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A Study on the Volatility of Agricultural Commodities in Lagos and Ibadan Markets in Nigeria

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ABSTRACT

In agricultural market where the value of agricultural derivatives is unpredictable, having insight in volatilities of agricultural commodities in these markets is very important for investors and the government. Appling discrete maximum likelihood, we derived the equation for the volatility of the agricultural commodity price and applied it to the data obtained from World Food Programme (WFP) food prices in Nigeria. We then compared the annual volatilities of same agricultural commodity in Lagos market and Oyo market to gain some insight in the uncertainty in the agricultural commodity price. We obtained from our study that the price of Yam and Maize (White) is more stable in Lagos (Lagos) market than price of Maize (White) in Oyo (Ibadan) market. Furthermore, price of Cowpeas (Brown) is relatively stable in Ibadan market compared to Lagos market and we also deduced that the price volatility of Sorghum (White) is relatively stable in Ibadan market compared to Lagos market for the period considered.

1. Introduction

Financial derivatives are financial instruments that are linked to a specific financial indicator or commodity and through which specific financial risks can be traded in financial markets in their own right. Transactions in financial derivatives should be treated as separate transactions rather than as an integral part of the value of underlying transactions to which they may be linked. The value of a financial derivative is often derived from the price of an underlying asset value. Since the future reference price of the underlying item is not known with certainty, the value of the financial derivative at maturity can only be anticipated or estimated. Financial derivatives can be used for a number of purposes such as risk management, hedging, arbitrage between markets and speculations (IMF, 1998). Valuing or pricing financial derivative products is one of the most common problems in mathematical finance. Apart from approximations by discrete –time models, there are basically two main methods to obtain valuation formula for a given financial derivative: pricing by the Martingales method (also known as no arbitrage method) and pricing using the Partial Differential Equations (PDEs), (Heath and Schweizer, 2000).

The study of price volatility of agricultural commodities in Nigeria market is very important since policymakers and participants along the food supply chain are interested in the volatility of agricultural commodities and to better understand the expected future evolution in the prices of these agricultural commodities (Matthews, 2010). Borawski *et al*., (2018), also examined the price volatility of some agricultural commodities like beef, pork and wheat in Poland using 650 weekly observations from 2003 to 2015. In their work, they found that the global market situation impacted Polish agricultural markets, with the integration of Polish into EU, the global financial crisis in 2008 and EU zone problems having the strongest impact on Polish agricultural market. Zheng and Xugun, (2023), studied the price volatility transmission of perishable agricultural product. Volatility transmission is the price phenomenon that influences upstream production and downstream consumption in agricultural commodity markets. Their work examined the relationship between product perishability and price volatility transmission along the agricultural market chain. They adopted data from litchi and apple markets in China to investigate how price volatilities are transmitted across the farm, wholesale and retail stages using high – frequency data. Some evidence of price transmission is also found in (Boyd & Bellemare, 2020; Abdallah *et al*., 2020; Chavas & Pan, 2020; Tan & Zeng, 2019).

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In international agricultural commodity market, the existing price volatility can present a food security threat around the world. For instance, for a lot of people around the globe whose survival depends on small scale farming, the price volatility is beginning to present more challenges (FAO, 2018). Volatility in prices of agricultural commodities over the years have given people concern about the condition of food and nutrition in emerging nations' impoverished people (Minot, 2014). The uncertainty in prices of agricultural commodities in Nigeria market can adversely affect the achievement of the target economic growth and standard of living (Adams & Paice, 2017). As also evidence in (Uduji *et al*., 2019a, 2019b), uncertainty in food price in the market is one of the pressing challenges for policy maker trying to solve the problems associated with food security and economics. As a result of price volatility in agricultural commodities, a lot of programmes have been set up in sub – Saharan African to react to this growing food prices in the region. (Smith and Abraham, 2016). For instance, the Nigeria federal government in 2012 launched the scheme called Growth Enhancement Support Scheme (GESS) for the purpose of finding better ways in delivery of agricultural inputs, improve yields, stimulate food security and enhance economic progress in the rural part of Nigeria (Adesina, 2012). Therefore, agricultural commodities price volatility can create serious economic problems in Africa (Arezki and Bruckner, 2016). Besides, approximately 60% of human population in sub – Saharan Africa earn their livelihood from agriculture with about 28% making use of agricultural land that is less than two hectares (Alper *et al*., 2016).

