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CLIMATE CHANGE ADAPTATION AMONG POULTRY FARMERS: EVIDENCE FROM NIGERIA

By

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Food Security Policy *Research Papers*

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Table of Contents

ABSTRACT

Most climate change adaptation studies in agriculture focus on staple food crops. Few studies have examined livestock farmers in Africa and even fewer have considered small animals such as poultry. Heat stress associated with climate change is a challenge to poultry farmers due to its negative effect on chicken growth and productivity. As the poultry subsector across Africa expands to meet changing consumption patterns, understanding how farmers deal with the realities of poultry production due to climate change is critical. This study explores the level and determinants of the adoption of climate change adaptation strategies among poultry farmers in Nigeria. A multivariate probit analysis reveals that poultry farmers practice climate change adaptation strategies with a clear heterogeneity of strategies at different production scales. Small farms tend to invest in traditional strategies such as the stocking of local breeds while medium and large farms adopt modern technologies such as air and water ventilation and the use of bulbs that emit less heat. Our study finds that farmers who have experienced heat related losses are more likely to adopt modern practices and more likely to adopt multiple adaptation strategies at a time.

Keywords: Climate change, adaptation, poultry farmers, Nigeria

1. INTRODUCTION

Agriculture in West Africa is expected to be one of the hardest hit by climate change (Parry et al. 2004). Global climate and crop production models forecast lower yields for staple crops in the region due to climate change (Jones and Thornton 2009; Sonneveld et al. 2012). Climate change impacts will be even more pronounced in arid and semi-arid areas where increased drought frequencies are expected to reduce vegetation cover and livestock numbers; and higher temperatures to cause an increase in the demand of already scarce water sources for livestock (Thornton et al. 2009). Nigeria is not exempt from the impacts of climate change. Studies have documented increased variability in rainfall, dry spells during the rainy seasons and increased frequency of a reduction in the frequency and amount of precipitation for a number of weeks once the rainy season sets in (Adejuwon and Odekunle 2006).

Most climate change impact studies in agriculture focus on staple food crops (Seo and Mendelsohn 2008). There are limited studies that have examined the effects of climate change on African livestock and those few tend to focus on large livestock such as beef cattle (Debela et al. 2015; Silvestri et al. 2012; Zampaligré et al. 2014). Very little is available on small animals such as poultry despite their sensitivity to climate change and their significant contribution to rural livelihoods (Nyoni et al. 2018). Consequently, this study hopes to contribute to this gap by exploring climate change adaptation in poultry production in Nigeria, one of the largest economies in Africa and expected to be among the top three countries in terms of population by 2050 (United Nations 2017).

The Nigerian poultry sub-sector is experiencing rapid growth and transformation. This is associated with the transformation of diets as incomes and urbanization increase (Liverpool-Tasie et al. 2017). Being both a source of protein and income for many households in Nigeria, poultry plays an important role in food security. Despite its importance for livelihoods in the country, there is limited information about how the Nigerian poultry subsector is affected by climate change. There is even less on how poultry farmers are adapting to climate change. Adaptation (as defined by IPCC (2014) refers to the process of adjustment to actual or expected climate and its effects. However, there is evidence that poultry is directly and indirectly affected by increasing temperatures in the region. Higher temperatures and heat stress can affect poultry growth rates (Gous 2010) and reduce meat quality (Gregory 2010; Nyoni et al. 2018). Increased temperatures could increase bird mortality and changes in climate regimes could increase the risk of disease outbreak (Gilbert et al. 2008; Nyoni et al. 2018; Turnpenny et al. 2001). Climate change affects the poultry industry indirectly as well. Maize is a key ingredient in poultry feed and lower maize yields due to climate change will affect the availability and price of feed and the profitability of the poultry enterprise. In Nigeria, majority of the maize produced domestically is produced in the North and serves consumers and feed mills across the entire nation. Thus both short term shocks and long term climate change introduce additional challenges to the successful development of this rapidly growing subsector.

This article explores the level and determinants of the adoption of various climate change adaptation strategies for poultry farmers in Nigeria. We use data from a sample of small, medium and large poultry farmers to explore the heterogeneity of adoption and types of practices by poultry farmers at different production scales and the drivers of the adoption of multiple strategies. The remainder of the paper is organized as follows: Section 2 discusses climate change adaptation and livestock production in Africa. Section 3 describes the data used and the empirical approach. Section 4 presents the study results and Section 5 concludes.

