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RESEARCH AND TECHNOLOGY INNOVATION, FOOD SECURITY AND ECONOMIC GROWTH IN NIGERIA: IMPLICATIONS FOR AGRIPRENEURS AND POLICYMAKERS

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ABSTRACT

Population growth and more recently, the Covid-19 pandemic, have increased the number of severely food insecure people in sub-Saharan Africa. Food security is one of the most prominent tasks facing the global environment especially in Asia and Africa. With the increase in the population, drought, floods, disease outbreaks, poor farm network systems, water poverty, weak political and economic institutions, selfish leadership and economic challenges in Africa, the food security crisis appears to be an important issue that will require strategic and urgent attention. There is no doubt that traditional ways of farming are not sustainable in Africa because the land available for agriculture reduces as the population increases over time. Investment in new technologies is one of the strategies to improve farm yields and livestock outputs, and reduces the risk and negative effects of weather. The role of agripreneurship, in this context, towards ensuring food security cannot be underestimated. This study is quantitative research which analyses the historical and current time series data in order to predict the future event using inferential statistics. This study investigates the relationship between food security (FST), agricultural research and technology innovation (RTI) and economic growth (GDP) in Nigeria between 1980 and 2018. The study utilizes cointegration and causality tests to determine the long run relationship among the variables and their causal directions so as to know which variable caused the others. Understanding this relationship among the variables and causal direction are vital to making appropriate suggestions for policy makers. The results of the Johansen cointegration test reveals an existence of a long run relationship between the three series (FST, RTI, GDP). The results of vector error correction model indicate a short run causality from GDP to FST and RTI, respectively. Furthermore, the results of long run causality show two-way causality between FST and RTI, one-way causality from GDP to FST and RTI without feedback. This implies that when the economic activities improve in Nigeria in the short run, this engenders agricultural technology innovation deployment in the country which facilitates food security in the long run, while food security also facilitates agricultural technology innovation. The two-way causality between RTI and FST established in this study implies that increase in agricultural research investment would improve food security and vice versa. Thus, government and other private players such as agripreneurs in agricultural sector should intensify their spending in agricultural research on the one hand, and government should also provide appropriate incentives to motivate private stakeholders for agricultural R&D investment on the other hand.

Key words: Research and technology innovation, agripreneurship, food security, economic growth, Nigeria

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INTRODUCTION

The global population is witnessing a phenomenal change leaving some continents with a teeming population and others with an ageing population. A further development is the rapid urbanisation of African cities, which poses new challenges to policy makers to ensure food security. The world population is estimated to surge and peak from the current 7.8 billion people to 9.7 billion people in 2064, and then fall afterwards to 8.8 billion by 2100 [1]. Many countries, such as Spain, Germany and Portugal in Europe, Japan and South Korea in Asia and various other countries will experience a significant drop in their population [1]. More so, many people in these countries will age leaving very few people in the working-age population to work, pay tax, and cater for the aged population. Moreover, many African countries will experience an overwhelming increase in their population, and Nigeria is projected to become the second most populous nation globally by 2100 with a population projected at 800 million [2]. There is no doubt that the availability and access to food will become a contentious issue, especially in the years to come if proper planning is not put in place. Approximately 795 million individuals, or one in every nine individuals in the world, is undernourished [3]. The majority of undernourished individuals are from developing nations in Africa and Asia [4]. There is urgent need to reduce food wastage and to support farming in more advanced economies, while there is a simultaneous need to reduce hunger and undernourishment in less-developed nations through increased food production and access. Furthermore, food security is key to the accomplishment of the first three sustainable development goals (SDG) of the United Nations (UN) namely: no poverty, zero hunger and good health and well-being. Also, the impact of the Covid-19 pandemic, together with the lockdown that accompanied it, has left a large population of sub-Saharan Africa with scarcity of food due to their inability to farm and fear of contracting the virus [5]. There is no doubt that Covid-19 has worsened food insecurity globally, thus, there is a more urgent call on entrepreneurs and policymakers to address food security issues in developing nations.

