters, such as the North of Ghana, but due to data constraints, markets located in the north and east of Ghana were not investigated. For future research, more comprehensive market integration analyses across all fertilizer markets in the 16 regions are recommended. Second, it is germane to ascertain whether the high cost of transportation paid by farmers acts as a disincentive to the use of fertilizers by farmers. Finally, we established that subsidized fertilizer prices influence the subsequent prices of commercial fertilizers; however, we could not establish whether subsidized fertilizers were crowding out commercial fertilizers at the retail outlets since commercial fertilizer prices had the lowest margins for all value chain actors.

# REFERENCES


Acharya, S. S., Chand, R., Birthal, P. S., Kumar, S., & Negi, D. S. (2012). Market integration and price transmission in India: A case of rice and wheat with special reference to the world food crisis of 2007/08. Food and Agriculture Organization, Rome. 63pp.

AGRA (2019). Africa Agriculture Status Report: The Hidden Middle: A Quiet Revolution in the Private Sector Driving Agricultural Transformation. Nairobi, Kenya: Alliance for a Green Revolution in Africa (AGRA), (Issue 7).

Alexander, C., & Wyeth, J. (1994). Cointegration and market integration: An application to the Indonesian rice market. Journal of Development Studies, 30, 303-328.

Ansah, I. G., Lambongang, M., & Donkoh, S. A. (2020). Ghana's Planting for Food and Jobs Programme: A Look at the Role of Capability in Farmers' Participation. Journal of Human Development and Capabilities, 21(2), 161-182.

Aristei, D., & Gallo, M. (2016). Does gender matter for firms' access to credit? Evidence from international data. Finance Research Letters, 18, 67-75.

Barrett, C. B. (2008). Spatial Market Integration. The New Palgrave Dictionary of Economics, 2nd Edition, Lawrence E. Blume, Steven N. Durlauf, eds., London: Palgrave Macmillan, Forthcoming, Available at SSRN: https://ssrn.com/abstract=1142520

Bank of Ghana (BoG) (2020): Treasury Bill Rates. https://www.bog.gov.gh/treasury-and-the-markets/treasury-bill-rates Accessed: 2020-07-18

Baulch, B. (1997). Transfer costs, spatial arbitrage, and testing for food market integration. American Journal of Agricultural Economics, 79, 477-487.

Baquedano, F. G. & Liefert, W. M. (2014). Market integration and price transmission in consumer markets of developing countries. Food Policy, 44, 103-114.

Bjørnland, H. C. (1996). The dynamic effects of aggregate demand, supply and oil price shocks. Discussion Papers No. 174, 1- 42

Blein, R., Soule, B. G., Dupaigre, B. F. & Yerima, B. (2008). Agricultural Potential of West Africa. Economic Community of West African States (ECOWAS). Foundation pour l'agriculture et la ruralité dans le monde (FARM), 118.

Bonilla Cedrez, C., Chamberlin, J., Guo, Z. & Hijmans, R. J. (2020). Spatial variation in fertilizer prices in Sub-Saharan Africa. PloS One, 15(1), e0227764.

Brinkman, H. J., De Pee, S., Sanogo, I., Subran, L. & Bloem, M. W. (2010). High food prices and the global financial crisis have reduced access to nutritious food and worsened nutritional status and health. The Journal of Nutrition, 140(1), 153-161.

Carlton, D. W. (2007). Market Definition: Use and abuse. Competition Policy International, 3(1).

Chakraborty, K. (2016). Determinants of demand for fertilizer: A case for India. Asian Journal of Agriculture and Development, 13(1362-2017-804), 77-86.

Chembezi, D. M. (1990). Estimating fertilizer demand and output supply for Malawi's smallholder agriculture. Agricultural Systems, 33(4), 293–314.

Danso-Abbeam, G., Aidoo, R., Agyemang, K. O. & Ohene-Yankyera, K. (2012). Technical efficiency in Ghana's cocoa industry: evidence from Bibiani-Anhwiaso-Bekwai District. Journal of Development and Agricultural Economics, 4(10), 287-294.

Delgado, C. L. (1986). A variance component approach to food grain market integration in northern Nigeria. American Journal of Agricultural Economics, 68(4), 970-979.

Dowding, K. & Taylor, B. R. (2020). Economic perspectives on government. Palgrave Macmillan.

Enders, C. K. (2010). Applied missing data analysis. New York: Guilford Press.

Farmcrowdy (2020). Farm Stories. Retrieved August 20, 2020 from https://www.farmcrowdy.com/farm-stories

Fama, E. G. (1991). Efficient capital markets: II. The Journal of Finance 46(5), 1575-1617.

FAO (2009). How to feed the world in 2050: Executive Summary. Food and Agriculture Organization. 35pp.

FAO (2015). Boosting Africa's soil: from the Abuja declaration on fertilizers to a sustainable soil management framework for food and nutrition security in Africa by 2030. Food and Agriculture Organization (FAO) Regional overview of food insecurity in Africa. 16pp.

FAO (2020). Ghana at a glance | FAO in Ghana | Food and Agriculture Organization of the United Nations. Retrieved May 6, 2020 from http://www.fao.org/ghana/fao-in-ghana/ghana-at-a-glance/en

Fuentes, P.A., Bumb, B., & Johnson, M. (2012). Improving fertilizer markets in West Africa: the fertilizer supply chain in Ghana. IFDC Paper Series, 30pp.

Galang, I. M. R. (2014). A spatial integration analysis of the regional fertilizer markets in the Philippines. Philippines Institute for Development Studies (PIDS) Discussion Paper Series, 2014. 27pp.

Ghana Cocoa Board (2018). Environmental and social management system (ESMS). Ghana Cocoa Board Report on October 25th, 2018, 40pp.

Groom, B., & Tak, M. (2015). Welfare analysis of changing food prices: a nonparametric examination of rice policies in India. Food Security, 7(1), 121-141.

Hamilton, J. D. (1983). Oil and the macroeconomy since World War II. Journal of political economy, 91(2), 228-248.

Hoover, K. D., Johansen, S., & Juselius, K. (2008). Allowing the data to speak freely: The macroeconometrics of the cointegrated vector autoregression. American Economic Review, 98(2), 251-55.

Houssou, N., Andam, K., & Asante-Addo, C. (2017). Can better targeting improve the effectiveness of Ghana's Fertilizer Subsidy Program? Lessons from Ghana and other countries in Africa south of the Sahara. International Food Policy Research Institute (IFPRI) Discussion Paper 01605 February 2017. 37pp.

Hu, Z., & Brorsen, B. W. (2017). Spatial price transmission and efficiency in the urea market. Agribusiness, 33(1), 98-115.

Huang, W. Y. (2009). Factors contributing to the recent increase in US fertilizer prices, 2002-08. DIANE Publishing. United States Department of Agriculture (USDA): A Report from the Economic Research Service. 21pp.

Iddrisu, A. M., Gafa, D. W., Abubakari, M., Emini, C. A., & Beaumais, O. (2020). How the fertilizer subsidy program can boost economic growth and employment in Ghana. Accessed on August 20, 2020 from https://www.africaportal.org/publications/how-fertilizer-subsidy-program-can-boost-economic-growth-and-employment-ghana

IFDC (2019). Ghana fertilizer value chain optimization study. International Fertilizer Development Centre (IFDC) Report for United States Agency for International Development (USAID) under the Feed The Future initiative, 95pp.

Jayaraj, D. S. (2016). Analysis of Financial Integration in India: A VECM approach. IOSR Journal of Business and Management , 27-38.

Jayne, T. S. (1994). Do high food marketing costs constrain cash crop production? Economic Development and Cultural Change, 42(2), 387–402.

Jayne, T. S., Kelly, V., & Crawford, E. (2003). Fertilizer consumption trends in Sub-Saharan Africa. Food Security II Policy Synthesis 69, 1-4.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica: journal of the Econometric Society, 1551-1580.

Johansen, S., & Juselius, K. (1994). Identification of the long-run and the short-run structure an application to the ISLM model. Journal of Econometrics, 63(1), 7-36.

Ikeora, J. J. E., Igbodika, M. N., & Andabai, P. W. (2016). Banking sector reforms and the performance of the Nigerian economy: A Vector Error Correction Investigation (Vecm). European Journal of Research and Reflection in Management Sciences, 4(2), 1-8.