2. CLIMATE CHANGE ADAPTATION AND LIVESTOCK PRODUCTION IN AFRICA

Though not as visible in the literature, livestock farmers are already experiencing the adverse effects of climate change. Pastoralists in Burkina Faso associated changes in temperature and rainfall patterns with increased animal mortality, reduced water sources in the dry season, decreased animal productivity, and the occurrence of new animal diseases (Zampaligré et al. 2014). Kenyan pastoralists also reported that climate change has led to a reduction in the availability of feed sources for livestock as well as a reduction in herd size (Silvestri et al. 2012). Additionally, farmers in Southern Ethiopia expressed similar concerns in relation to climate change because it poses a serious threat to their main sources of livelihood (Debela et al. 2015). Furthermore, in South Western Nigeria, livestock farmers attributed the limited availability of green pastures and water to an increase in the length of dry spells (Ayanlade et al. 2017).

To respond to the challenges resulting from changes in the climate, livestock farmers need to invest in adaptation strategies. The decision to adopt a strategy depends on a farmers knowledge and belief about the benefits of a strategy, the scale of his operation, likely risk associated with not adapting and his financial ability to bear the cost associated with the strategy (Ayanlade et al. 2018; Massetti and Mendelsohn 2018; Seo and Mendelsohn 2008). Farmers' experiences of loss due to climate factors is likely to affect their perception about climate change and adoption of adaptation strategies (Woods et al. 2017; Zamasiya et al. 2017). Farmers' perceptions of climate change have been captured in the literature (Debela et al. 2015; Mulenga et al. 2017; Tambo and Abdoulaye 2013; Woods et al. 2017; Zamasiya et al. 2017). Yet, little is known about the effect of such experiences with climate-based losses on the adoption of adaptation strategies in livestock production systems, and more specifically in poultry farming. Consequently, this study explicitly incorporates farmers' experiences with extreme weather (heat stress) on their adaptation and choice of adaptation strategy. This is the first study the authors are aware of to both explore farmer adaptation to climate change among poultry farmers with an explicit focus on their experiences with climate induced losses.

3. MATERIALS AND METHODS

a) Data

This study relies on poultry farmers' survey conducted in Kaduna and Oyo states in Nigeria between August and September 2017. The sampling strategy adopted in both locations was purposive. For smallholder poultry farms, we selected the two local government areas[1] (LGAs) with the largest production of chickens from the 11 LGAs that constitute the greater Ibadan Area (and feed the Lagos food shed in southern Nigeria) and the 4 LGAs that constitute the greater Kaduna City Area. Next, the wards within each selected LGA were stratified into low, medium and high production areas. Focusing on the medium and high production wards within in each LGA, the households were categorized into four groups according to the number of birds held: zero to less than or equal to five

[1] Local government areas are the third tier of government administration in Nigeria, similar to a county in the USA

birds, five to less than or equal to 30 birds, 30 to less than or equal to 100 birds, and more than 150 birds.

The final sample for the household farms consists of a random selection of 150 households from each of the four categories mentioned above. For non-household farms, all the farms identified in the 11 (4) LGAs in Ibadan (Kaduna) were listed and subsequently included in the sample. Given that there were non-responses, the analysis in this paper includes 1301 poultry farms across 9 LGAs; 677 farmers in Oyo state and 624 in Kaduna state. The survey gathered socio-demographic information on poultry farmers and the characteristics of their farms including management and marketing practices. We also collected information on farmers' perceptions of climate change and their adaptation strategies in response to an increase in the length of heat stress now compared to 20-30 years ago. Throughout this process, we interacted extensively various actors along the poultry value chain in Nigeria including poultry farmers, veterinary doctors, animal scientists, researchers and poultry input dealers.