Meanwhile, agripreneurship (entrepreneurship in agriculture) is becoming very popular as more entrepreneurs are making creative and innovative contributions to agricultural business. The role that research and technology innovation plays in the agricultural sector towards achieving food security and economic growth cannot be overemphasised [6]. Science, technology and innovation (STI) tend to occupy a strategic position in achieving the SDGs of zero-hunger, no poverty, good health and well-being. The application of technology innovation in agriculture by

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agripreneurs and government, also known as agriculture technology and innovation, can deliver a method which ensures food security. Food security could be achieved through boosting crop and livestock production, and it could also increase the income of people across the value-chain of agricultural production, which invariably increases the economic growth of a country [7]. Agricultural technology innovation also encompasses the constant usage of new and existing knowledge and technologies stemming from both indigenous and imported sources to enhance food production and household welfare [8, 9, 10, 11]. Agricultural technology innovation is also instrumental to food access, food utilisation and food stability which are main components of food security. This technology innovation aids in appropriate transportation, storage and refrigeration of farm produce that are rich in nutrients, provision of accurate weather forecast and early warning systems which reduce wastages and uncertainties of the farming system [3]. Furthermore, technology innovation has been documented, among others, to reduce the losses experienced by farmers, sustain the nutrient of some farm produce that would have otherwise wasted, reduce food prices and improve human productivity [3, 11].

Access to adequate and nutritious food provides individuals with requisite mental, physical and intellectual fitness for performing their tasks productively. It is believed that a healthy individual would perform his/her jobs better, earn more income and contribute more to the national income and GDP of the country [12]. By implication, food insecurity could adversely affect the economic development as malnutrition could lead to illness, which impairs the human (mental, physical and intellectual) capital of people in the country households and reduces their earnings [7]. Consequently, individuals (or a country) with higher incomes tend to have the ability to access more nutritious food compared to those with low incomes, although some individuals in high-income countries also suffer illness such as obesity due to their lifestyle and higher calorie intake [13].

While technology innovation and economic growth could be acknowledged as key success factors to food security, food security and technology innovation could also be significant factors towards economic growth. On the other hand, economic growth and food security could be determinants of technology innovation in a country. There is an interrelationship between food security, technology innovation and economic growth [7, 21], but there is lack of information on the triangular relationship between the three variables in developing countries, especially in Nigeria. This study seeks to examine the nexus between research and technology innovation, food security and economic growth so as to make recommendations

that will assist policy makers in proper planning for sustainable solutions to food insecurity in the country.

LITERATURE REVIEW

Overview of food insecurity and agricultural technology innovation in Nigeria

The Food and Agriculture Organization (FAO) of the United Nations stated that, "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" including sanitation and healthy living [14, 15]. Globally, the number of people that go hungry is above 820 million posing a great challenge for realising the zero-hunger target by 2030 as stated in SDGs [14].

The prevalence of undernourishment is increasing in Africa having stood at an average of 19.9% in 2018. Compared to the global figure of 10.8%, it is apparent that Africa faces the highest rate of undernourishment. Specifically, the number of undernourished people in Nigeria rose from 11.4 million in the period 2000-2002, to 24.6 million in the period 2017-2019 [15]. This corresponds to an increase from 9.1% in 2000-2002 to 12.6% in 2017-2019 as shown in Table 1 [15]. Meanwhile, the global prevalence of undernourishment reduced from 13.4% in 2000-2002 to 8.8% in 2017-2019 [15].

The number of severely food insecure people in Nigeria rose from 11.8 million in the period 2014-2016 to 17.8 million in 2017-2019, which corresponds to 6.5 and 9.1% of the prevalence of severely food insecure in Nigeria, respectively, as indicated in Table 1, compared to 8.1 and 9.2% of the global prevalence of severely food insecure for the period 2014-2016 and 2017-2019. The rate of increase in the number of severely food insecure people is higher in Nigeria than the world over the periods stated above. The total number of agricultural researchers in Nigeria increased from 1,309 in 2000 to 2,976 researchers in 2014, and agricultural researchers per 100,000 farmers were 10.6 per 100,000 farmers in the year 2000 and increased to 23.7 per 100,000 farmers in 2014 [15]. Although the number of researchers doubled in the fourteen years, it could not significantly reduce the country's level of food insecurity which could be as a result of the level of technology adoption within that period. In the quest of boosting agricultural production capacity towards achieving food security in the recent time, many agricultural technology firms (otherwise known as agri-tech firms and agripreneurs) have started their operations in Nigeria. These agripreneurs provide the necessary funds, tools and technology for farmers and agribusinesses to enhance food

