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FULL-LENGTH RESEARCH ARTICLE

Exploring Impact of Climate Change on Poultry Production in Nigeria

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Abstract The study explored the impacts of climate change on poultry production in Africa's most populous country, Nigeria. Other control variables such as gross national income (GNI) per capita (GNI), official exchange rate of the Naira and value of loans guaranteed to the poultry sector were also considered. Times-series data from 1981 to 2020 were obtained from the Central Bank of Nigeria Statistical Bulletin, World Development Indicators, FAOSTAT and World Bank Climate Change Knowledge Portal. Leveraging on the autoregressive distributed lag model (ARDL) and threshold analysis the study revealed that 1% increase in annual days with heat index > 35 °C will cause a significant decrease in poultry production by 0.14% in the long-run. In addition, the coefficient of annual maximum number of consecutive dry days was positively related to poultry production. It was revealed that 1% increase in rainfall will cause a significant increase in poultry production by 0.84% in the long-run and 0.60% in the short-run. The study further indicated that 1% increase in GNI per capita will lead to a 0.38% increase in poultry production in the short-run and 0.54% in the long-run. In accordance, the official exchange rate of the naira was also positively related to poultry production and 1% increase in official exchange rate tends to result in 0.04% and 0.05% increases in poultry production in the short-run and long-run. However, increase in value of loans guaranteed to the poultry sector appeared to be insignificant and could assist the poultry farmers in sourcing for poultry inputs targeted at increasing poultry production. According to threshold analysis, the country's poultry output may be negatively impacted by rainfall and dry days above certain threshold levels, which are 122–135 days and 1146–1237 mm, respectively. The findings of the study present an opportunity for poultry farmers in Nigeria to embrace climate smart agricultural practices in the face of changing climate in Nigeria. The Nigerian government should maintain stable and sustainable exchange rate of the naira and sustain the loans guaranteed to the poultry sector to improve the uptake of climate smart poultry production, increase agricultural gross domestic product and gross national income in the country.

Keywords ARDL · Climate change · Poultry production · Poultry smart · Poultry in Nigeria · Temperature effect · Rainfall effect · Time-series analysis

Introduction

Poultry production is a significant part of animal industry in agriculture globally. This industry has become more popular due to the growing demand for chicken meat and eggs as healthy protein sources. For smallholders around the world, poultry production offers high-quality, affordable animal protein, a high opportunity for investment, job opportunities, and a source of income [5, 17, 20] Producing broilers and laying hens make poultry one of the most

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significant industries in the world. Meat and egg production for chicken have been increasing rapidly on a global scale [33]. Chicken is the second most consumed animal source food in the world, accounting for around 40% of all 60 meat production [41]. Chicken is consumed by people from all different countries, faiths, and customs. Africa's agriculture heavily relies on the production of chicken, with rural households raising around 80% of the continent's poultry [42]. Therefore, the production of poultry has a significant socioeconomic impact as well as positive effects on nutrition and human well-being [40]. In addition to producing revenue and serving as a liquid household asset, poultry also offers nourishment and raises social standing. In low-income and developing nations, in particular, it provides a source of protein and micronutrients that has the potential to enhance food security and lower poverty [59]. Farmyard manure from poultry farms is a byproduct rich in plant nutrients like nitrogen (N), phosphorus (P), and a few trace elements that are necessary for crop growth. The physical and biological qualities of soil are enhanced by poultry manure [2]. Applying poultry manure as an organic fertilizer to agricultural land is an ideal solution to increase crop yield.

In Africa, providing food for the continent's inhabitants, generating income, and helping to create jobs make poultry farming an extremely valuable business. Rural poultry supplies 20% of the animal protein consumed in Africa and over 70% of the chicken products [24]. Seventy percent of all chickens in sub-Saharan Africa (SSA) are indigenous chickens, with rural chicken production making up around 60% of the region's poultry [24]. According to [22], more than 80% of people reside in rural areas in East Africa, and more than 75% of these families raise native chickens. Thus, the poultry market in Africa is anticipated to have rapid growth in ten years to come due to rising consumer demand for chicken products [5]. Nigeria's poultry industry is the second-largest in Africa, generating more than 180 million birds that produce 454 billion tons of meat and 3.8 million tons of eggs [41]. Poultry sector is Nigeria's most commercialized animal sub-sector and contributes about 30% of total agriculture and 8% of total GDP [41]. In addition to contributing close to 58.2% of all animal output in Nigeria, the poultry subsector employs about 14 million people [42]. In Nigeria, about 70% of the chicken production is raised by rural farming households since it is easier to rear and manage than other farm animals [40].