b) Empirical strategy

The decision to adopt a specific adaption strategy depends on an unobservable latent variable (farmer's utility), which is determined by one or more explanatory variables such as their experience with poultry farming, their knowledge about the practices, their scale of operation etc. The higher the utility, the greater the probability of adoption. Although we do not observe the latent variable $\boldsymbol{Y_{im}^*}$ for each strategy m that farmer i can adopt, we can quantify the ultimate decision in terms of the farmer adopting or not adopting with a variable $\boldsymbol{Y_{im}}$. This is a binary decision which can be estimated using a probit model where the response probability depends on a set of parameters which are a function of the standard normal cumulative distribution. In our study we are considering 8 different strategies. Thus we model the farmer's adoption decision using the following 8 equation multivariate probit model in line with Cappellari and Jenkins (2003)

$$\boldsymbol{Y_{im}^* = [X_{im}'\beta_m + \varepsilon_{im}]; m = 1, 2, \dots, 8}$$

$\boldsymbol{Y_{im}}$= 1 if $\boldsymbol{Y_{im}^*} > 0$ and 0 otherwise, $\boldsymbol{\varepsilon_{im}}$, m = 1, …, 8, are error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations ϱjk = ϱkj as off-diagonal elements.

$\boldsymbol{X_{im}}$ is the vector of explanatory variables included in the model. $\boldsymbol{\beta_m}$ is a vector of parameters to be estimated. We evaluate the multivariate probit model using Geweke-Hajivassiliou-Keane (GHK) smooth recursive conditioning simulator. For each observation, a likelihood contribution is calculated for each replication, and the simulated likelihood contribution is the average of the values derived from all the replications. The simulated likelihood function for the sample as a whole is then maximized using maximum likelihood.

Next, we model the extent of adoption of the adaptation strategies. Here we define a new outcome variable equal to the number of strategies adopted by farmer i. The outcome variable now is a count variable which takes on the following nonnegative integer values: {0, 1, 2, 3, 4, 5, 6, 7, 8} We estimate the model using the poisson estimation strategy The underlying poisson distribution has the advantage of only being determined by its mean (Wooldridge 2010). The probability that the outcome variable y equals the number of adaptation strategies adopted can be modelled as follows:

$$P(y|\boldsymbol{x}) = \exp[-\mu(\boldsymbol{x})]\,[\mu(\boldsymbol{x})]^y/y!;\ y = 0,1,2,3,4,5,6,7,8$$

where $y!$ is y factorial, $\mu(\boldsymbol{x}) = \exp(\boldsymbol{x\beta})$, and $\boldsymbol{x}$ is a vector of explanatory variables include in the model. $\boldsymbol{\beta}$ is a vector of parameters to be estimated.

To confirm that our results are not driven by the selection of the estimation strategy, we also express the extent of adoption as the share of the total number of strategies that a farmer adopts. The outcome variable (y) here is the number of strategies adopted out of a total of eight strategies. We use a fractional probit model and model the conditional mean as a probit function:

$$E(y|\boldsymbol{x}) = \Phi(\boldsymbol{x\beta})$$

where Φ is the normal distribution and $\boldsymbol{x}$ is a vector of explanatory variables include in the model. $\boldsymbol{\beta}$ is a vector of parameters to be estimated.

4. RESULTS AND DISCUSSION

a) Descriptive statistics

The average poultry farmer in our sample is 53 years old though medium and large farms tend to be owned by slightly younger farmers; between 40 and 48 years old (Table 1). Backyard poultry farming seems to be the domain of women with about 60% of small poultry farmers are women. While more of the medium and large farms tend to be managed by men, there is still significant female participation. This is consistent with Liverpool-Tasie et al. (2017) that documented active engagement of women in this livestock subsector in Nigeria. Poultry farmers with large farms have been in the business for an average of 8 years while those in medium farms for an average of 7 years. Contrary to the idea that farmers with medium and large farms will be more likely to specialize, we find that over 60% of medium and large poultry farmers have other occupations beside farming. One plausible explanation for this is that many medium and large farm owners maintain other jobs to supplement their income and enable them to bear the financial burden of running such farms and the shocks inherent in the subsector. Membership in a poultry association is more prominent among large farms.

Asset distribution varies across farm types. While nearly 20% of large poultry farms own a truck, this is an asset owned by only 3% of medium farms. This clearly reflects different transportation needs based on the size of the farm. Many poultry farms in Nigeria own wells or boreholes. This is not surprising given the poor water supply in the country. While many more farms own wells compared to boreholes (expected as the costs of drilling boreholes is significantly higher than for wells), over 95% of large farms have their own independent water supply.