Agriculture can be viewed as a backbone for a developing nation like Nigeria. Therefore, price volatility of agricultural commodities is a very important component in such a developing economy. The work of Wajid *et al*., (2021), focuses on determinant of agricultural commodities price volatility in Pakistan, where they investigated the price volatility of agricultural commodities and food products in Pakistan using data ranging from June 1983 to June 2018. The work of Adeyemi *et al*., (2019), also discussed the macroeconomic impact of price volatility of agricultural commodities in Nigeria from 1970 to 2017 using Autoregressive Distributive Lag (ARDL) cointegration and Impulse – Response Function (IRF) analysis where they found that, there is evidence of persistent fluctuation in the macroeconomic variables observed. Hence, agriculture is very important for sustaining development and reducing poverty in a nation like Nigeria. It can also be a sources of livelihood and economic growth (WBR, 2023; Adebayo *et al*., 2016).

It is widely accepted that agricultural sector of nation's economy can contribute immensely to the nation's economic growth and development. Therefore, it is very important for such country to develop its agricultural sector. Therefore, the work of Osabohien *et al*., (2018), use the Autoregressive Distributive Lag (ARDL) to study the contribution to food production and export in Nigeria. The study pointed out that the major determinants in studying the effective performance of agricultural sector are technology and institutional framework. Since the use of modern agricultural activities can increase agricultural production (Osabohien *et al*., 2018).

One of the feature of a well – functioning agricultural product markets is price fluctuations. However, when this volatility becomes large and unexpected, it does negatively impact the food security of consumers, farmers and entire country. Volatility can be defined as the variation (amplitude and frequency) of commodities price changes around their mean value (Huchet – Bourdon, 2011). As it can be seen in (European Commission, 2009; Matthews, 2010), we have two kinds of volatility; historical and implicit volatilities. The historical volatility considers data from the past (past commodities prices). It shows the uncertainty in the price of commodities in the past while implicit volatility is the future markets' expectation on volatility of the price of the commodities. In our work, we will consider only historical changes in price of agricultural commodities in Nigeria market. As in OECD (2009), agriculture have exposure to some risks which are; production risk, market risk, institutional risk, personal and financial. It is obvious that the market risk is related to volatility of prices of the agricultural commodities in Nigeria market and these uncertainties in prices are important determinant on how much a farmer would be willing to invest in a particular commodity.

One important component for economic growth is trade. It can also be seen as important tools in securing food, reducing poverty etc. of nation (Nigeria). Nigeria to some extend depends on agricultural commodities export for foreign earnings and for financing its budget. Therefore, changes in price of agricultural commodities could have negative effect on the overall nation's development. This study examines the volatility of selected agricultural commodities over the past eight years to eleven years in Lagos and Ibadan markets in Nigeria. The analysis utilizes data obtained from world food program.

2. Methods

2.1 The constant elasticity of variance (CEV) model

We assume that the price of the agricultural derivative follows the following stochastic differential equation:

$$dX_t = rX_t dt + \sigma X_t^{\alpha} dW_t, \qquad X_0 > 0 \tag{1}$$

where r is the percentage drift, σ is the percentage volatility, with restriction $r \in \mathbb{R}, \sigma > 0$. Furthermore, α is the Elasticity of Variance (CEV), which is considered to be in the interval $[0,1]$. The initial price is $X_0 = X > 0$.