Despite these important implications, climate change has impacted the poultry production [26, 29, 49], notwithstanding the fact that animal production as a whole contributes significantly to climate change [9]. Poultry production is known to be impacted by climate change globally; for instance, poultry is actively affected by high temperatures, excessive humidity, and heat stress. Variations in the changing environment lead to increase in body temperature, a drop in feed intake and efficiency, a decrease in weight, a high death rate, a decrease in the production of meat, and a decrease in the quality of eggs [3, 37, 58].

However, existing studies have examined climate change impacts on agricultural production, focusing mainly on crop production [30, 46, 55, 57] with few studies on livestock (poultry production) in Nigeria and India [4, 14, 38, 41, 47]. Interestingly, these studies on poultry production used more of temperature and rainfall as climate variables to explore the impacts of climate change on poultry production, though these studies contributed to knowledge but has obvious limitations in that it did not broadly explore other novel and important climate variables such as annual days with heat index > 35 °C and annual maximum number of consecutive dry days. Again, previous studies failed to include other controlled non-climate variables such as GNI per capita, official exchange rate, and value of loans guaranteed to the poultry sector. These alone differ the study from previous published works. Again, there is a dearth of studies on the impact of climate change and poultry production in sub-Saharan Africa that considered these important novel climate variables such as annual days with heat index > 35 °C and annual maximum number of consecutive dry days making the study the first to consider these variables in assessing the impacts of climate change on poultry production in Nigeria and Africa at large.

Materials and Methods

Data Sources

Data were obtained from the Central Bank of Nigeria 2021 Statistical Bulletin [8], World Development Indicators [61], FAOSTAT [18], and World Bank Climate Change Knowledge Portal [60]. Time-series data were obtained for variables of interest from these sources for a period of 40 years (1981–2020) that is sufficient for any time-series analysis. Specifically, data were obtained on loans guaranteed to the poultry sector, and official exchange rate from the Central Bank of Nigeria 2020 Statistical Bulletin. Mean temperature, annual days with heat index > 35 °C, annual maximum number of consecutive dry days, and rainfall data were obtained from the World Bank Climate Change Knowledge Portal. Chicken production data were obtained from FAOSTAT, while gross national income (GNI) per capita data were obtained from the World Development Indicators of the World Bank Group (See Table S1 for details). Official exchange rate data obtained from the Central Bank of Nigeria Statistical Bulletin were used to convert naira values of loans guaranteed to the poultry sector to Dollar values. This was done to control for inflation.

Econometric Framework and Model Specification

Autoregressive distributed lag regression (ARDL) was used to model the impact of climate change on poultry production in Nigeria. This model was applied because of its advantage in handling the short run and long dynamics of the impacts of the explanatory variables on the dependent variable, and simultaneously checking for cointegrating relationships among the variables using the Bounds test [16, 27, 28, 46, 47].

The dataset was first subjected to unit root tests using the augmented Dickey–Fuller (ADF) and the Phillips–Perron tests for the unit root tests to determine the stationarity or otherwise of our dataset. The literature recommends this approach while dealing with time-series data to avoid spurious or misleading results [10, 15, 19, 43, 44]. In the present investigation, the White's test was used to test for homoscedasticity, Durbin–Watson test was used to test for autocorrelation, Ramsey RESET test was used to test for omitted variables, and cumulative sum plot to test for parameter and structural stability of the ARDL model. The dependent variables in this paper are chicken production, while the predictors include loan guaranteed to the poultry sector, mean temperature, loans guaranteed to the poultry sector, and official exchange rate, annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall, and gross national income (GNI) per capita. The outcomes of these tests were presented in the results section. The implicit model of the ARDL technique used to model the impacts of climate change on poultry production in Nigeria is stated thus:

$$\begin{aligned} \mathrm{PPdn}_t = & f(\mathrm{ADHI}_t, \mathrm{AMNCDD}_t, \mathrm{RAIN}_t \\ & , \mathrm{TEMP}_t, \mathrm{GNI}_t, \mathrm{FOREX}_t, \mathrm{LOAN}_t, \mathrm{e}_t) \end{aligned} \quad (1)$$

where

PPdn = Chicken production (tons).

ADHI = Annual Days with Heat Index > 35 °C.

AMNCDD = Annual Max Number of Consecutive Dry Days.

RAIN = Rainfall (mm).

TEMP = Temperature (°C).

GNI = Gross National Income per capita (constant 2015 US$).

FOREX = Official Exchange Rate of the Naira (N/ US$1.00).

LOAN = Value of Loans Guaranteed to the Poultry Sector ($' Thousand).

e = error term.

t = time, t:2000, 2001, 2002, …, 2020 year.

The observations of the dependent and independent variables were converted to their respective natural logarithmic values and used in the final analysis to eliminate/ reduce heteroskedasticity.

Results and Discussion

Summary Statistics

The summary statistics of the dependent and independent variables are presented in Table S2. The mean of annual days with heat index > 35 °C and annual maximum number of consecutive dry days was 9.8 and 129.6 with a minimum values of 2.08 and 108.8, respectively; this denotes an increasing rate in annual days with heat index > 35 °C and annual maximum number of consecutive dry days in the period under study. The mean rainfall was 1159.7 mm with a standard deviation of 84.9 mm, while the average temperature was 27.2 °C with a standard deviation of 0.3 °C indicating significant variance in Nigeria climate variables over time, which can affect poultry production in the country. In Nigeria, [19, 46] found identical mean and standard deviation values for rainfall and temperature in their investigations spanning 39 and 37 years, respectively. Furthermore, the mean gross national income per capita, official exchange rate of the naira and chicken production in Nigeria were 1794.2, 100.9 and 191,148.9 with their minimum values of 1308.1, 0.6 and 122,000.0, respectively, this further indicates that these variables increased significantly within the period under investigation. However, the mean value of loans guaranteed to the poultry sector within the study period was considerably lower than the maximum value for loan with a high standard deviation. This could mean that the loan provided for the poultry sector during the period of survey may not be sustainable due to inconsistencies in government policies; others can include interest rates, collateral demands and other documents as may be required by the financial institutions. This is in agreement with previously published reports [6, 34]. To achieve the needed output, it is necessary to narrow the significant disparity between the maximum value of loans guaranteed to the poultry sector and the mean value.

Trend Analyses/Graphs of the Dependent and Independent Variables

The trend analysis of the dependent and independent variables is presented in Figure S1 to Figure S8. The annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall, average temperature, gross national income per capita, official exchange rate of the naira, and chicken production in Nigeria showed a consistent fluctuating trend patterns indicating a rise and fall scenario. The line of best fit showed a positive trend in the variables (like annual days with heat index > 35 °C, annual max number of consecutive dry days, rainfall, temperature, GNI per capita, official exchange rate of the naira, and chicken production) (Figure S1 to Figure S6 & Figure S8) over the time and further indicating an increasing trend during the period of investigation (Figure S7). These results correspond to the findings of [16, 46] in Nigeria. In contrast, the trend for value of loans guaranteed to the poultry sector in Nigeria from 1981 to 2020 showed a negative slope, and this connotes a decrease in the value of loans guaranteed to the poultry sector under the period of investigation.

Multicollinearity Test

The outcome of the variance inflation factor (VIF) used to assess if there is multicollinearity among the independent variables is shown in Table S3. The outcome demonstrates that there is no multicollinearity among the independent variables, as indicated by the tolerance estimations of the VIF for each independent variable. Chidiebere-Mark et al. [10], Emenekwe et al. [16], Onyeneke et al. [43], Onyeneke et al. [44], Onyeneke et al. [45] also reported the absence of multicollinearity using VIF in similar studies.