Receiving training and keeping financial records are largely restricted to medium and large-scale farms. Only about 10% of small farms keep financial records compared to 55 and 79% for medium and large farms respectively. While about 30% of medium and large farms got some training on poultry production, only 4% of small farms did. A key difference between medium and large farms is that the latter tend to have more access to private training (22% compared to 10% for medium farms). This implies that the poultry sector is fueling an increased demand for private extension services. While investment in feed is more prevalent among larger farms, we see evidence of their use among small farms. Between 60% and 70% of large and medium farms buy feed compared to 15% of small farmers.

Table 1. Descriptive statistics of key variables

	All	T1[a]	T2	T3
		Mean		
Age (years)	53.02	53.66	41.41	44.69

Male (0/1)	0.39	0.37	0.69	0.57
Education (0/1)	0.68	0.67	0.87	0.95
Number of years farming	5.91	5.83	7.01	8.05
Job other than farmer (0/1)	0.64	0.63	0.83	0.67
Own freezer (0/1)	0.01	0.01	0.06	0.05
Own truck (0/1)	0.00	0.00	0.03	0.18
Received training in chicken production from gov(0/1)	0.02	0.02	0.11	0.10
Received training in chicken production from private (0/1)	0.02	0.02	0.10	0.22
Received training in chicken production (0/1)	0.05	0.04	0.27	0.39
Member of association (0/1)	0.01	0.00	0.17	0.31
Poultry farm size (number of birds)	108.80	15.20	438.73	4725.08
Record keeping (0/1)	0.10	0.08	0.55	0.79
Own borehole (0/1)	0.27	0.26	0.29	0.58
Own well (0/1)	0.54	0.54	0.65	0.61
Own borehole or well (0/1)	0.58	0.57	0.75	0.95
Experienced loss from weather event (0/1)	0.10	0.10	0.18	0.19
Buy feed (0/1)	0.15	0.12	0.57	0.70
Number of observations	1301	449	428	424

[a] T1, T2 and T3 refer to farm size (bird holding) terciles where T1= 0-100 birds, T2=101=1000 birds and T3=>1000 birds. The descriptive statistics have been weighted to be representative of the study regions.

b) Climate change adaptation strategies of poultry farmers

Poultry farmers in Nigeria perceive the occurrence of climatic changes related to temperature. About 68% of poultry farmers in our sample believe that the temperature has increased significantly. Almost 50% of all poultry farmers reported that they had observed an increase in the length of heat stress in their state. Consequently, this study considers a set of eight adaptation strategies that poultry farmers are recommended to use in response to heat stress[2] . These strategies include air ventilation, water ventilation, engagement in fish farming, litter spreading and decaking in chicken houses, the use of energy efficient bulbs, the use of vitamins and medicines for the birds. These strategies are relatively novel in the context of the study because they have emerged as a practice in recent years. Additionally, we incorporate traditional practices which we define to include early stocking of birds, higher frequency of litter change during the heat period, and keeping local breeds of birds.

In this study, air ventilation refers to the use of fans, air conditioning, or desert coolers in chicken coops. This strategy can regulate heat levels in poultry farms but also help with the evacuation of smells that emanate from poultry waste. Water ventilation has functions similar to those of air ventilation. For instance, the use of water sprinklers or cooling pads for the birds enable better internal

[2] The list of selected strategies was drawn up based on interactions with various actors along the poultry value chain in Nigeria including poultry farmers, veterinary doctors, animal scientists, researchers and poultry input dealers. All of these practices can be considered as climate change adaptation strategies because according to the IPPC (2007), adaptation can be autonomous (i.e., adaptation happens without deliberate policy decisions) or planned (i.e., adaptation resulting from deliberate interventions).

thermoregulation. Evidence gathered during focus group discussions suggest that farmers use these different types of ventilation methods to reduce the incidence of heat stress as well as reduce mortality rates and improve feed intake and conversion rates for their birds.

Engagement in an integrated farming system comprised of poultry and fish farms is another adaptation strategy. This has the advantage of providing a cooler environment for the birds when the temperatures get warmer. Poultry farmers who are also owners of fish farms shared that the water of the pond cools the environment for the birds and it also gives them access to water. This is useful because a cooler environment is conducive to better-feed conversion ratios (and growth) and increases egg production.