Kelly, V. A. (2005). Farmers' Demand for Fertilizer in Sub-Saharan Africa. Michigan State University, Department of Agricultural, Food and Resource Economics, Staff Paper Series 11612. https://doi.org/10.22004/ag.econ.11612

Klutse, A. R., Bationo, A., & Mando, A. (2018). Socio-economic determinants and trends on fertilizer use in West Africa. In: Improving the Profitability, Sustainability and Efficiency of Nutrients through Site Specific Fertilizer Recommendations in West Africa. Agro-Ecosystems (pp. 253-274).

Lutz, C., Tilburg, A. V., & Kamp, B. V. D. (1995). The process of short-and long-term price integration in the Benin maize market. European Review of Agricultural Economics, 22(2), 191-212.

Mabe, F. N., Danso-Abbeam, G., & Ehiakpor, D. S. (2018). Assessment of implementation of Planting for Food and Jobs (PFJ) programms: lessons and way forward. Agriculture Policy Support, 36-56p. https://doi.org/10.13140/RG.2.2.34030.46402

Mahmood, S., Musibau, H. O., & Masud, A. (2017). The analysis of Pedroni Co-integration and VECM on export performance and exchange rate fluctuation. International Journal of Advanced and Applied Sciences, 4(11), 43-48.

Manos, B., Begum, M. A. A., Kamruzzaman, M., Nakou, I., & Papathanasiou, J. (2007). Fertilizer price policy, the environment, and farms behavior. Journal of Policy Modeling, 29(1), 87-97.

Maxwell, J. A. (2012). Qualitative research design: An interactive approach (Vol. 41). Sage publications. 219pp.

Mohanty, S. K., & Mishra, S. (2020). Regulatory reform and market efficiency: The case of Indian agricultural commodity futures markets. Research in International Business and Finance 52, 101145.

Morsy, H. (2020). Access to finance–mind the gender gap. The Quarterly Review of Economics and Finance. Working Paper No. 202, 30pp.

Obayelu, A. E., & Salau, A. S. (2010). Agricultural response to prices and exchange rate in Nigeria: Application of co-integration and Vector Error Correction Model (VECM). Journal of Agricultural Sciences 1(2), 73-81.

Obisesan, A. A., Akinlade, R. J., & Fajimi, F. O. (2013). Determinants of fertilizer use among smallholder food crop farmers in Ondo State, Nigeria. American Journal of Research Communication 1(7), 254-260.

Otieno, B. A. (2017). Econometric modelling of short run parsimonious and long run co-integrated real exchange rate determinants in Kenya. African Journal of Education, Science and Technology 3(3), 155-165.

Otsuka, K., & Muraoka, R. (2017). A green revolution for sub-Saharan Africa: Past failures and future prospects. Journal of African Economies 26, 173-198.

Petrick, M., & Latruffe, L. (2003). Credit access and borrowing costs in Poland's agricultural credit market: a hedonic pricing approach. Institute of Agricultural Development in Transition Economics (IAMO), IAMO Discussion Papers 14905. https://doi.org/10.22004/ag.econ.14905

Priebe, F. (2019). Dynamic Model Selection for Automated Machine Learning in Time Series. 77pp.

Ragasa, C. & Chapoto, A. (2017). Moving in the right direction? The role of price subsidies in fertilizer use and maize productivity in Ghana. Food security 9(2), 329-353

Rashid, S., Tefera, N., Minot, N., & Ayele, G. (2014). Fertilizer in Ethiopia: An Assessment of Policies, Value Chain, and Profitability. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2373214

Rapsomanikis, G., Hallam, D., & Conforti, P. (2006). Market integration and price transmission in selected food and cash crop markets of developing countries: review and applications. Agricultural Commodity Markets and Trade 187-217.

Richards, D., Abbam-Boadu, P., & Ekwulugo, F. (2016). Economic Union (ECOWAS) of challenged relevance and market compatibility. The Business & Management Review 7(5), 422.

Richardson, J. D. (1978). Some empirical evidence on commodity arbitrage and the law of one price. Journal of International Economics 8(2), 341-351.

Ripplinger, D., & Miljkovic, D. (2017). Fertilizer, Natural Gas, and Corn: A Case of a Price Switching Regime (No. 1187-2019-2278).

Rojas, M., & Rojas, L.A. (1997). Transaction Costs in Mexico's Preferential Credit. Development Policy Review 15, 23-46.

Rufino, C. C. (2008). Inter-Regional Integration of the Philippine Rice Market. DLSU-AKL Working Paper Series, 6.

Sauer, R. M., & Wiesemeyer, K. H. (2018). Entrepreneurship and gender: differential access to finance and divergent business value. Oxford Review of Economic Policy 34(4), 584-596.

Scheiterle, L., Häring, V., Birner, R., & Bosch, C. (2019). Soil, Striga, or subsidies? Determinants of maize productivity in northern Ghana. Agricultural Economics 50(4), 479-494.

Shakhovskoy, M., Cuevas, C. M., Wattel, C. J., Sopov, M. B., van Asseldonk, M. A. P. M., Pamuk, H., ... & Carroll, T. (2020). Role of government in rural and agri-finance: Transitioning to private sector involvement: Briefing note 17. ISF. 16p.

Sheffet, O. (2017). Differentially private ordinary least squares. In: Proceedings of the 34th International Conference on Machine Learning.70, 3105-3114.

Sohail, A. S., Sameen, M., & Ahmed, Q. (2019, January). Understanding Monetary Policy Communication: A VECM Approach Based on Pakistan. In: 2019 International Conference on Green and Human Information Technology (ICGHIT) (pp. 133-138). IEEE.

Wiredu, A. N., Zeller, M., & Diagne, A. (2019). Impacts of Fertilizer Subsidy on Food Security of Rice Producing Households in northern Ghana. Proceedings of the 6th African Conference of Agricultural Economists, Abuja, FCT, Nigeria. 27pp.

World Bank (2020). Population, total - Ghana. Data retrieved May 6, 2020, from https://data.worldbank.org/indicator/SP.POP.TOTL?end=2018&locations=GH&most_recent_year_desc=false&start=1960

Worthington, A. C., & Higgs, H. (2009). Efficiency in the Australian stock market, 1875–2006: a note on extreme long-run random walk behaviour. Applied Economics Letters, 16(3), 301-306.

Yen, G., & Lee, C.F. (2008). Efficient markets hypothesis (EMH): past, present, and future. Review of Pacific Basin Financial Markets and Policies 11(2), 305-329..