Unit Root Test

To ascertain whether the dependent and independent variables were stationary or non-stationary, the unit root test was used in the study. This determined the sort of analysis that was performed after that. To determine the stationarity of the variables, the augmented Dickey–Fuller test and Phillips–Perron test were utilized in the study. Table S4 displays the outcomes of the unit root test. The result shows that under augmented Dickey–Fuller test, annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall and temperature were all stationary, while chicken production, GNI per capita, official exchange rate of the naira, and value of loans guaranteed to the poultry sector were not stationary at level and interestingly all became stationary at the first difference. Again, under the Phillips–Perron test, annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall and temperature were all stationary, while chicken production, GNI per capita, official exchange rate of the naira, and value of loans guaranteed to the poultry sector remained not stationary at level but were further stationary at the first difference. However, this implies that the variables under study were not integrated of the same order under both the augmented Dickey–Fuller and the Phillips–Perron tests, and this justifies the test for co-integration [10, 46] and further suggests that the ARDL model is most statistical suitable in this case in estimating the impact of the independent variables on the dependent variable.

ARDL-Bounds Test for Cointegration

Long-run relationship between chicken production, annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall, temperature, GNI per capita, official exchange rate of the naira, and value of loans guaranteed to the poultry sector were analyzed using bounds test and presented in Table S5. At the first difference, the F-computed result (7.6) is higher than the F-critical value at the 1% level (4.3) (Table S5). The analysis made use of the approximated p values generated by STATA 17 software and the Kripfganz and Schneider (2020) critical values. The result produced implies that there is a long-run relationship between chicken production, annual days with heat index > 35 °C, annual max number of consecutive dry days, rainfall, temperature, GNI per capita, official exchange rate of the naira, and value of loans guaranteed to the poultry sector in Nigeria between 1981 and 2020. The model and dataset do not exhibit autocorrelation, serial correlation, or heteroskedasticity, according to the Durbin–Watson statistic (1.8) and White's test. No variables were missing, according to the Ramsey RESET test. Additionally, the t test result (-6.3) was greater than the t-critical values at both I(0) and I(1) and significant at 1%. This demonstrates that the independent factors had significant impacts on the dependent variable. Additionally, the model is correctly specified, supporting the suitability of the econometric model employed in this study. This supports the findings of [12, 23, 47, 52].

Structural Stability of the ARDL Model

To ascertain if the model has a structural flaw, the study employed the ordinary least squares (OLS) cumulative sum test for parameter stability. The outcome is shown in Table S6. The result demonstrates that the model was stable because there was no structural break in it. The structural stability of the econometric model is further demonstrated in Figure S11. The findings of the cumulative sum test for parameter stability were well contained within 95% confidence boundaries, leading to the acceptance of the null hypothesis that there were no structural breaks (absence of structural break). Further illustrating the stability and dependability of the model are the CUSUM (cumulative sum) plot for the ECM's (error correction model) stability coefficients and the CUSUM of squares plot for the same stability coefficients (Figures S9 and S10). As a result, it may be inferred that during the review period, the parameter estimations are structurally stable. As a result, it can be concluded that the ARDL model utilized for the study is accurate and reliable for making forecasts and policy decisions. These findings confirm that using ARDL to simulate how climate change will affect Nigerian poultry production is a suitable approach. The results are similar to the findings of [11, 46, 47, 56].

Short-run and Long-run Estimates of the ARDL ECM

The study used the autoregressive distributed lag model (ARDL) to estimate the impacts of annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall, temperature, GNI per capita, official exchange rate of the naira, and value of loans guaranteed to the poultry sector on poultry production in Nigeria within the period (1981 to 2020).