The use of energy efficient bulbs in chicken houses also promotes a cooler environment on the farm by emitting less heat. Anecdotal evidence suggest that many farmers adopt efficient bulbs over conventional ones with the aim to reduce the exposure of birds to heat but also to lower the cost of energy on their farms. Warmer temperatures are associated with heat stresses for the birds but also a higher incidence of diseases. Thus, farmers also use vitamins to prevent heat strokes in the birds and medicines to prevent diseases.

The traditional adaptation strategies are known to farmers as good practices that can improve productivity on their farm but also help them respond to a warmer climate. Early stocking is the process of breeding day old chicks (layers) in October such as they can start laying eggs in January/February before it gets too hot in March/April. Several poultry farmers adopt this strategy to allow their layers to benefit from the low temperatures during the laying period. This improves the number of eggs they lay per day. In addition, the frequency of litter change and cleaning of pens during the heat period is negatively correlated with the buildup of heat on the farms. In effect, it prevents the unnecessary accumulation of chicken waste which in turn produces methane. This is because the accumulation of methane exposes birds to warmer temperatures in the pens. In the Nigerian context, the Shika brown is a local breed of bird that is heat tolerant. Contrary to what it name suggests, the Shika brown has light colored feathers which reflect heat. Developed by the National Animal Production Research Institute (NAPRI) at Ahmadu Bello University, the Shika brown is known for its large and brown eggs, and high feed conversion efficiency (Dessie and Getachew 2016). In view of the warmer temperatures that farmers are experiencing, the Shika Brown has the added bonuses of being highly adaptable to the heat and to diseases.

The adoption of the various adaptation strategies in Nigeria varies significantly across farms of different sizes. While about 20% of medium and large farms have both poultry and fish farms on the same premise, only 1% of small farms reported the same. For water ventilation as well, adoption rates by the smallest farmers is less than 1%. For Larger farms, while 15% of large farms adopt water ventilation practices, only about 2% of medium farms adopt this practice. This reflects differences in the strategies that are being adopted across farm sizes. Though the adoption of air ventilation practices is generally higher than water ventilation, adoption is largely restricted to larger farms. Sixteen percent of the large farms use air ventilation alongside 6% of medium farms in both states. The adoption rate for energy efficient bulbs is relatively higher than air and water ventilation but varies across farm type. It is also largely adopted by larger farms, at more than 30%, compared to 16% for medium farms, and only 7% for small farms. Investments in medicines and vitamins increase with farm size but many more farmers buy vitamins. Overall close to 30% of farmers buy vitamins for their birds but this is driven by medium and large farm. The same holds true for medicines because the 13% of farms which buy some is disaggregated by 10% of small farms, 54% of medium farms and 75% of large farms.

As noted earlier, our traditional strategies include early stocking, frequency of litter change and keeping local breeds. Overall about 70% of all farms implement these practices. However, the number of farms which adopt them decreases as the size of the farm increases. In effect, 72% of small farms commonly revert to these practices but only 40% of medium and large farm do the same. A look at each of the strategies that make up the traditional strategies present a similar picture. The practice of early stocking though more popular among medium and large farms is still only practiced by about 5% of medium and large farms in both states. The use of litter spreading or decaking of the chicken houses also varies significantly across farm types. Among the practices where we do see significant participation of small poultry farmers is in the frequent change in litter and the use of local breed. For the frequency of litter change, this is 60% of small farms compared to only about half of medium and large farms (30-35%). Changing the litter is considered a labor-intensive practice and this might reflect the willingness of small farms to adopt adaptation strategies that might be more labor intensive but less costly. As for keeping local birds, it is practiced by 65% of small farm, 16% of medium farms but only 4% of large farms. Interaction with small farms revealed that they prefer local breeds because they are low maintenance and can sustain heat stresses better than imported breed.