# Appendices

## Appendix 1. Objective 1: Cost Components and Distribution of Margins

### *Appendix Table 1A. Descriptive statistics*

| | Retailers | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NPK 12 22 21 | | | | NPK 12 30 17 | | | | NPK 20 10 10 | | | | NPK 23 10 5 | | | | NPK 25 10 10 | | | | NPK15 20 20 | | | | Urea | | | | Ammonium Sulfate | | | | | | |
| | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | | | | | |
| | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Hand cost** | **Inte rate** | **Fin Cost (Urea)** | **Trans/bag** | **Rent/bag** |
| **Mean** | 98 | 137 | 74 | 80 | 114 | 141 | 73 | 83 | 116 | 121 | 74 | 80 | 114 | 127 | 73 | 79 | 111 | 124 | 73 | 80 | 113 | 119 | 73 | 77 | 113 | 118 | 71 | 80 | 89 | 100 | 1 | 0 | 24 | 2 | 1 |
| **Median** | 98 | 130 | 74 | 80 | 115 | 135 | 75 | 84 | 115 | 120 | 70 | 75 | 115 | 120 | 72 | 75 | 115 | 120 | 70 | 78 | 110 | 120 | 70 | 75 | 112 | 120 | 70 | 80 | 90 | 100 | 1 | 0 | 24 | 2 | 1 |
| **Maximum** | 100 | 168 | 76 | 90 | 130 | 168 | 75 | 90 | 168 | 168 | 95 | 100 | 168 | 168 | 85 | 90 | 168 | 168 | 90 | 95 | 168 | 168 | 84 | 84 | 160 | 160 | 86 | 90 | 120 | 130 | 5 | 0 | 38 | 8 | 3 |
| **Minimum** | 95 | 110 | 70 | 74 | 95 | 120 | 70 | 75 | 90 | 90 | 65 | 74 | 86 | 110 | 50 | 70 | 75 | 90 | 60 | 70 | 95 | 84 | 69 | 71 | 90 | 90 | 60 | 65 | 68 | 68 | 0 | 0 | 6 | 0 | 1 |
| **Std. Dev** | 3.5 | 25.1 | 2.3 | 5.6 | 14.9 | 24.6 | 2.5 | 7.5 | 16.1 | 15.0 | 6.5 | 7.9 | 16.5 | 16.5 | 6.2 | 4.9 | 15.7 | 17.6 | 5.5 | 5.5 | 14.6 | 17.7 | 4.4 | 4.2 | 19.1 | 18.1 | 5.6 | 4.2 | 11.2 | 17.2 | 0.7 | 0.0 | 6.5 | 1.5 | 0.4 |
| **Skewness** | 0.0 | 0.4 | -0.7 | 0.5 | -0.2 | 0.4 | -0.6 | -0.2 | 1.2 | 1.6 | 1.7 | 1.6 | 1.3 | 1.7 | -0.8 | 0.4 | 0.9 | 1.3 | 0.8 | 0.5 | 2.5 | 1.5 | 1.3 | 0.9 | 1.0 | 0.7 | 0.3 | -0.6 | 0.2 | 0.0 | 3.0 | -3.3 | -0.2 | 1.1 | 2.6 |
| **Kurtosis** | 1.0 | 1.5 | 2.3 | 2.1 | 1.7 | 1.5 | 1.5 | 1.5 | 5.5 | 7.3 | 5.6 | 4.3 | 5.5 | 4.8 | 5.1 | 2.0 | 6.8 | 4.7 | 4.6 | 2.4 | 10.4 | 6.2 | 3.6 | 2.1 | 3.6 | 3.3 | 2.3 | 5.5 | 2.7 | 1.8 | 17.2 | 20.0 | 3.9 | 4.2 | 9.1 |
| **Jarque-Bera** | 0.3 | 0.7 | 0.5 | 0.6 | 0.3 | 0.4 | 1.0 | 0.3 | 14.7 | 36.9 | 21.2 | 16.6 | 21.6 | 21.2 | 18.3 | 3.6 | 25.4 | 19.4 | 8.7 | 2.6 | 73.1 | 17.9 | 9.2 | 4.0 | 8.6 | 4.0 | 2.7 | 21.3 | 0.6 | 3.2 | 976.2 | 1183.0 | 1.9 | 28.0 | 110.2 |
| **Probability** | 0.8 | 0.7 | 0.8 | 0.7 | 0.9 | 0.8 | 0.6 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.3 | 0.0 | 0.7 | 0.2 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 |

| | Distributors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NPK 12 22 21 | | | | NPK 12 30 17 | | | | NPK 20 10 10 | | | | NPK 23 10 5 | | | | NPK 25 10 10 | | | | NPK15 20 20 | | | | Urea | | | | Ammonium Sulfate | | | | | | |
| | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | Subsidized | | Commercial | | | | | | |
| | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Buy** | **Sell** | **Hand cost** | **Inte rate** | **Fin Cost (Urea)** | **Trans/bag** | **Rent/bag** |
| **Mean** | 121 | 133 | 78 | 80 | 124 | 120 | 78 | 80 | 123 | 128 | 78 | 83 | 118 | 130 | 74 | 82 | 116 | 126 | 74 | 81 | 120 | 125 | 76 | 81 | 113 | 118 | 72 | 79 | 87 | 94 | 1 | 0 | 25 | 3 | 1 |
| **Median** | 110 | 120 | 77 | 84 | 110 | 120 | 75 | 82 | 113 | 120 | 81 | 84 | 120 | 130 | 74 | 84 | 113 | 128 | 74 | 84 | 110 | 120 | 75 | 84 | 110 | 120 | 72 | 80 | 85 | 90 | 1 | 0 | 24 | 3 | 1 |
| **Maximum** | 168 | 168 | 84 | 84 | 168 | 120 | 84 | 84 | 168 | 168 | 84 | 84 | 168 | 168 | 84 | 90 | 168 | 168 | 84 | 90 | 168 | 168 | 84 | 84 | 160 | 160 | 80 | 85 | 145 | 120 | 5 | 1 | 40 | 8 | 3 |
| **Minimum** | 80 | 90 | 69 | 70 | 95 | 120 | 70 | 70 | 95 | 90 | 66 | 75 | 95 | 90 | 64 | 72 | 72 | 60 | 66 | 60 | 95 | 90 | 66 | 71 | 90 | 80 | 63 | 68 | 50 | 60 | 0 | 0 | 8 | 0 | 1 |
| **Std. Dev** | 32.3 | 34.0 | 6.0 | 5.6 | 31.6 | NA | 6.1 | 6.6 | 27.9 | 30.0 | 6.5 | 2.6 | 20.9 | 21.2 | 6.7 | 4.7 | 26.2 | 25.8 | 5.9 | 6.1 | 27.0 | 26.2 | 6.6 | 4.8 | 19.6 | 16.5 | 5.4 | 4.1 | 19.5 | 14.9 | 1.0 | 0.1 | 8.8 | 2.2 | 0.6 |
| **Skewness** | 0.5 | 0.0 | -0.1 | -1.0 | 0.5 | NA | 0.0 | -0.9 | 0.8 | 0.3 | -0.5 | -2.6 | 1.1 | 0.1 | 0.2 | -0.7 | 0.7 | -0.9 | 0.6 | -0.2 | 1.0 | 0.6 | 0.0 | -1.0 | 1.0 | 0.0 | -0.1 | -1.4 | 1.1 | 0.0 | 3.0 | 4.1 | -0.1 | 0.8 | 2.2 |
| **Kurtosis** | 1.8 | 1.5 | 1.5 | 2.4 | 1.6 | NA | 1.3 | 2.1 | 2.1 | 1.7 | 1.8 | 8.4 | 3.6 | 2.7 | 1.7 | 2.4 | 2.9 | 4.0 | 2.2 | 6.2 | 2.3 | 2.3 | 1.7 | 2.5 | 3.5 | 4.0 | 1.8 | 4.7 | 4.5 | 2.6 | 12.0 | 23.8 | 2.1 | 2.7 | 6.5 |
| **Jarque-Bera** | 0.9 | 0.5 | 0.8 | 1.2 | 0.6 | NA | 0.9 | 0.7 | 1.4 | 0.5 | 1.6 | 33.0 | 4.6 | 0.1 | 2.1 | 2.3 | 1.3 | 1.5 | 1.9 | 24.8 | 1.9 | 0.6 | 1.0 | 2.0 | 4.6 | 0.9 | 1.7 | 12.2 | 7.9 | 0.2 | 199.1 | 870.4 | 0.9 | 4.3 | 15.9 |
| **Probability** | 0.6 | 0.8 | 0.7 | 0.5 | 0.7 | NA | 0.7 | 0.7 | 0.5 | 0.8 | 0.5 | 0.0 | 0.1 | 1.0 | 0.4 | 0.3 | 0.5 | 0.5 | 0.4 | 0.0 | 0.4 | 0.7 | 0.6 | 0.4 | 0.1 | 0.6 | 0.4 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 0.6 | 0.1 | 0.0 |

*Appendix Table 1B. Percentage composition of stakeholders in survey area*

| **Attributes** | **Retailer %** | **Distributor %** |
|---|---|---|
| **Gender** | | |
| Female | 21 | 17 |
| Male | 79 | 83 |
| **Education** | | |
| None | 34 | 45 |
| Primary school | 44 | 40 |
| Junior high | 6 | 5 |
| High school | 3 | 2 |
| Tertiary | 14 | 7 |
| **Smartphone Ownership** | | |
| Do not own | 18 | 5 |
| Own | 82 | 95 |
| **Technology Skill** | | |
| Very bad | 13 | 7 |
| Bad | 8 | 5 |
| Average | 25 | 21 |
| Good | 25 | 31 |
| Very good | 28 | 36 |
| **Storage Ownership** | | |
| No | 40 | 52 |
| Yes | 60 | 48 |
| **Mode of Payment** | | |
| Collect grain | 19 | 14 |
| Cash only | 81 | 86 |

## Appendix 2A. Determine the Level of Market Integration in the Fertilizer Value Chain

**UNIT ROOT TEST- KASOA MARKET AT LEVEL**

Null Hypothesis: KAS_MAK has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -0.461549 | 0.8924 |
| Test critical values: | 1% level | -3.511262 | |
| | 5% level | -2.896779 | |
| | 10% level | -2.585626 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- KASOA MARKET AT FIRST DIFFERENCE**

Null Hypothesis: D(KAS_MAK) has a unit root
Exogenous: Constant

Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -7.786163 | 0.0000 |
| Test critical values: | 1% level | -3.513344 | |
| | 5% level | -2.897678 | |
| | 10% level | -2.586103 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- KOFORIDUA MARKET AT LEVEL**