The long-run and short-run elasticities of annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall, temperature, GNI per capita, official exchange rate of the naira, and value of loans guaranteed to the poultry sector with respect to poultry production are presented in Table S7. Results depict that the ECM result was negative (-0.7) and statistically significant at the 1% level of probability. This demonstrates how much the variables must be adjusted each year to reach long-term equilibrium. The ECM value shows that the annual correction for the shift in chicken output from short to long term would be 70%. This further suggests that the short-term adjustments/shocks/distortions in chicken production are predicted to have a 72% long-term magnitude adjustment to equilibrium that supports earlier findings by Onyeneke et al. [46], Onyeneke et al. [47], Chidiebere-Mark et al. [10], and Emenekwe et al. [16] in their respective studies in Nigeria.

The coefficients of annual days with heat index > 35 °C were not significant in the short-run but was negatively significant in the long-run at 1% level of probability. This implies that annual days with heat index > 35 °C has a negative impact on poultry production. A 1% increase in annual days with heat index > 35 °C will cause a significant decrease in poultry production by 0.1% in the long-run. According to empirical research [3, 36, 53, 58, 62], an increase in the number of yearly days with a heat index over 35 °C leads to heat stress in chicken layers and lower availability of nutrients and energy for egg production. Additionally, it results in more eggshells that are too thin and also leads to seasonal decrease in egg production. It restricts the amount of grain that chickens consume, which causes vitamin deficiencies in birds. Heat stress also has an impact on meat quality. The number of days per year with a heat index of 35 °C or above promotes respiratory alkalosis, which then leads to an acid–base imbalance, which in turn causes the birds to be less active and perform poorly. In some cases, this causes loss in body weight and eventual high mortality. This causes significant economic loss to the poultry farmers.

The coefficient of annual maximum number of consecutive dry days was positive and significant both in the short-run and long-run at 1% level of probability, and this implies that coefficient of annual maximum number of consecutive dry days was positively related to poultry production. This implies that increase in annual maximum number of consecutive dry days will increase poultry production. That is a 1% increase in annual maximum number of consecutive dry days will increase poultry production by 0.5% and 0.7%, respectively. In the long-run, the maximum number of dry days per year is anticipated to allow poultry litters, (made of bedding materials like shavings, rice hulls, etc.) [13] and other components to be kept dry throughout the year. This facilitates water evaporation process, increased bird performances, increased bird activity, increased energy needed for egg laying and production, as well as increased efficiency in birds leading to healthy birds and meat quality production [35, 48]. Every poultry farm must maintain dry litter, and doing so can only be done by having the most consecutive dry days feasible. Dry litter conditions have an impact on bird performance in terms of growth, weight gain, size, etc., [21] which has an impact on the overall profitability of poultry farmers. A healthier flock habitat, less disease transmission, and reduced ammonia levels are all benefits of dry litter in chicken farming. However, since the health of poultry birds and that of the farmers are equally affected with wet poultry litters, therefore, maximum number of consecutive dry days is needed to keep the health of both the poultry workers and the welfare of birds reared [20]. Further, more number of consecutive dry days permits high air quality, which is necessary for appropriate ventilation in the production of chicken. This further improves the welfare of poultry birds, mitigates poultry disease spread, and promotes production efficiency. Because they cannot perspire, birds expel excess heat through panting, vigorously flapping their wings, and breathing. Ventilation improves the comfort and welfare of the birds, which improves their health and performance [9]. It also helps to remove excess heat and humidity from the sheds where the birds are kept.