To capture farmers' perceptions about climate change, the survey asked respondents whether they have noticed changes for a set of climate variables now compared to when they were teenagers. The average age of the farmers included in the sample is more than 45 years old. This means that the responses capture changes over at least a period of 30 years. Poultry farmers seem to be more concerned with changes that relate to temperature. In effect, 68% of the farmers believe that temperature has increased overtime while 45% expressed concerns for an increase in the length of the heat stress (Table 2). This is aligned with studies that have used long term climate simulation models to assess temperature trends. Hassan et al. (2013) estimated changes in the normal daily maximum temperature in Nigeria for the warmest month between 2000 and 2050. One of the models predicts an increase of 2 to 2.5C in the North compared to 1.5 to 2C in the South. This is also consistent with studies (e.g., Ayanlade et al. 2017; Tambo and Abdoulaye 2013) that have shown that smallholder farmers in Nigeria have observed increasing temperature in recent decades.

We also inquired whether the same farmers have experienced any loss of product (chicken, eggs) due to weather events such as heat wave. This question was motivated by the fact that birds are comfortable in temperatures ranging between 10 and 30ºC and even reduce their feed intake by 3 to 5% for each additional 1ºC increase (National Research Council 1981). Thus, understanding how increases in temperature affected farms is important. Ten percent of all farmers responded positively but this average is masked by differences across farm types. Effectively, close to 20% of medium and large farms experienced losses related to climate compared to only 10% of small farms.

Table 2. Climate adaptation strategies and farmers' perceptions

	All	T1[a]	T2	T3
	Mean			
Use Air ventilation (0/1)	0.045	0.042	0.062	0.163
Use Water ventilation (0/1)	0.003	0.000	0.016	0.147
Pays for litter spreading or decaking or clean out (0/1)	0.062	0.044	0.367	0.487
Use Traditional practices (0/1)	0.708	0.723	0.390	0.411
Buy medicines (0/1)	0.127	0.102	0.543	0.752

Buys vitamins (0/1)	0.292	0.277	0.507	0.723
Have a fish farm (0/1)	0.009	0.004	0.089	0.153
Use Energy efficient bulb (0/1)	0.078	0.070	0.160	0.334
Average temperature increased (0/1)	0.682	0.701	0.323	0.292
Length of heat stress is longer (0/1)	0.451	0.460	0.250	0.297
Experienced loss from weather event (0/1)	0.100	0.100	0.180	0.190
Number of observations	1301	449	428	424

Note: [a] T1, T2 and T3 refer to farm size (bird holding) terciles where T1= 0-100 birds, T2=101=1000 birds and T3=>1000 birds. The values have been weighted to be representative of the study regions.

c) Determinants of adopting climate change adaptation strategies

Next, we turn to the determinants of adopting climate change adaptation strategies from the multivariate probit, poisson and fractional response models. The variables of interest are farm characteristics (e.g. size of farm), temperature and farmer characteristics such as farming experience, social networks and personal experience of loss due to extreme heat.

In Table 3, the results on the determinants of the adoption of adaptation strategies show that farmers who have experienced climate related losses are more likely to adopt water ventilation, pay for litter spreading, buy medicines and vitamins or use energy efficient bulbs. This is expected since all the above strategies increase the ability of farmers to respond to the negative impacts of extreme heat. On the other hand, exposure to extreme heat discourages investment in a fish farm. This indicates that farms are less likely to invest in building a fish farm on the poultry farm if they have incurred losses in the past.