production resulting in improved outputs, yields, lower costs and smarter marketing [16, 17]. Agripreneurs such as Farmcrowdy, have facilitated digital platforms where investors are given the opportunity to participate in agribusiness in real time by funding farms and trading in agricultural commodities. An additional 50 million people have been projected by ECOWAS to suffer from food insecurity and malnutrition between June and August 2020 because of the Covid-19 pandemic [18]. The digital platforms have assisted in raising enough capital for the farmers who ordinarily did not have access to new farming technologies that may improve farm yields. With the current growing trend of these agri-tech firms (agripreneurs) in Nigeria, and the support of the government in regulating the sector to boost the investors' confidence and improve digital agribusiness across the value-chain, more food is expected to be produced in the country.

Empirical literature on food security, research and technology innovation, and economic growth

Mutenje *et al.* [7] conducted a study on agricultural innovations and food security in Malawi using a maximum simulated likelihood estimation [7]. The outcome disclosed that the adoption of advanced maize and storage technologies caused a significant upsurge in maize output per unit area. The exploratory study in Singapore found that the country has been able to adopt various technology innovations that have significantly enhanced food security [19]. Some of the technology innovations adopted include vertical farming, the Internet of Things, aquaponics, active and smart packaging, food waste processing, natural preservatives, insect farming and microalgae farming. Furthermore, the study of Fuglie [20] asserted that research and development (R&D) spending in the agricultural sector tends to generate technology innovation, which drives food production and access. The outcomes of the study reveal that R&D investment is a critical factor of agricultural productivity. There are few other studies which also emphasise the positive impact of R&D and innovation investment on agricultural productivity and food security [21, 22]. However, there are other studies that found that the effect of R&D and innovation investment on agriculture remain constant, uncertain or have a long lag period before it reflects on agricultural production [23, 24, 25]. Also, precision and wireless sensing technologies as well as the Internet of Things in agriculture have been applied in many advanced economies to provide the farmers with speedy and dependable extensive information, which enables them to maximize their outputs from the farm throughout the year, thereby enhancing food security [8, 26].

The study of Pourreza [13] opines that food security has a great influence on economic growth. The authors believed that food insecurity impairs human capital

through health, which affects productivity, income and the economic growth of a country. Additionally, the results of Manap and Ismail [12] indicate that as food security improves, economic growth increases, signifying a significant positive impact of food security on GDP of dry-land developing countries. Swietlik examined the link between GDP per capita and food security in selected regions of the world for the period between 2012 and 2015. The results showed that countries with higher GDP per capita witness the most significant improvement in food security [27]. Also, Breisinger and Ecker [28] reveal that broader-based economic growth, in addition to rapid economic growth, is required to end the food and nutrition security crisis in Yemen. A few other studies also support the positive and significant effect of economic growth on food security [29]. However, the study of Desta [30] reveals that lack of economic growth and unequal distribution of income are not the cause of food insecurity in Ethiopia, rather, food insecurity is caused by improper management of inflationary pressures, budget deficit, population growth, and poor storage of farm produce. Additional studies also assert that other factors outside economic growth are responsible for food security, as an increase in economic growth alone cannot improve food security [31].

In the study relating to research and technology innovation and economic growth, Ouru and Mose [32] in their study conducted in East Africa found a strong connection between agricultural R&D, technology innovation and sectoral economic growth of East African countries. The study suggests that innovation via raising Agricultural R&D expenditure and robust institutions can adequately propel sustainable sectoral output growth and development in East Africa economies. Stoian *et al.* [33] conducted a study on agricultural R&D and income growth of farmers among the EU countries using regression model on data obtained from European international databases for the period of 2004–2020. The outcomes reveal that agricultural R&D expenditures have significant impact on the farmers' income growth in majority of the EU countries with few of them experiencing less impact. While some empirical studies affirmed the significant impact of investment in agricultural R&D and innovation on output and farmers' income growth, others could not establish such impacts [34-36].