The coefficient of rainfall was positive and significant both in the short-run and long-run bases at 1% level of probability. This implies that rain has a positive relationship and implication for poultry production in Nigeria. This indicates that increase in rainfall increases poultry production, in that a 1% increase in rainfall will cause a significant increase in poultry production by 0.8% in the long-run and 0.6% in the short-run. In the long-run, temperatures reduction and heat discomfort in poultry production are alleviated by rains. Rainfall is therefore required to control the excesses of high and unwarranted temperatures as well as heat stress in poultry production [38]. Temperatures exceeding 24 °C and heat stress above 35 °C impede poultry production by reducing growth and egg production as well as decreasing the quality and safety of poultry and eggs [3, 50]. Once again, during the rainy season, birds eat more feed than they do during the dry season, which causes them to acquire more weight, develop in size and, more efficiently, produce more meat [32]. Furthermore, increase rain also makes it possible to collect rainwater for use in providing poultry birds with enough water. However, this finding differs from [54], who reported that difficulties related to water shortages in poultry production are being made worse by droughts occurring more frequently. The most crucial nutrient for the general well-being and productivity of commercial broilers and layers is water [49]. It is crucial for the control of the bird's body temperature, food digestion, nutrient delivery, joint and organ lubrication, and waste disposal. It also plays a crucial function in every area of metabolism. Harvesting rainwater reduces the need for external water supplies, which is cost-effective for chicken farms. Water availability is crucial, and going without it for several hours would probably result in a drop in egg production or perhaps death. In order for digestion to take place, water in the crop softens the feed. Dry grain can clump together in the crop without water and push against the bird's carotid artery, reducing blood supply to the brain. Generally speaking, a shortage of water affects poultry birds more severely than a lack of feed [49].

The coefficient of gross national income was positive and significant in the short-run and long-run. This implies that the gross national income per capita has a positive relationship with poultry production only in the long-run and short-run. This indicates that a 1% increase in gross national income per capita will lead to a 0.4% increase in poultry production in the short-run and 0.5% in the long-run. Increased commercialization of chicken egg and meat production is anticipated to have a substantial impact on the farmers' overall income and nation's gross domestic product [5]. This finding differs from [7], who found that poultry production had insignificant effect on agricultural GDP in Nigeria. Furthermore, poultry farming significantly affects the nation's domestic income, providing between 6 and 8 percent of real GDP in Nigeria in year 2020 [51]. About 30% of agriculture's GDP comes from poultry farming alone, which boosts overall productivity and improves food security [31].

The coefficient of official exchange rate of the naira was positive and significant at 10% level of probability in both the short-run and long-run bases. This implies that the official exchange rate of the naira is positively related to poultry production, in that a 1% increase in official exchange rate of the naira will result in 0.04% and 0.05% increases in poultry production in the short-run and long-run, respectively. This further implies that in the long-run the official exchange rate of the naira will have a positive direct impact on poultry exportation, in that at higher exchange rate; Nigeria exported more of her poultry products to foreign consumers within the period under investigation. This means that increases in official exchange rate of the naira increase the exportation of poultry products such as eggs, meats, and manure thereby stimulating increase in domestic poultry production [39] and a reduction in import of poultry products [25]. Again increasing official exchange rate of the naira will encourage both local and commercial poultry producers and industries in producing more poultry birds. At increasing official exchange rate of the naira and exportation of our poultry products, there is a corresponding inflow of more foreign currencies into the country [1]; hence, this could result in the provision of more poultry inputs such as feeds and feed formulation materials thus leading to increased poultry production. The capital inflows could as well contribute to agriculture gross domestic product in the country.

The coefficient of value of loans guaranteed to the poultry sector at lag of the first difference was positive and significant at 1% in the short-run only. This implies that this variable had a short-run relationship with poultry production. This implies that a 1% increase in value of loans guaranteed to the poultry sector will yield a corresponding increase of 0.04% in poultry production in the short-run. This percentage value seems insignificant and could assist the poultry farmers in sourcing for poultry inputs targeted at increasing poultry production within the period under study. The reason for the low percentage value could be because of inconsistency in government policies regarding poultry production, others could be fiscal and monetary policies which directly and indirectly affects poultry farming. Seemingly financial institution's requirements may also pose a setback in securing such loans [6, 34].

Threshold Analysis between Annual Maximum Number of Consecutive Days, Rainfall and Poultry Production

The paper further conducted a threshold analysis to determine the level of rainfall and annual maximum number of consecutive dry days that could support poultry production in Nigeria. The threshold analysis was done in three orders. The result shows that the threshold for annual maximum number of consecutive dry days that could support poultry production in Nigeria is between 122.2 and 135.7 days. After, this threshold, poultry production may be adversely affected. Also, the threshold for annual rainfall that could support poultry production in Nigeria is between 1146.4 and 1237.4 mm. This could be the reason why the two variables significantly increased poultry production in the long-run in the country as indicated in Table S7. The mean values of the variables (see Table S2) are within the thresholds produced by the results of the threshold regression analysis.