2.2 Estimation of the parameters of the agricultural derivative model

2.2.1 Discrete maximum likelihood method

Here, we discussed the parameter estimation procedures where the diffusion process X is strictly observed at discrete points. One of the major problems encountered in the discrete maximum likelihood parameter estimation framework is now to find a closed form expression that involves the unknown parameters that approximates the transition probability density function (PDF) (Danjuma & Dange, 2022). In order to overcome this problem, we will consider the Gaussian transition density function. The idea behind the maximum likelihood method is to find the parameter values so that the actual outcome has the maximum probability.

2.2.2 The exact maximum likelihood estimation for constant elasticity of variance model parameters

Let $\{X(t): t \geq 0\}$ be a stochastic process that satisfies the Markov's property. Assume that we observe this process at a discrete collection of times points $\{t_0, t_1, \dots, t_n\}$, where $t_0 = 0, t_i = {i\tau}/{n}$ for $i = 1,2, \dots, n$. Let $\{X(t_0), X(t_1), \dots, X(t_i)\}$ be the available data. For simplicity, we use $X_i = X(t_i)$. Let $\boldsymbol{\theta}$ be the parameters defining the process $\{X(t): t \geq 0\}$. Then likelihood function can be defined as

$$L(\boldsymbol{\theta}|X_1, X_2, \dots, X_n) = \prod_{i=1}^{n} p(X_{t_i}|X_{t_{i-1}}; \boldsymbol{\theta})$$

where $p(X_{t_i}|X_{t_{i-1}}; \boldsymbol{\theta})$ is called the transition density. For the Geometric Brownian Motion (GBM) process the transition density is:

$$p(X_{t_i}|X_{t_{i-1}}; \boldsymbol{\theta}) = \frac{1}{\sigma X_i \sqrt{2\pi\Delta t}} exp\left[-\frac{\left(log\left(\frac{X_i}{X_{i-1}}\right) - \left(r - \frac{\sigma^2}{2}\right)\Delta t \right)^2}{2\sigma^2 \Delta t} \right]$$

Thus, the likelihood function is:

$$L(\boldsymbol{\theta}|X_1, X_2, \dots, X_n) = \prod_{i=1}^{n} \frac{1}{\sigma X_i \sqrt{2\pi\Delta t}} exp\left[-\frac{\left(log\left(\frac{X_i}{X_{i-1}}\right) - \left(r - \frac{\sigma^2}{2}\right)\Delta t \right)^2}{2\sigma^2 \Delta t} \right]$$

$$= \prod_{i=1}^{n} \left(\frac{1}{\sqrt{2\pi\Delta t}} \frac{1}{\sigma X_i} exp\left[-\frac{\left(log\left(\frac{X_i}{X_{i-1}}\right) - \left(r - \frac{\sigma^2}{2}\right)\Delta t \right)^2}{2\sigma^2 \Delta t} \right] \right) \tag{2}$$

Therefore, taking natural logarithm of both sides of (2) results in the log – likelihood function of the form:

$$l(\boldsymbol{\theta}|X_1, X_2, \dots, X_n) = \log L(\boldsymbol{\theta}|X_1, X_2, \dots, X_n) = -\frac{n}{2}\log(2\pi\Delta t) - \sum_{i=1}^{n} \log(\sigma X_i)$$

$$-\frac{1}{2}\sum_{i=1}^{n} \frac{\left(log\left(\frac{X_i}{X_{i-1}}\right) - \left(r - \frac{\sigma^2}{2}\right)\Delta t \right)^2}{\sigma^2 \Delta t} \tag{3}$$

Now,

$$\frac{\partial l}{\partial r} = -0 - 0 - \frac{1}{2}\sum_{i=1}^{n} \frac{log\left(\frac{X_i}{X_{i-1}}\right) - \left(r - \frac{\sigma^2}{2}\right)\Delta t}{\sigma^2 \Delta t}(-2\Delta t) \quad (4)$$