Table 3. Determinants of the adoption of adaptation strategies

	Air ventilation		Water ventilation		Litter spreading		Traditional practices		Medicines		Vitamins		Fish farm		Energy efficient bulb	
Experienced loss from weather event (0/1)	-0.02	(0.16)	1.38***	(0.18)	0.44***	(0.12)	0.04	(0.11)	0.46***	(0.12)	0.43***	(0.11)	-0.51***	(0.18)	0.77***	(0.12)
CV of temperature	0.94*	(0.55)	1.09***	(0.38)	1.32***	(0.25)	-0.85***	(0.18)	-0.48*	(0.27)	-0.68**	(0.29)	-0.09	(0.21)	1.06***	(0.25)
Farm size is in tercile 2	0.14	(0.25)	5.31	(2071.8)	1.31***	(0.16)	-0.92***	(0.12)	0.67***	(0.11)	0.58***	(0.11)	0.89***	(0.19)	0.05	(0.13)
Farm size is in tercile 3	0.61**	(0.26)	6.07	(2071.8)	1.43***	(0.17)	-1.03***	(0.14)	1.06***	(0.13)	0.90***	(0.13)	0.96***	(0.21)	0.56***	(0.15)
Male (0/1)	-0.37**	(0.18)	0.42	(0.31)	-0.23	(0.14)	0.09	(0.14)	0.29**	(0.12)	0.13	(0.12)	0.21	(0.17)	-0.03	(0.15)
Education (0/1)	0.00	(.)	0.05	(0.47)	0.41**	(0.18)	-0.30*	(0.16)	0.07	(0.13)	-0.02	(0.13)	0.045	(0.21)	-0.02	(0.16)
Number of years in poultry farming	-0.02*	(0.01)	-0.02	(0.02)	-0.00	(0.01)	0.03***	(0.01)	0.01	(0.01)	0.00	(0.01)	0.01	(0.01)	-0.02***	(0.01)
Received training in chicken production (0/1)	-0.06	(0.15)	0.62***	(0.18)	-0.08	(0.11)	-0.30***	(0.10)	0.48***	(0.09)	0.49***	(0.09)	0.13	(0.12)	0.10	(0.11)
Member of poultry association (0/1)	0.61***	(0.15)	0.14	(0.21)	0.51***	(0.12)	-0.04	(0.12)	-0.43***	(0.11)	-0.49***	(0.11)	0.43***	(0.13)	-0.29**	(0.13)
Job other than farmer (0/1)	0.26	(0.22)	-1.08***	(0.36)	0.30*	(0.17)	0.37**	(0.16)	0.24*	(0.14)	0.11	(0.14)	0.11	(0.20)	-0.11	(0.16)
Own well or borehole (0/1)	-0.11	(0.23)	0.33	(0.40)	0.17	(0.14)	-0.34***	(0.12)	-0.01	(0.11)	0.14	(0.11)	-0.03	(0.18)	0.22*	(0.13)
Bookkeeping (0/1)	0.62***	(0.17)	0.06	(0.19)	0.22**	(0.11)	0.39***	(0.10)	0.48***	(0.09)	0.49***	(0.09)	0.27**	(0.14)	0.04	(0.11)
LGA[a] is Igabi	-0.24	(0.19)	-0.49**	(0.24)	0.09	(0.13)	-0.33***	(0.13)	-0.41***	(0.13)	-0.29**	(0.12)	-0.08	(0.18)	-0.53***	(0.13)
LGA is Kaduna North	0.26	(0.47)	0.19	(0.53)	0.47	(0.44)	-0.26	(0.41)	0.00	(.)	0.00	(.)	0.00	(.)	0.19	(0.42)
LGA is Kaduna South	1.52	(1.09)	0.00	(.)	0.25	(0.95)	0.00	(.)	0.00	(.)	0.00	(.)	0.00	(.)	0	(.)
LGA is Akinyele	-0.29	(0.61)	-0.54	(0.51)	-1.19***	(0.46)	-0.08	(0.26)	-1.20***	(0.29)	-1.05***	(0.30)	0.28	(0.29)	-1.31***	(0.47)
LGA is Egbeda	1.25*	(0.76)	0.34	(0.51)	1.55***	(0.35)	0.13	(0.25)	-0.95***	(0.37)	-1.18***	(0.40)	0.40	(0.28)	0.34	(0.35)
LGA is Ido	0.73*	(0.39)	-0.27	(0.37)	-0.36	(0.25)	0.22	(0.20)	-1.15***	(0.23)	-0.97***	(0.23)	0.09	(0.25)	0.28	(0.22)
LGA is Lagelu	0.00	(.)	0.00	(.)	0.61	(0.38)	0.94***	(0.31)	-0.94**	(0.38)	-1.08***	(0.41)	0.32	(0.29)	0.23	(0.36)
LGA is Oluyole	-0.16	(0.48)	0.33	(0.35)	-0.64**	(0.32)	0.79***	(0.26)	-0.44	(0.27)	-0.32	(0.28)	-0.31	(0.33)	-0.34	(0.31)
Constant	-8.88**	(4.14)	-15.24	(2071.8)	-12.16***	(1.88)	6.82***	(1.34)	2.63	(2.00)	4.17*	(2.15)	-2.10	(1.56)	-8.42***	(1.84)

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

[a] Akinleye, Egbeda, Ido, Lagelu, Oluyole, Ona Ara and South west are in Oyo state while Chikun, Igabi, Kaduna North and Kaduna South are in Kaduna state. Chikun is base for LGAs