Null Hypothesis: KOF_MAK has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -1.633092 | 0.4610 |
| Test critical values: | 1% level | -3.516676 | |
| | 5% level | -2.899115 | |
| | 10% level | -2.586866 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- KOFORIDUA MARKET AT FIRST DIFFERENCE**

Null Hypothesis: D(KOF_MAK) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.241306 | 0.0214 |
| Test critical values: | 1% level | -3.520307 | |
| | 5% level | -2.900670 | |
| | 10% level | -2.587691 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST - MANKESSIM MARKET AT LEVEL**

Null Hypothesis: MAN_MAK has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -1.539230 | 0.5086 |
| Test critical values: | 1% level | -3.517847 | |
| | 5% level | -2.899619 | |
| | 10% level | -2.587134 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST - MANKESSIM MARKET AT FIRST DIFFERENCE**

Null Hypothesis: D(MAN_MAK) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -6.081129 | 0.0000 |
| Test critical values: | 1% level | -3.517847 | |
| | 5% level | -2.899619 | |
| | 10% level | -2.587134 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- SECKONDI MARKET AT LEVELS**

Null Hypothesis: SEK_MAR has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -1.975771 | 0.2969 |
| Test critical values: | 1% level | -3.511262 | |
| | 5% level | -2.896779 | |
| | 10% level | -2.585626 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- SEKONDI MARKET AT FIRST DIFFERENCE**

Null Hypothesis: D(SEK_MAR) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -7.221907 | 0.0000 |
| Test critical values: | 1% level | -3.511262 | |
| | 5% level | -2.896779 | |
| | 10% level | -2.585626 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- TAKORADI MARKET AT LEVEL**

Null Hypothesis: TAK_MAK has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.346104 | 0.1603 |
| Test critical values: | 1% level | -3.510259 | |
| | 5% level | -2.896346 | |
| | 10% level | -2.585396 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- TAKORADI MARKET AT FIRST DIFFERENCE**

Null Hypothesis: D(TAK_MAK) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -7.365407 | 0.0000 |
| Test critical values: | 1% level | -3.510259 | |
| | 5% level | -2.896346 | |
| | 10% level | -2.585396 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- TECHNIMAN MARKET AT LEVELS**

Null Hypothesis: TECH_MAK has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.088279 | 0.2499 |
| Test critical values: | 1% level | -3.510259 | |
| | 5% level | -2.896346 | |
| | 10% level | -2.585396 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- TECHNIMAN MARKET AT FIRST DIFFERENCE**

Null Hypothesis: D(TECH_MAK) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -7.115513 | 0.0000 |
| Test critical values: | 1% level | -3.510259 | |
| | 5% level | -2.896346 | |
| | 10% level | -2.585396 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- WENCH MARKET AT LEVEL**

Null Hypothesis: WEN_MAK has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.176433 | 0.2164 |
| Test critical values: | 1% level | -3.510259 | |
| | 5% level | -2.896346 | |
| | 10% level | -2.585396 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- WENCH MARKET AT FIRST DIFFERENCE**

Null Hypothesis: D(WEN_MAK) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -7.340624 | 0.0000 |
| Test critical values: | 1% level | -3.510259 | |
| | 5% level | -2.896346 | |
| | 10% level | -2.585396 | |

*MacKinnon (1996) one-sided p-values.

## Appendix 2B. Market Cointegration (Long-Run Relationship)

Date: 06/05/20 Time: 19:21
Sample (adjusted): 5 80
Included observations: 72 after adjustments
Trend assumption: Linear deterministic trend
Series: KAS_MAK KOF_MAK MAN_MAK SEK_MAR TAK_MAK TECH_MAK WEN_MAK
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 * | 0.515405 | 155.2104 | 125.6154 | 0.0002 |
| At most 1 * | 0.472945 | 103.0506 | 95.75366 | 0.0143 |
| At most 2 | 0.319450 | 56.93817 | 69.81889 | 0.3412 |
| At most 3 | 0.186705 | 29.22870 | 47.85613 | 0.7574 |
| At most 4 | 0.110963 | 14.34905 | 29.79707 | 0.8204 |
| At most 5 | 0.058011 | 5.880675 | 15.49471 | 0.7096 |
| At most 6 | 0.021676 | 1.577857 | 3.841466 | 0.2091 |

Trace test indicates 2 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 * | 0.515405 | 52.15984 | 46.23142 | 0.0104 |
| At most 1 * | 0.472945 | 46.11241 | 40.07757 | 0.0093 |
| At most 2 | 0.319450 | 27.70947 | 33.87687 | 0.2272 |
| At most 3 | 0.186705 | 14.87965 | 27.58434 | 0.7577 |
| At most 4 | 0.110963 | 8.468371 | 21.13162 | 0.8728 |
| At most 5 | 0.058011 | 4.302818 | 14.26460 | 0.8261 |
| At most 6 | 0.021676 | 1.577857 | 3.841466 | 0.2091 |

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

## Appendix 3. Relationship between Commercial and Subsidized Fertilizers

## Appendix 3A

**UNIT ROOT TEST NPK AT LEVELS**

Null Hypothesis: NPK has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -1.556696 | 0.4989 |
| Test critical values: | 1% level | -3.533204 | |
| | 5% level | -2.906210 | |
| | 10% level | -2.590628 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST NPK AT FIRST DIFFERENCE**

Null Hypothesis: D(NPK) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -4.503577 | 0.0005 |
| Test critical values: | 1% level | -3.538362 | |
| | 5% level | -2.908420 | |
| | 10% level | -2.591799 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- SUBSIDIZED NPK AT LEVEL**

Null Hypothesis: SNPK has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | 0.930954 | 0.9952 |
| Test critical values: | 1% level | -3.568308 | |
| | 5% level | -2.921175 | |
| | 10% level | -2.598551 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST- SUBSIDIZED NPK AT FIRST DIFFERENCE**

Null Hypothesis: D(SNPK) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -6.238303 | 0.0000 |
| Test critical values: | 1% level | -3.592462 | |
| | 5% level | -2.931404 | |
| | 10% level | -2.603944 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST SUBSIDIZED UREA AT LEVEL**

Null Hypothesis: SUREA has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | 0.818019 | 0.9934 |
| Test critical values: | 1% level | -3.565430 | |
| | 5% level | -2.919952 | |
| | 10% level | -2.597905 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST SUBSIDIZED UREA AT FIRST DIFFERENCE**

Null Hypothesis: D(SUREA) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -6.382652 | 0.0000 |
| Test critical values: | 1% level | -3.588509 | |
| | 5% level | -2.929734 | |
| | 10% level | -2.603064 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST UREA AT LEVEL**

Null Hypothesis: UREA has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -1.049207 | 0.7315 |
| Test critical values: | 1% level | -3.521579 | |
| | 5% level | -2.901217 | |
| | 10% level | -2.587981 | |

*MacKinnon (1996) one-sided p-values.

**UNIT ROOT TEST UREA AT FIRST DIFFERENCE**

Null Hypothesis: D(UREA) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=2)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -8.547421 | 0.0000 |
| Test critical values: | 1% level | -3.527045 | |
| | 5% level | -2.903566 | |
| | 10% level | -2.589227 | |

*MacKinnon (1996) one-sided p-values.