The empirical literature has shown differing results from various studies relating to the nexus between research and technology innovation and food security, between food security and economic growth, as well as between research and technology innovation and economic growth. However, there is scarcity of research on the triangular relationship between research and technology innovation, food security and economic growth that bring the three variables together despite the useful policy implications that could emanate from the outcomes of their relationships.

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Specifically, in developing countries like Nigeria that are faced with large population projection, there is need for the policy makers to plan appropriately in meeting the needs of the country's population in terms of food security so as to prevent malnutrition, hunger and other social vices that come with food crises. Hence, this study aims to assess the relationship among these three variables in Nigeria.

MATERIALS AND METHODS

This study is based on annual data of the daily supply of calories (measured in kilocalories per person per day) as a proxy for food security (FST), real GDP per capita (constant 2011 prices using purchasing power parity) as proxy for economic growth (GDP) and agricultural research spending (in million Dollars at constant 2011 prices using purchasing power parity) as a proxy for research and technology innovation (RTI) for the period between 1980 and 2018 in Nigeria. Agricultural research spending is considered as an appropriate measure for research and technology innovation in this study, as it has been documented in various studies that research spending leads to technology innovation, and no other national data is available for Nigeria's technology innovation over this period. The data for food security and research and technology innovation were obtained from the Food and Agriculture Organization Corporate Statistical Database [15] while that of the GDP was obtained from the World Development Indicators (WDI) update 2020.

The model for this study is based on the premise that economic growth and the level of technology innovation of a country tend to drive the level of food security. This is shown by a simple model as follows:

$$\mathrm{FST_t} = \alpha_0 + \alpha_1 \mathrm{GDP_t} + \alpha_2 \mathrm{RTI_t} + \mathrm{u_t} \qquad \text{eq. 1}$$

The series are further expressed in a natural logarithm as stated in eq. 2 below

$$\ln\mathrm{FST_t} = \alpha_0 + \alpha_1 \ln\mathrm{GDP_t} + \alpha_2 \ln\mathrm{RTI_t} + \mathrm{u_t} \qquad \text{eq. 2}$$

lnFST, lnGDP and lnRTI represent the natural log of food security, economic growth and research and technology innovation, respectively, while $\alpha_0, \alpha_1, \alpha_2$ and $\mathrm{u_t}$ represent the constant term, coefficient of lnGDP, coefficient of lnRTI and error term, respectively. A unit root test is carried out using Augmented Dickey-Fuller (ADF) test to ascertain the order of integration of the series. This test is conducted to eliminate the spurious outcomes from the model, and when data are stationary at first difference I(1), then they become useful for the cointegration

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test [37, 38]. The application of the Johansen cointegration test in determining the long run association among the variables requires the series under study to be integrated of the same order I(1) [37]. The test confirms whether or not the series are related and can move together, and their abilities to converge in the long run after witnessing some shocks in the short run [38]. The variables that are cointegrated implies that they have some kind of relationships which could be used to understand their linkage and their impacts on one another. The Johansen cointegration test is therefore conducted in this paper to assess the long-term association between food security, economic growth and research and technology innovation. The presence of cointegration and the number of cointegrating equation(s) are obtained from the outcomes of trace test and maximum eigenvalue test. If the presence of relationship is established, a further step could be made to determine the direction of impact.

Since the existence of co-integration among the series only implies that there is a long run relationship among the variables and does not signify any causal direction among them, then there is need to apply the vector error correction model (VECM). The VECM is applied to show the causal direction (if any) among the variables in both the short run and the long run as long as the variables are of the same order of integration I(1) [39, 40]. The VECM for the three variables are stated thus:

$$\Delta \ln FST_t = \theta_1 + \sum_{i=1}^{p} [\alpha_{1i} \Delta \ln FST_{t-i} + \beta_{1i} \Delta \ln GDP_{t-i} + \psi_{1i} \Delta \ln RTI_{t-i}] + \mu_1 ECM_{t-1} + \varepsilon_{1t} \quad \text{eq. 3}$$