Equating (4) to zero gives:

$$\sum_{i=1}^{n} \frac{log\left(\frac{X_i}{X_{i-1}}\right) - \left(r - \frac{\sigma^2}{2}\right)\Delta t}{\sigma^2} = 0$$

$$\sum_{i=1}^{n} log\left(\frac{X_i}{X_{i-1}}\right) - \sum_{i=1}^{n}\left(r - \frac{\sigma^2}{2}\right)\Delta t = 0$$

Let $\bar{X} = \left(r - \frac{\sigma^2}{2}\right)\Delta t$, then

$$\sum_{i=1}^{n} log\left(\frac{X_i}{X_{i-1}}\right) - n\bar{X} = 0$$

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} log\left(\frac{X_i}{X_{i-1}}\right)$$

Similarly,

$$\frac{\partial l}{\partial \sigma} = -0 - \sum_{i=1}^{n} \frac{1}{\sigma X_i}(X_i) - \frac{1}{2}\sum_{i=1}^{n} \frac{\left(log\left(\frac{X_i}{X_{i-1}}\right) - \bar{X}\right)^2}{\sigma^4 (\Delta t)^2}(-2\sigma\Delta t)$$

$$= -\frac{n}{\sigma} + \sum_{i=1}^{n} \frac{\left(log\left(\frac{X_i}{X_{i-1}}\right) - \bar{X}\right)^2}{\sigma^3 \Delta t} \quad (5)$$

Equating Equation (5) to zero gives:

$$\frac{n}{\sigma} = \sum_{i=1}^{n} \frac{\left(log\left(\frac{X_i}{X_{i-1}}\right) - \bar{X}\right)^2}{\sigma^3 \Delta t}$$

$$n\Delta t\sigma^2 = \sum_{i=1}^{n}\left(log\left(\frac{X_i}{X_{i-1}}\right) - \bar{X}\right)^2$$

$$\sigma^2 = \frac{1}{n\Delta t}\sum_{i=1}^{n}\left(log\left(\frac{X_i}{X_{i-1}}\right) - \bar{X}\right)^2$$

$$\bar{\sigma} = \sqrt{\frac{1}{n\Delta t}\sum_{i=1}^{n}\left(log\left(\frac{X_i}{X_{i-1}}\right) - \bar{X}\right)^2} \quad (6)$$

Since,

$$\bar{X} = \left(r - \frac{\sigma^2}{2}\right)\Delta t$$

$$r\Delta t = \bar{X} + \frac{\sigma^2}{2}\Delta t$$

$$\bar{r} = \frac{1}{\Delta t}\left(\bar{X} + \frac{\sigma^2}{2}\Delta t\right) = \frac{\bar{X}}{\Delta t} + \frac{\bar{\sigma}^2}{2} \quad (7)$$

3. Results and Discussion

Here, using equation (6), we evaluated the volatilities of some agricultural commodities like Yam, Maize (White), Cowpeas (Brown) and Sorghum (White) in Lagos and Oyo markets to gain some insight into how the prices

of these commodities evolved in the markets annually and compared the volatilities of these agricultural commodities in the Lagos with Oyo markets.

Table 1. Commodity Price Volatility

Commodity Category: Cereals and Tubers

Commodity: Yam **State: Lagos Market: Lagos**

Year	2015	2016	2017	2020	2021	2022
Price Volatility	0.7366	0.8188	0.4239	0.2896	0.2255	0.0954

Sources: WFP (World Food Program) food prices nga (2023)

Commodity Category: Cereals and Tubers

Commodity: Yam **State: Oyo Market: Ibadan**

Year	2015	2016	2017	2020	2021	2022
Price Volatility	1.4512	1.4753	0.6802	1.483	0.8194	0.1587

Sources: WFP (World Food Program) food prices nga (2023)

Table 2. Commodity Price Volatility

Commodity Category: Cereals and Tubers

Commodity: Maize (White) **State: Lagos Market: Lagos**

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Price Volatility	0.2960	0.2968	0.3362	0.4252	0.3827	0.1322	0.0654	0.3056	0.2533	0.0379