## Appendix 3B

**LAG SELECTION FOR COINTEGRATION**

A)VAR Lag Order Selection Criteria
Endogenous variables: NPK SNPK UREA SUREA
Exogenous variables: C
Date: 06/05/20   Time: 20:22
Sample: 1 97
Included observations: 36

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | -728.8986 | NA | 5.66e+12 | 40.71659 | 40.89254 | 40.77800 |
| 1 | -549.6333 | 308.7347 | 6.56e+08 | 31.64629 | 32.52603 | 31.95334 |
| 2 | -532.1014 | 26.29782 | 6.25e+08 | 31.56119 | 33.14471 | 32.11388 |
| 3 | -490.9673 | 52.56027* | 1.70e+08* | 30.16485* | 32.45215* | 30.96318* |

* 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

## Appendix 3C

**COINTEGRATION TEST- NPK SNPK SUREA UREA**

Date: 06/05/20 Time: 20:23
Sample (adjusted): 5 94
Included observations: 29 after adjustments
Trend assumption: Linear deterministic trend
Series: NPK SNPK SUREA UREA
Lags interval (in first differences): 1 to 3

Unrestricted Cointegration Rank Test (Trace)

| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None | 0.511619 | 36.32105 | 47.85613 | 0.3804 |
| At most 1 | 0.335510 | 15.53794 | 29.79707 | 0.7443 |
| At most 2 | 0.109776 | 3.684591 | 15.49471 | 0.9273 |
| At most 3 | 0.010715 | 0.312412 | 3.841466 | 0.5762 |

Trace test indicates no cointegration 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 | 0.511619 | 20.78311 | 27.58434 | 0.2896 |
| At most 1 | 0.335510 | 11.85335 | 21.13162 | 0.5622 |
| At most 2 | 0.109776 | 3.372180 | 14.26460 | 0.9189 |
| At most 3 | 0.010715 | 0.312412 | 3.841466 | 0.5762 |

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

## Appendix 3D

**RESULT OF VAR MODELLING FOR *SUBSIDIZED AND COMMERCIAL FERT.***

Vector Autoregression Estimates
Date: 06/05/20 Time: 20:37
Sample (adjusted): 3 94
Included observations: 43 after adjustments
Standard errors in ( ) & t-statistics in [ ]

| | NPK | SNPK |
|---|---|---|
| CNPK(-1) | 0.496028 | -0.036943 |
| | (0.15358) | (0.05980) |
| | [ 3.22978] | [-0.61778] |
| CNPK(-2) | 0.337847 | -0.041173 |
| | (0.15379) | (0.05988) |
| | [ 2.19684] | [-0.68757] |
| SNPK(-1) | 1.035798 | 0.928045 |
| | (0.42843) | (0.16682) |
| | [ 2.41766] | [ 5.56312] |
| SNPK(-2) | -0.976656 | 0.121003 |
| | (0.44772) | (0.17433) |
| | [-2.18139] | [ 0.69409] |
| C | 55.66948 | 19.96889 |
| | (37.1883) | (14.4802) |
| | [ 1.49696] | [ 1.37904] |
| R-squared | 0.795973 | 0.986912 |
| Adj. R-squared | 0.774496 | 0.985534 |
| Sum sq. resids | 36166.80 | 5483.397 |
| S.E. equation | 30.85058 | 12.01249 |
| F-statistic | 37.06242 | 716.3421 |
| Log likelihood | -205.8103 | -165.2524 |
| Akaike AIC | 9.805132 | 7.918715 |
| Schwarz SC | 10.00992 | 8.123506 |
| Mean dependent | 495.4419 | 392.6512 |
| S.D. dependent | 64.96604 | 99.87561 |
| Determinant resid covariance (dof adj.) | | 122221.9 |
| Determinant resid covariance | | 95450.72 |
| Log likelihood | | -368.5556 |
| Akaike information criterion | | 17.60724 |
| Schwarz criterion | | 18.01682 |

## Appendix 3E

**OLS ESTIMATES FROM VAR MODELLING**

System: UNTITLED
Estimation Method: Least Squares
Date: 06/05/20 Time: 20:44
Sample: 3 95
Included observations: 48
Total system (unbalanced) observations 91

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(1) | 0.503776 | 0.147995 | 3.404005 | 0.0010 |
| C(2) | 0.299172 | 0.147358 | 2.030241 | 0.0456 |
| C(3) | 1.025162 | 0.415194 | 2.469116 | 0.0156 |
| C(4) | -0.955641 | 0.433090 | -2.206566 | 0.0302 |
| C(5) | 65.80344 | 33.52670 | 1.962717 | 0.0531 |
| C(6) | -0.036943 | 0.059800 | -0.617782 | 0.5385 |
| C(7) | -0.041173 | 0.059881 | -0.687567 | 0.4937 |
| C(8) | 0.928045 | 0.166821 | 5.563123 | 0.0000 |
| C(9) | 0.121003 | 0.174333 | 0.694091 | 0.4896 |
| C(10) | 19.96889 | 14.48024 | 1.379043 | 0.1717 |
| Determinant residual covariance | | 93357.96 | | |

Equation: NPK = C(1)*NPK(-1) + C(2)*NPK(-2) + C(3)*SNPK(-1) +
C(4)
*SNPK(-2) + C(5)
Observations: 48

| | | | |
|---|---|---|---|
| R-squared | 0.802748 | Mean dependent var | 493.1250 |
| Adjusted R-squared | 0.784399 | S.D. dependent var | 64.61527 |
| S.E. of regression | 30.00269 | Sum squared resid | 38706.95 |
| Durbin-Watson stat | 2.252276 | | |

Equation: SNPK = C(6)*NPK(-1) + C(7)*NPK(-2) + C(8)*SNPK(-1) +
C(9)
*SNPK(-2) + C(10)
Observations: 43

| | | | |
|---|---|---|---|
| R-squared | 0.986912 | Mean dependent var | 392.6512 |
| Adjusted R-squared | 0.985534 | S.D. dependent var | 99.87561 |
| S.E. of regression | 12.01249 | Sum squared resid | 5483.396 |
| Durbin-Watson stat | 2.292795 | | |

NPK = C(1)*NPK(-1) + C(2)*NPK(-2) + C(3)*SNPK(-1) + C(4)*SNPK(-2) + C(5)

SNPK = C(6)*NPK(-1) + C(7)*NPK(-2) + C(8)*SNPK(-1) + C(9)*SNPK(-2) + C(10)

## Appendix 3F

***CAUSALITY FROM SUBSIDIZED NPK TO COMMERCIAL NPK***

**WALD TEST FOR LAGS OF SUBSIDIZED NPK**

Wald Test:
Equation: Untitled

| Test Statistic | Value | df | Probability |
|---|---|---|---|
| F-statistic | 4.710162 | (2, 43) | 0.0141 |
| Chi-square | 9.420324 | 2 | 0.0090 |

Null Hypothesis: C(3)=C(4)=0
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value | Std. Err. |
|---|---|---|
| C(3) | 1.025162 | 0.415194 |
| C(4) | -0.955641 | 0.433090 |

Restrictions are linear in coefficients.

## Appendix 3G

***CAUSALITY FROM COMMERCIAL NPK TO SUBSIDIZED NPK***

**WALD TEST FOR LAGS OF C**NPK

Wald Test:
Equation: Untitled

| Test Statistic | Value | df | Probability |
|---|---|---|---|
| F-statistic | 2.443921 | (2, 38) | 0.1004 |
| Chi-square | 4.887841 | 2 | 0.0868 |

Null Hypothesis: C(6)=C(7)=0
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value | Std. Err. |
|---|---|---|
| C(6) | -0.036943 | 0.059800 |
| C(7) | -0.041173 | 0.059881 |

Restrictions are linear in coefficients.

## Appendix 3H

**RELATIONSHIP BETWEEN SUBSIDIZED UREA AND COMMERCIAL UREA**

Vector Autoregression Estimates
Date: 06/06/20 Time: 02:32
Sample (adjusted): 3 94
Included observations: 44 after adjustments
Standard errors in ( ) & t-statistics in [ ]

| | CUREA | SUREA |
|---|---|---|
| CUREA(-1) | 0.842581 | -0.025104 |
| | (0.14514) | (0.04489) |
| | [ 5.80537] | [-0.55928] |
| CUREA(-2) | 0.103051 | -0.022035 |
| | (0.14926) | (0.04616) |
| | [ 0.69041] | [-0.47735] |
| SUREA(-1) | 1.872830 | 0.944375 |
| | (0.51432) | (0.15906) |
| | [ 3.64139] | [ 5.93723] |
| SUREA(-2) | -1.827219 | 0.097235 |
| | (0.53850) | (0.16654) |
| | [-3.39315] | [ 0.58385] |
| C | 10.40678 | 7.863733 |
| | (35.3121) | (10.9208) |
| | [ 0.29471] | [ 0.72007] |
| R-squared | 0.846167 | 0.987822 |
| Adj. R-squared | 0.830390 | 0.986573 |
| Sum sq. resids | 63417.84 | 6065.554 |
| S.E. equation | 40.32491 | 12.47105 |
| F-statistic | 53.63056 | 790.8832 |
| Log likelihood | -222.4461 | -170.8095 |
| Akaike AIC | 10.33846 | 7.991341 |
| Schwarz SC | 10.54121 | 8.194090 |
| Mean dependent | 485.3636 | 370.8864 |
| S.D. dependent | 97.91455 | 107.6256 |

| | |
|---|---|
| Determinant resid covariance (dof adj.) | 251568.1 |
| Determinant resid covariance | 197642.1 |
| Log likelihood | -393.1393 |
| Akaike information criterion | 18.32451 |
| Schwarz criterion | 18.73001 |