$$\Delta \ln GDP_t = \theta_2 + \sum_{i=1}^{p} [\alpha_{2i} \Delta \ln FST_{t-i} + \beta_{2i} \Delta \ln GDP_{t-i} + \psi_{2i} \Delta \ln RTI_{t-i}] + \mu_2 ECM_{t-1} + \varepsilon_{2t} \quad \text{eq. 4}$$

$$\Delta \ln RTI_t = \theta_3 + \sum_{i=1}^{p} [\alpha_{3i} \Delta \ln FST_{t-i} + \beta_{3i} \Delta \ln GDP_{t-i} + \psi_{3i} \Delta \ln RTI_{t-i}] + \mu_3 ECM_{t-1} + \varepsilon_{3t} \quad \text{eq. 5}$$

Each of the equations above indicates that the previous value of the dependent variable and the present values of the independent variables are determinants of the present value of the dependent variable. The joint significance of the coefficients of each of the lagged regressors in each equation denoted by α, β and ψ explained the short- run impact of the independent variable to the dependent variable. Meanwhile, the long run causality is estimated by the significance level of the respective μ coefficient on the ECM, which also measures the speed of adjustment back to the equilibrium.

RESULTS AND DISCUSSION

The outcomes of the ADF test conducted denote that the three series, namely lnFST, lnGDP and lnRTI have unit root initially (at levels) and became stationary at

first difference I(1) as depicted in Table 2. While lnGDP and lnRTI are stationary at first difference I(1) at 1% level of significance, lnFST is stationary at first difference I(1) using a 5% level of significance. This confirms the appropriateness of going further to conduct the Johansen cointegration test as all three variables are integrated of the same order I(1). The results of the Johansen cointegration test show that the series are co-integrated at a 5% level of significance. This is revealed from the trace and maximum eigenvalue tests in Table 3, and the results confirmed the presence of a long run relationship among food security, economic growth and research and technology innovation in Nigeria.

Having shown that lnFST, lnGDP and lnRTI are co-integrated, then the direction of causality using the Granger causality test within the framework of VECM was conducted for both long run and short run periods and the results are displayed in Table 4. In the long run, as shown in Table 4, taking the food security (eq. 3), the coefficient of the ECM is -0.013 and is significant at 5% level, indicating a long-run causality from economic growth and research and innovation to food security. Also, taking economic growth (eq. 4) in the long run, the coefficient of ECM is 0.008 and it is not significant even at 10% level, depicting no long run causality from food security and research and innovation to economic growth. Meanwhile, taking research and technology in the long run (eq 5), the coefficient of ECM is -0.024 and it is significant at 10% level suggesting a long run causality from food security and economic growth to research and technology innovation. There is a tendency for the short-term shocks to be adjusted back to equilibrium in the long run in eq. 3 and eq. 5.

Furthermore, Table 4 reveals the outcomes of short run causality among the series. It could be observed in eq. 3 that there is short run causality from only economic growth to food security as no causality was observed from research and technology innovation to food security. In eq. 4, neither food security nor research and innovation could cause economic growth in the short run, whereas only economic growth could cause research and technology innovation in the short run of eq. 5.

The findings suggest that there is one-way causality from economic growth to food security and also from economic growth to research and technology innovation without any feedback effect in the short run. No causality was detected between research and technology innovation and food security in the short run. This insinuates that economic growth or income is an important factor which engenders food security and research and technology innovation in Nigeria in the short run [41]. The result is similar to some related studies which confirm causality from

economic growth to food security and technology innovation [27, 29, 32]. The increase in Nigerian GDP would enable the country to invest in research and innovation as well as reduce the food insecurity crisis in the country. The failure of the existence of short run causality between food security and research and technology innovation could be as a result of the current relatively low level of investment in research in Nigeria, specifically in agricultural research, which is not enough to significantly improve food security. However, the results of the long run suggest a two-way causality between food security and research and technology innovation, a one-way causality from economic growth to food security, and also a one-way causality from economic growth to research and technology innovation without any feedback results. It could be deduced from the results that economic growth, which Granger-causes research and innovation in the short run, would have impact that could result in Granger-causing food security in the long run. The triangular results of the long run signify that economic growth Granger-causes agricultural research and technology innovation, hence agricultural research and technology innovation Granger-cause food security.