Sources: WFP (World Food Program) food prices nga (2023)

Commodity Category: Cereals and Tubers

Commodity: Maize (White) **State: Oyo Market: Ibadan**

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Price Volatility	0.4339	0.3141	0.3154	0.3713	0.3911	0.2186	0.2565	0.3823	0.5767	0.000

Sources: WFP (World Food Program) food prices nga (2023)

Table 3. Commodity Price Volatility

Commodity Category: Pulses and Nuts

Commodity: Cowpeas (Brown) **State: Lagos Market: Lagos**

Year	2015	2016	2017	2018	2020	2021	2022
Price Volatility	0.2114	0.2278	0.1429	0.2966	0.3112	0.4633	0.0684

Sources: WFP (World Food Program) food prices nga (2023)

Commodity Category: Pulses and Nuts

Commodity: Cowpeas (Brown) **State: Oyo Market: Ibadan**

Year	2015	2016	2017	2018	2020	2021	2022
Price Volatility	0.0595	0.5723	0.2588	0.1628	0.1919	0.3311	0.0300

Sources: WFP (World Food Program) food prices nga (2023)

Table 4. Commodity Price Volatility

Commodity Category: Cereals and Tubers

Commodity: Sorghum (White) State: Lagos Market: Lagos

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
price Volatility	0.2604	0.3588	0.1548	0.1814	0.2921	0.1659	0.0823	0.0721	0.6127

Year	2021	2022
Price Volatility	0.2108	0.0353

Sources: WFP (World Food Program) food prices nga (2023)

Commodity Category: Cereals and Tubers

Commodity: Sorghum (White) State: Oyo Market: Ibadan

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Price Volatility	0.1328	0.2796	0.1468	0.1222	0.6297	0.3449	0.1178	0.0695	0.5634

Year	2021	2022
Price Volatility	0.2558	0.0052

Sources: WFP (World Food Program) food prices nga (2023)

From Table 1, we can see that the annual volatilities of Yam price in Lagos market is relatively lower compared to the annual price volatilities of Yam in Oyo (Ibadan) market. Therefore, we can conclude that the price of Yam is more stable in Lagos (Lagos) market compared to the price of Yam in Oyo (Ibadan) market. Similarly, from Table 2, we can also see that the annual volatilities of Maize (White) price in Lagos market is relatively lower compared to the price volatilities of Maize (White) in Oyo (Ibadan) market. Therefore, we can also draw from the table that the price of Maize (White) is more stable in Lagos (Lagos) market compare to the price of Maize (White) in Oyo (Ibadan) market. Furthermore, from Table 3, the comparison of the price volatilities of Cowpeas (Brown) in Lagos market and Ibadan market shows except for the year 2016 and 2017, that the price volatilities of the agricultural commodity in Ibadan market is lower compared to that of Lagos market. Therefore, price of Cowpeas (Brown) is relatively stable in Ibadan market compared to Lagos market. Also from comparison of Sorghum (White) in Lagos market with Ibadan market in Table 4, we can see that in year 2016, 2017, 2018 and 2021 out of the 11years period we considered, the price volatilities of Sorghum (White) in Ibadan market is greater than that of Lagos market. Hence, we can also deduce that the price of the agricultural commodity is relative stable in Ibadan market compared to Lagos market.

4. Conclusion

We have compared the annual volatilities of some agricultural commodities in Lagos market and Ibadan market to gain some insight on the uncertainty in these agricultural commodities price. Therefore, from this study, we can conclude that the price of Yam is more stable in Lagos (Lagos) market than price of Yam in Oyo (Ibadan) market. Similarly, we obtained that the price of Maize (White) is more stable in Lagos (Lagos) market than price of Maize (White) in Oyo (Ibadan) market. Furthermore, price of Cowpeas (Brown) is relatively stable in Ibadan market compared to Lagos market and we also deduced that the price volatility of Sorghum (White) is relative stable in Ibadan market compared to Lagos market for the period considered.

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