## Appendix 3I

**OLS ESTIMATES FROM VAR MODELLING (RELATION BETWEEN SUBSIDIZED UREA AND COMMERCIAL UREA)**

System: UNTITLED
Estimation Method: Least Squares
Date: 06/06/20   Time: 02:33
Sample: 3 95
Included observations: 49
Total system (unbalanced) observations 93

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(1) | 0.846319 | 0.138743 | 6.099908 | 0.0000 |
| C(2) | 0.083870 | 0.141283 | 0.593630 | 0.5544 |
| C(3) | 1.911468 | 0.490061 | 3.900467 | 0.0002 |
| C(4) | -1.869203 | 0.512643 | -3.646212 | 0.0005 |
| C(5) | 18.05536 | 31.62136 | 0.570986 | 0.5696 |
| C(6) | -0.025104 | 0.044886 | -0.559279 | 0.5775 |
| C(7) | -0.022035 | 0.046161 | -0.477353 | 0.6344 |
| C(8) | 0.944375 | 0.159060 | 5.937229 | 0.0000 |
| C(9) | 0.097235 | 0.166539 | 0.583853 | 0.5609 |
| C(10) | 7.863733 | 10.92076 | 0.720072 | 0.4735 |
| Determinant residual covariance | | 183652.6 | | |

Equation: UREA = C(1)*UREA(-1) + C(2)*UREA(-2) + C(3)*SUREA(-1) +
C(4)*SUREA(-2) + C(5)
Observations: 49

| | | | |
|---|---|---|---|
| R-squared | 0.852577 | Mean dependent var | 480.5306 |
| Adjusted R-squared | 0.839175 | S.D. dependent var | 96.26788 |
| S.E. of regression | 38.60632 | Sum squared resid | 65579.72 |
| Durbin-Watson stat | 1.879545 | | |

Equation: SUREA = C(6)*UREA(-1) + C(7)*UREA(-2) + C(8)*SUREA(-1) +
C(9)*SUREA(-2) + C(10)
Observations: 44

| | | | |
|---|---|---|---|
| R-squared | 0.987822 | Mean dependent var | 370.8864 |
| Adjusted R-squared | 0.986573 | S.D. dependent var | 107.6256 |
| S.E. of regression | 12.47105 | Sum squared resid | 6065.554 |
| Durbin-Watson stat | 2.309775 | | |

**NOTE:**

**UREA = C(1)*UREA(-1) + C(2)*UREA(-2) + C(3)*SUREA(-1) + C(4)*SUREA(-2) + C(5)**

**SUREA = C(6)*UREA(-1) + C(7)*UREA(-2) + C(8)*SUREA(-1) + C(9)*SUREA(-2) + C(10)**

## Appendix 3J

***CAUSALITY FROM SUBSIDIZED UREA TO COMMERCIAL UREA***

**WALD TEST FOR SUBSIDIZED UREA**

Wald Test:
Equation: Untitled

| Test Statistic | Value | df | Probability |
|---|---|---|---|
| F-statistic | 8.757442 | (2, 44) | 0.0006 |
| Chi-square | 17.51488 | 2 | 0.0002 |

Null Hypothesis: C(3)=C(4)=0
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value | Std. Err. |
|---|---|---|
| C(3) | 1.911468 | 0.490061 |
| C(4) | -1.869203 | 0.512643 |

Restrictions are linear in coefficients.

## Appendix 3K

***CAUSALITY FROM COMMERCIAL NPK TO SUBSIDIZED NPK***

**WALD TEST FOR UREA**

Wald Test:
Equation: Untitled

| Test Statistic | Value | df | Probability |
|---|---|---|---|
| F-statistic | 1.316736 | (2, 39) | 0.2797 |
| Chi-square | 2.633472 | 2 | 0.2680 |

Null Hypothesis: C(6)=C(7)=0
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value | Std. Err. |
|---|---|---|
| C(6) | -0.025104 | 0.044886 |
| C(7) | -0.022035 | 0.046161 |

Restrictions are linear in coefficients.

## Appendix 4A

QUESTIONNAIRES



# Value Chain analysis (Farmers)

Enter a time

hh:mm

Community

Region

Gender

- ◯ Male
- ◯ Female

1.0 Farm Attributes

1.1 Number of farm employees

1.2 Are you a member of a cooperative/association ?

- ◯ Yes
- ◯ No

1.3 If Yes, kindly list the cooperatives/associations you are a member.

1.4 Are you a commercial farmer or subsistence farmer ?

*A subsistence farmer produces for to meet family consumption/needs only.*

- ◯ Commercial
- ◯ Subsistence

1.5 What is the size of your household?

1.6 How old are you?

1.7 Do you own your farmland?

- Yes
- No

1.8 What is your total farm size ?
*(Acres)*

1.9 What is the total farm size fertilizer was applied

1.10 Do you have a storage facility for your products?

- Yes
- No

1.11 If Yes, how many 50kg bags can it hold?

1.12 How many years have you been farming?

1.13 Do you have other businesses aside from farming?

- Yes
- No

1.14 If Yes, kindly list other off-farm businesses.

1.15 Have you received any form of agricultural training?

- Yes
- No

1.16 If Yes, kindly list the organizations that organized the trainings and the types of trainings.

1.17 Do you own a smart phone or computer?

- Yes
- No

1.18 How do you rate your skills in using technology e.g smart phones and computers?

- Very good
- Good
- Average
- Bad
- Very bad

1.19 What is your highest education level?

- Tertiary
- High School
- Primary School
- None

2.1 Do you have access to subsidized fertilizers?

- Yes
- No

2.2 Do you purchase commercial fertilizers?

- Yes
- No
- Option 3

2.3 What quantity of subsidized fertilizers do you purchase (50kg bags)?

| **2.4 Kindly list the types and prices of subsidized fertilizers you purchase.** | **Name of commercial fertilizers** | **Quantity (50kg bags)** | **Unit Price** | **Source (retailer/wholesaler and name)** |
|---|---|---|---|---|
| **1** | | | | |
| **2** | | | | |
| **3** | | | | |
| **4** | | | | |

| | | | | |
|---|---|---|---|---|
| **5** | | | | |
| **2.5 Kindly list the types and prices of commercial fertilizers you purchase.** | **Name of commercial fertilizers** | **Quantity** | **Unit Price** | **Source (retailer/wholesaler and name)** |
| **1** | | | | |
| **2** | | | | |
| **3** | | | | |
| **4** | | | | |
| **5** | | | | |

2.6 Where do you purchase your fertilizers (towns/cities)?

2.7 How many minutes does it take you to get to the fertilizer market?

2.8 How much does it cost you to transport the fertilizers to the farm (GHS)?

2.9 Do you own any of these vehicles for farm use?

*thick as many as possible*

- ☐ truck
- ☐ Car
- ☐ Tricycle
- ☐ Bike

2.10 Do you own livestock?

- ○ Yes
- ○ No

2.11 Do you apply animal manure?

- Yes
- No

2.12 Is your farm irrigated?

- Yes
- No

| 2.13 Kindly list the crops, varieties, quantity of fertilizer used and commodity prices. | Crop | Farm size | Output (50kg bags) | Variety cultivated | Type and quantity of fertilizer | 2019 commodity market price | 2020 commodity market price |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

2.14 What is the total quantity of fertilizers you use in a year (50kg bags)?

2.15 What determines the quantity of fertilizers you utilize ?

2.16 How much do you spend on fertilizers in a year (GHS)?

2.17 How much do you spend on other farm inputs e.g. seeds, pesticides etc (GHS)?

2.18 How much do you spend on labour (GHS)?

2.19 Please list additional costs and amount you incur aside from cost of fertilizers, seeds, pesticides and labour?

2.20 Do you have off-takers or a ready market for your commodities?

- Yes
- No

3.1 Do you need additional finance for your farm business expansion?

- Yes
- No

3.2 Have you had access to finance before?

- Yes
- No

3.3 If No, what are the reasons for not accessing credit?

3.4 Are you currently on loan?

- Yes
- No

3.5 What is the average loan amount you access (GHS)?

3.6 What is the cost of loan application fee (GHS)?

3.7 What is the average loan interest rate per year (%)?

3.8 What is the average loan tenor/duration?

- 1-3 months
- 3-6months
- 6-9months
- 9-12months
- 12months and above

3.9 Cost of collateral evaluation if applicable (GHS)?

3.10 How many trips do you make to the bank before accessing credit ?

3.11 Cost of single trip to bank (to and from)?

3.12 How much upfront charge is requested before access to credit (GHS)?

3.13 Kindly list others cost associated with credit access and their amount (GHS).

3.14 Kindly indicate the ease at which you access credit?

- Very easy
- Easy
- Sometimes
- Difficult
- Very Difficult

3.15 What are the constraints you face in increasing your fertilizer use?

3.16 What is the average loan amount you need to expand your fertilizer business (GHS)?

3.17 Rank the following challenges associated with credit access according to severity (1-5)

1st choice *

- Collateral
- High interest rate
- late approval
- Bank is too far
- Trips to bank
- Gratification & bribes