Conclusions

This paper assessed the impacts of annual days with heat index > 35 °C, annual maximum number of consecutive dry days, rainfall, temperature, GNI per capita, official exchange rate of the naira, and value of loans guaranteed to the poultry sector on chicken production in Nigeria using secondary data spanning a period of 40 years (1981 to 2020) obtained from the Central Bank of Nigeria 2021 Statistical Bulletin, World Development Indicators, FAOSTAT and World Bank Climate Change Knowledge Portal. Using the autoregressive distributed lag (ARDL) model, it was revealed that 1% increase in annual days with heat index > 35 °C will cause a significant decrease in poultry production by 0.14% in the long-run. In addition, the coefficient of annual maximum number of consecutive dry days was positively related to poultry production implying the fact that dry days create a healthier flock habitat and benefits chicken farming. The analysis showed that 1% increase in annual maximum number of consecutive dry days will increase poultry production by 0.47% and 0.66%, respectively. It was revealed that 1% increase in rainfall will cause a significant increase in poultry production by 0.84% in the long-run and 0.60% in the short-run. The study further indicated that 1% increase in GNI per capita will lead to a 0.38% increase in poultry production in the short-run and 0.54% in the long-run. In accordance, the official exchange rate of the naira was also positively related to poultry production and 1% increase in official exchange rate tends to result in 0.04% and 0.05% increases in poultry production in the short-run and long-run. However, increase in value of loans guaranteed to the poultry sector appeared to be insignificant and could assist the poultry farmers in sourcing for poultry inputs targeted at increasing poultry production. The threshold analysis suggests that the country's poultry output may be negatively impacted by rainfall and dry days above certain threshold levels, which are 122–135 days and 1146–1237 mm, respectively.

However, the finding of the study generally implies that climate change impacted poultry production in Nigeria both positively and negatively. Nigerian government should also maintain stable and sustainable exchange rate of the naira to improve poultry production in the country. Also, sustaining the loans guaranteed to the poultry sector by the Nigerian government will further assist the poultry farmers, poultry industries and other poultry commercial producers in the country in improving and increasing poultry production in Nigeria; thus, this will, in turn, improve agricultural gross domestic product and, at large, the gross national income in Nigeria.

The findings of the study also present an opportunity for poultry farmers in Nigeria to embrace climate smart agricultural practices in the face of changing climate and weather conditions in Nigeria. The study recommends Nigerian government to increase loans guaranteed to the poultry sector to boost poultry production, income and food security.

The study presents interest findings for building resilience of the poultry sector in Nigeria and other areas with similar contexts. However, it is important to mention one limitation of this study. The study did not factor chicken mortality in the model because of lack of data on this variable. Considering mortality data in relation to chicken production and climatic data is also important to understand the influence of changing climatic scenario on Nigerian poultry production. There is therefore the need to increase collection, reporting and recording of all data on important poultry production indicators. When such data become available, future studies should incorporate them in their analyses to provide more comprehensive insight on the short-term and long-term effects of climate change and other production-related variables on poultry output across different countries of the world to allow for continental/regional differences. The current study (and its robust design and adopted analytical techniques) nonetheless suffices for the illumination of the effects of climate change on poultry production in Nigeria and similar contexts.

Author Contributions EO, RO, GN contributed to conceptualization; RO contributed to formal analysis, methodology, and supervision; EO and GN contributed to investigation; EO and RO contributed to validation; EO and MO contributed to visualization; EO, RO, GN, MO contributed to writing—original draft; EO, RO, GN, MO contributed to writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Data Availability The data used for this study are openly/publicly available. The data can be downloaded from the World Development

Indicators website, World Bank Climate Change Knowledge Portal website, FAOSTAT website, and Central Bank of Nigeria website.

Declarations

Conflicts of interest The authors declare no conflict of interest.

Informed Consent Not applicable.

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