Diagnostic tests were conducted to determine the fitness of the model in equation 2, and the results reveal that the model is free from autocorrelation and heteroscedasticity, and residuals were also found to be normally distributed as shown in Table 5.

The managerial and policy implications of this study cannot be underestimated as the population of Nigeria is increasing and is projected to be the second most populous nation in the world by year 2100 [2]. The policy makers and the planners in Nigeria need to give urgent attention to spending and investment in agricultural research and technology innovation as this would enhance agricultural productivity, improve nutritious food, and ensure food security. Government should provide appropriate policies which could foster investment in agricultural research for both the public (such agricultural institutions) and private (such as agripreneurs) stakeholders in agricultural sector to improve food security.

CONCLUSION

This study utilised the ADF test to investigate the unit root, the Johansen co-integration test to confirm the long run relationship among the variables and VECM to probe the short run and long run causality among the variables. The three series are I(1) and one co-integrating equation was found which established the existence of long run connections among the variables. The results of the short run Granger causality test reveal that there is a one-way causality from economic growth to

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food security and research and technology innovation without feedback and no other forms of causality exist in the short run. Meanwhile, the long run Granger causality test indicates a two-way causality between food security and research and technology innovation and a one-way causality from economic growth to both food security and agricultural research and technology innovation. Increase in economic activities seems to Granger-cause food security and research and technology innovation both in the short run and the long run. However, in the long run, there is also two-way causality between agricultural research and innovation and food security.

Government, through policies, should encourage investment in agricultural research and innovation which would enable the country to achieve the sustainable development goal of zero hunger. This could be achieved through direct spending on agricultural research in various research institutions and governmental agencies, creating an enabling environment for agripreneurs who engage in digital agribusiness, supporting the smallholder farmers with seeds and other farm requirements as well as encouraging local firms to go into technologically advanced farming by offering them low interest loans, tax rebate/tax holidays and specialised trainings.

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Table 1: Overview of food security in Nigeria

Index	2000-2002	2014-2016	2017-2019
Number of undernourished people (in million)			
Nigeria	11.4	16.6	24.6
World	833.2	613.8	673
Prevalence of undernourishment (in %)			
Nigeria	9.1	9.2	12.6
World	13.4	8.3	8.8
Number of severely food insecure people (in million)			
Nigeria	N/A	11.8	17.8
World	N/A	597.8	703.3
Prevalence of severely food insecure (in %)			
Nigeria	N/A	6.5	9.1
World	N/A	8.1	9.2
Agricultural Researchers in Nigeria (in number)			
Total number of agricultural researchers	1309	2976	N/A
Number of agricultural researchers per 100,000 farmers	10.6	23.7	N/A

Source: [15]; N/A denotes Not Available

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Table 2: ADF unit root test

Series	Levels	First Difference
lnFST	-1.7573	-2.9970**
lnGDP	-1.2250	-4.1447***
lnRTI	-0.1083	-4.9569***

***, **, * denote significance at 1%, 5% and 10% levels, respectively

Table 3: Co-integration test

Hypothesis	**Test Statistics**	
H_o	Trace	Max. eigenvalues
R = 0	32.5346*	30.4209*
R ≤ 1	18.1485	17.2134
R ≤ 2	15.0518	14.1415

*denote significance at 5% level

Table 4: Causality test

	Long run	**Short run**
Causality	**Error correction term**	**Chi-square**
Δ lnFST equation	-0.0129**	
Δ lnGDP		6.5756*
Δ lnRTI		0.4503
Δ lnGDP equation	0.0083	
Δ lnFST		0.0171
Δ lnRTI		0.1091
Δ lnRTI equation	-0.0244*	
Δ ln FST		1.1950
Δ lnGDP		4.9806**

Note: ***, **, * denote significant at 1%, 5% and 10% levels

Table 5: Diagnostic tests

Test	**H_o**	**P-values**
Auto Correlation LM Test	No serial correlation	0.6716
Jarque-Bera (JB)	There is normality	0.1173
Heteroscedasticity	No heteroscedasticity	0.8111

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