2nd choice *

- Collateral
- High interest rate
- late approval
- Bank is too far
- Trips to bank
- Gratification & bribes

3rd choice *

- Collateral
- High interest rate
- late approval
- Bank is too far
- Trips to bank
- Gratification & bribes

3.18 How far is the bank from you (Minutes)

3.19 Do you own a fixed asset e.g. land, house etc.?

- Yes
- No

## 4.0 Fertilizer Market

4.1 Do you buy fertilizers on credit?

- Yes
- No

4.2 If YES, what is the average duration of repayment

- 1-3month
- 3-6months
- 6-12months
- 12months ans above

4.3 Is there an additional cost when you buy fertilizer on credit?

- Yes
- No

4.4 What is the average additional cost when you buy fertilizers (50kg bag) on credit (GHS)

4.5 How long does it take to sell your commodities (months)?

4.6 Which fertilizer product/company do you prefer and why?

| **5.0 What fertilizer challenges do you face as a farmer ?** | **Challenges** | **Solutions** |
|---|---|---|
| **1** | | |
| **2** | | |
| **3** | | |
| **4** | | |
| **5** | | |

5.1 Are you aware of the COVID-19 pandemic?

- Yes
- No

5.2 How has the COVID 19 pandemic affected your farming business?

5.3 In your opinion, what is the role of fertilizer application in responding to the impacts of COVID-19?

# Fertilizer value chain analysis (Distributors/retailers)

Enter a date and time

yyyy-mm-dd hh:mm

Community

Region

Gender

- Male
- Female

1.1 Number of employees

1.2 What is your highest level of education?

- Tertiary
- High school
- Primary School
- None

1.3 How old is your firm?

1.4 Do you have a license to operate?

- Yes
- No

1.5 List other non-fertilizer businesses/income you engage in.

*e.g. seeds, pesticides, farming, carpentry, transportation, public servant etc.*

1.6 What category of the fertilizer distribution network do you belong?

- [ ] Distributor
- [ ] Retailer
- [ ] Importer
- [ ] Blender

1.7 What is your sales volume in a year (50kg bags)?

- [ ] 100-500
- [ ] 500-1000
- [ ] 1000-5000
- [ ] 5000-10000
- [ ] 10000-20000
- [ ] 20000-50000
- [ ] 50000-100,000
- [ ] 100000-above

1.8 Have you received any training on fertilizer management etc.?

- ◯ Yes
- ◯ No

1.9 If Yes, how many trainings have you received ?

______________________________

1.10 Do you own a smart phone or a computer?

- ◯ Yes
- ◯ No

1.11 How do you rate your skills when using technology e.g smart phones and computers?

- ◯ Very good
- ◯ Good
- ◯ Average
- ◯ Bad
- ◯ Very bad

2.0 Fertilizer Storage

2.1 Do you own or rent your storage space?

*Kindly thick one of the options below*

- Own
- Rent

2.2 What is your total fertilizer storage capacity (50kg bags)?

*The total number of bags your store can contain at a time*

2.3 What is your average utilized storage capacity for fertilizers?

*The average number of 50kg bags in your store*

2.4 What is the cost of renting your storage facility in a year (GHS)?

2.5 Do you own a fixed asset e.g land or house?

- Yes
- No

Fertilizer Transportation

3.1 Do you transport fertilizers yourself or you share cost with others?

- Sole transporter of fertilizer
- Cost sharing with supplier
- Cost sharing with other actors
- Cost sharing with importers

3.2 Are you willing to share/collaborate with other players in fertilizer transportation e.g. retailers and distributors to increase your profitability?

- Yes
- No

3.3 Where do you buy your fertilizers (Name/town/city)?

3.4 How many minutes of travel does it take you to get to where you purchase your fertilizers?

3.5 What is the maximum truck capacity available for transporting fertilizers in the market (50kg bags)?

3.6 What is the actual average quantity of fertilizer you purchase at a time (50kg bags)?

*The average quantity per trip*

3.7 How much does it cost you to transport your fertilizers to your store (GHS)?

3.8 How much is your handling cost (loading and offloading) in GHS?

3.9 Where do you supply your fertilizers (communities/towns)?

3.10 How many minutes away are you from towns and cities you supply fertilizers?

*Convert hours to minutes*

4.0 Fertilizer Sales

4.1 Do you buy fertilizers on credit?

- Yes
- No

4.2 If Yes, what is the average repayment duration?

4.3 Do you sell fertilizers on credit?

- Yes
- No

4.4 If Yes, what is the average repayment duration?

- 1-3months
- 3-6months
- 6-12months
- 12months and Above

4.5 If YES, what is the default rate (%)?

4.6 Do you sell fertilizers in kind?

- Yes
- No

4.7 If Yes, Kindly specify what forms of payments you collect

| **4.8 What is the price of these fertilizers when you pay on the spot (Ghc)?** | **Commercial Spot purchasing prices** | **Subsidized Spot purchasing Prices** |
|---|---|---|
| **NPK 23 10 5 + 2MgO + 3S + 0.3ZN** | | |
| **NPK 25 10 10 + 3S + 3MgO + 0.3Zn** | | |
| **NPK 15 20 20 + 0.7Zn** | | |
| **10. SoA** | | |
| **NPK (15:15:15)** | | |
| **NPK 11 22 21 + 5S + 0.7Zn + 0.5B** | | |
| **NPK 20 10 10 + 3S** | | |
| **NPK 12 30 17 + 0.4Zn** | | |
| **KCl** | | |
| **Urea** | | |
| **Other** | | |

4.9 What is the additional cost when you buy fertilizer on credit (GHS)?

| **4.10 How much do you sell these fertilizers under the following circumstances?** | **Commercial Fertilizers Spot Selling Price** | **Spot Selling Prices for a 50kg bag of Subsidized Fertilizer** |
|---|---|---|
| **NPK 25 10 10 + 3S + 3MgO + 0.7Zn** | | |

| | | |
|---|---|---|
| **SoA** | | |
| **NPK 23 10 5 + 2MgO + 3S + 0.3ZN** | | |
| **NPK (15:15:15)** | | |
| **NPK 11 22 21 + 5S + 0.7Zn + 0.5B** | | |
| **NPK (23:10:10)** | | |
| **NPK 20 10 10 + 3S** | | |
| **NPK 15 20 20 + 0.7Zn** | | |
| **Urea** | | |
| **KCl** | | |
| **NPK 12 30 17 + 0.4Zn** | | |

4.11 What is the additional cost when you sell fertilizer on credit (GHS)?

| **4.12 List the top 5 selling fertilizers by volume?** | **Type of fertilizer** | **Why** |
|---|---|---|
| **1** | | |
| **2** | | |
| **3** | | |
| **4** | | |
| **5** | | |

## 5.0 Credit and Finance

5.1 What is you net evaluation of your fertilizer business?

5.2 Are you currently on loan?

- ◯ Yes
- ◯ No

5.3 Have you had access to loan from a bank/finance institution for your fertilizer business?

- ◯ Yes
- ◯ No

5.4 If No, What are your reasons for not accessing credit?

5.5 Do you engaged in informal borrowing?

- ◯ Yes
- ◯ No

5.6 If Yes, please specify source of borrowing?

5.7 What is the average loan amount you need for your fertilizer business (GHS)?

5.8 How often do you get the loan amount you applied for?

- ◯ Often
- ◯ Seldomly
- ◯ Never

5.9 How much is the loan application fee, upfront etc.?

5.10 What is the average interest rate per year for loans you have accessed?

5.11 What is the average loan tenor/duration

- 1-3months
- 3-6months
- 6-9months
- 9-12months
- 12months and Above

5.12 What is the average cost of collateral required to access loan?

5.13 What is the cost of collateral valuation/paper works?

5.14 How many trips do you make to the bank before credit is approved?

5.15 What is the cost of a single trip to the bank (GHS)?

5.16 Please indicate other costs and amount associated with access to credit (GHS)?

5.17 Kindly select an option below according to ease of credit access.

- Very easy
- Easy
- Sometimes
- Difficult
- Very difficult

5.18 Kindly rank these challenges according to severity

1st choice *

- collateral
- High interest rate
- banks are too far
- Loan amount is too small
- High upfront charges
- Bribes & gratifications

2nd choice *

- collateral
- High interest rate
- banks are too far
- Loan amount is too small
- High upfront charges
- Bribes & gratifications

3rd choice *

- ◯ collateral
- ◯ High interest rate
- ◯ banks are too far
- ◯ Loan amount is too small
- ◯ High upfront charges
- ◯ Bribes & gratifications

4th choice *

- ◯ collateral
- ◯ High interest rate
- ◯ banks are too far
- ◯ Loan amount is too small
- ◯ High upfront charges
- ◯ Bribes & gratifications

5th choice *

- ◯ collateral
- ◯ High interest rate
- ◯ banks are too far
- ◯ Loan amount is too small
- ◯ High upfront charges
- ◯ Bribes & gratifications

5.19 Do you need additional finance to expand your fertilizer business?

- ◯ Yes
- ◯ No

5.20 If you get additional finance how would it help your fertilizer business?

5.21 What is the average loan amount you need for your fertilizer business expansion?

6.1 How is your book keeping records?

*If records for the last 10 years exist =very good*

- ◯ Very Good
- ◯ Good
- ◯ Average
- ◯ Bad
- ◯ Very Bad

| **7.0 What are your challenges in the fertilizer market and what can be done to address them?** | **Challenges** | **Solutions** |
|---|---|---|
| **1** | | |
| **2** | | |

| | | |
|---|---|---|
| **3** | | |
| **4** | | |
| **5** | | |

7.1 How has the recent COVID-19 pandemic affected your business?

7.2 What is your fertilizer is your fertilizer market perception and future outlook?

| | | | |
|---|---|---|---|
| **1** | | | |
| **2** | | | |
| **3** | | | |
| **4** | | | |
| **5** | | | |
| **6** | | | |
| **7** | | | |

2.3 What is the average quantity of fertilizer you import in a year (tonnes)?

2.4 What is your cost of blending a ton of fertilizer (GHS)?

2.5 What is your installed blending capacity (tonnes)?

2.6 What is your average operating capacity (tonnes)?

*Before Covid-19*

2.7 What is your current operating capacity (tonnes)?

2.8 What is your maximum storage capacity (tonnes)?

2.9 What is the average storage capacity in a month (tonnes)?

2.10 Kindly indicate your business peak period (months)?

- [ ] January
- [ ] February
- [ ] March
- [ ] April
- [ ] May
- [ ] June
- [ ] July
- [ ] August
- [ ] September
- [ ] October
- [ ] November
- [ ] December

2.11 What is your peak capacity (tonnes)?

2.12 Are you willing to collaborate or share storage facilities with other industry actors to increase profitability?

- ◯ Yes
- ◯ No

| **2.13 Kindly list the fertilizer formulations you blend** | **Formulas** | **Volume** |
|---|---|---|
| **Row** | | |
| **1** | | |
| **2** | | |
| **2** | | |
| **4** | | |
| **5** | | |
| **6** | | |

## 3.0 Transportation/Distribution

3.1 Do you collaborate and partner with other importers to ship fertilizers?

- ◯ Yes
- ◯ No

3.2 If No, Why?

3.3 Would you like to collaborate and partner with other importers in shipping fertilizers to increase your profitability?

- ◯ Yes
- ◯ No

3.4 Do you own trucks for transportation?

- ◯ Yes
- ◯ No

3.5 If yes, how many trucks do you own?

3.6 Are you willing to collaborate or outsource your logistics in order to increase your profitability?

- ◯ Yes
- ◯ No

3.7 Kindly indicate your fertilizer distribution channels

- ☐ PFJ
- ☐ Plantations
- ☐ Open market
- ☐ COCOBOD

3.8 Do you have warehouses in all 16 regions in Ghana?

- ◯ Yes
- ◯ No

3.9 If No, kindly list the regions you own warehouses and distribution network?

*Regions/districts*

| 3.10 Kindly specify the prices of the following fertilizers for 2020 and 2019 | 2020 Subsidized Fertilizers Prices | 2020 Commercial Fertilizers Prices | 2019 Subsidized Fertilizers Prices | 2019 Commercial Fertilizers Prices |
|---|---|---|---|---|
| NPK 12 30 17 + 0.4Zn | | | | |
| NPK 11 22 21 + 5S + 0.7Zn + 0.5B | | | | |
| NPK 20 10 10 + 3S | | | | |
| NPK (15:15:15) | | | | |
| NPK 25 10 10 + 3S + 3MgO + 0.7Zn | | | | |
| Others | | | | |
| NPK 15 20 20 + 0.7Zn | | | | |
| KCl | | | | |
| SoA | | | | |
| NPK 23 10 5 + 2MgO + 3S + 0.3ZN | | | | |
| NPK (23:10:10) | | | | |
| Urea | | | | |

3.11 Who or what determines the price at which fertilizers are sold

*e.g government, international markets, demand, etc.*

| 3.12 List the 5 top selling commercial fertilizers by volume in descending order | Commercial Fertilizers (1-5) | Column |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |

3.13 What is the average duration for government subsidy repayment?

- ◯ 0-3months
- ◯ 3-6months
- ◯ 6-9months
- ◯ 9-12months
- ◯ 12months and above

3.14 How does the repayment affect your business?

3.15 Do you supply fertilizer on credit?

- ◯ Yes
- ◯ No

3.16 Is there an extra cost added when fertilizer is supplied on credit ?

- ◯ Yes
- ◯ No

3.17 If Yes, what is the average extra cost on a 50kg bag of fertilizer (GHS)?

3.18 If Yes, what is the average duration of repayment?

- ◯ 0-3months
- ◯ 3-6months
- ◯ 6-12months
- ◯ 12months and above

3.19 What is the default rate on fertilizers supplied on credit (%)?

3.20 Do you sell to FBOs and NGOs?

- ◯ Yes
- ◯ No

| **3.21 Kindly list the names, contacts and regions of your major distributors.** | **Names/contacts** | **Region/district** |
|---|---|---|
| **1** | | |
| **2** | | |
| **3** | | |
| **4** | | |
| **5** | | |
| **6** | | |
| **7** | | |
| **8** | | |
| **9** | | |
| **10** | | |

## 4.0 Business financing

4.1 Do you have access to credit?

- ◯ Yes
- ◯ No

4.2 If yes what is the average loan duration?

- ◯ 0-3months
- ◯ 3-6months
- ◯ 6-12months
- ◯ 12 and above

4.3 What is the average interest rate you get when you access credit (%)?

4.4 Kindly list additional cost and amount attached to access to credit (GHS)?

4.5 How much does it cost to get a letter of credit (GHS)?

4.6 Rank the following challenges associated with access to credit according to severity (1-5).

1st choice *

- ◯ High interest rate
- ◯ Trips to the bank
- ◯ Collateral
- ◯ Upfront charges
- ◯ Bribes & Gratification
- ◯ Late Approval
- ◯ Hidden Charges

2nd choice *

- ◯ High interest rate
- ◯ Trips to the bank
- ◯ Collateral
- ◯ Upfront charges
- ◯ Bribes & Gratification
- ◯ Late Approval
- ◯ Hidden Charges

3rd choice *

- ◯ High interest rate
- ◯ Trips to the bank
- ◯ Collateral
- ◯ Upfront charges
- ◯ Bribes & Gratification
- ◯ Late Approval
- ◯ Hidden Charges

| **4.7 What are your challenges in the fertilizer market and what can be done to address them?** | **Challenges** | **Solutions** |
|---|---|---|
| **1** | | |
| **2** | | |
| **3** | | |
| **4** | | |
| **5** | | |

5.0 COVID-19

5.1 What is the challenges of the COVID 19 Virus on your business and what can be done to address these challenges??

5.2 What is your fertilizer market perception and future outlook?

The Ghana customs authority (GCA) IFDC report for 2018 claims the cost of 1mt bagged Urea at the port of Tema is $394.20

5.3 Do you agree with the cost?

- ◯ Yes
- ◯ No

What is the cost for 2020, especially in the wake bagging 25kg as compared to 50 kg bags

5.4 How many days does it take you to clear your fertilizers at the port?

5.5 How much do you pay for demurrage per day

5.6 How long does subsidy repayment take ?