Experiencing loss due to extreme heat does not influence the adoption of air ventilation and traditional practices. As one would expect, the direction of the effect is negative for the former while it is positive for the latter. Since 70% of all farmers use traditional practices, one explanation for this finding, is that traditional practices are not effective at responding to extreme heat for all the types of farms. Indeed, as variability in temperature (coefficient of variation) increases poultry farmers are less likely to invest in traditional practices; the effect is even more pronounced for larger farms. Air ventilation which includes the use of expensive technologies such as air conditioner (AC) is an important investment just like a fish farm. Greater variability in temperatures promotes the adoption of air ventilation. This suggests that it is an effective strategy already adopted by farmers and as such there is no change in behavior because of climate induced losses. Overall, these results corroborate a recent finding that production shocks have heterogeneous effects on the adoption of agricultural practices (Gebremariam and Tesfaye 2018).

The results in Table 5 on the determinants of the adoption of multiple adaptation strategies lend credence to the findings above. Both the poisson and fractional probit response (FPR) models show that on average farmers who have personal experience of loss due to extreme heat are more likely to adopt multiple adaptation strategies. Compared to those who did not experience heat related losses, those who experienced it are 66.3 percentage points more likely to adopt multiple strategies. Additionally, those who suffered climate induced losses are 9 percentage points more likely to adopt a larger share of adaptation strategies.

The examination of the control variables included in each of the estimations also informs our understanding of the factors that affect the adoption of adaptation strategies. The scale of the farm as proxied by its size may positively or negatively influence adoption depending on the strategy being considered. Overall, increased variability in temperature is associated with a 34 percentage point increase in the adoption of multiple strategies and a 5 percentage point increase for the adoption of a larger share of strategies. This pattern is however not uniform across individual adaptation strategies. For instance, increased variability in temperature negatively affects the likelihood that poultry farmers will use traditional practices. This is probably because the farmers substitute the traditional practices for modern adaptation techniques such as air and water ventilation, as confirmed by the correlation matrix results in Table 4. There are heterogeneities in farm sizes for the adoption of the strategies considered in this study. As shown in Table 5, compared to small farms, medium and large farms are 68 and 111 percentage points more likely to practice any of the strategies, respectively. This shows that the larger the investment, the higher the probability that a farmer invests in adaptation strategies. This is also evident in Table 3 where compared to small farms, medium and large farms are more likely to adopt water ventilation, pay for litter spreading, buy vitamins and medicines own a fish farm, and use energy efficient bulbs. This seems to resonate with Silvestri et al. (2012)'s observation that wealthier livestock farmers are more likely to adapt to climate change.

Additionally, some of the strategies stand out in terms of where they are practiced. This is the case of air ventilation and traditional strategies which have a higher likelihood to be adopted by LGAs located in Oyo state compared to Kaduna state. Oyo state is home to some of the biggest farms in the country which have enough capital to invest in air ventilation; but it also appears to have many small farms given the preponderance of farms practicing traditional strategies. Moreover, compared to Chikun which is in Kaduna, farmers in Akinleye, in Oyo state, are 120 percentage points less likely to adopt multiple strategies and 15% less likely to invest in a large share of strategies.

Experience, access to information (via training) and the level of commercialization (average size of bird holdings) do not affect the probability of adoption in the same way. For instance, the number of years in poultry farming does not affect the probability of adopting multiple strategies. However, farmers who have more experience tend to adopt traditional practices but are warry of investing in energy efficient bulbs and air ventilation. This suggests that it is the new farmers who adopt modern adaptation strategies. This occurrence may also be function of the types of chicken houses that were built in more recent years.

Lastly, membership in a poultry farmer association is associated with a higher likelihood of adopting air and water ventilation, litter spreading. It also improves the chances that a poultry farm would build a fish pond in Kaduna. As shown in the descriptive statistics, record keeping is more prevailing among the large farms which also tend to be the commercial ones. Farms with financial records are 63 percentage points more likely to invest in multiple adaptation strategies. More specifically, they tend to invest in all the strategies except energy efficient bulbs and are indifferent about water ventilation.

Table 4. Complementarities and substitutabilities among adaptation practices

	Air ventilation	Water ventilation	Litter spreading	Traditional practices	Medicines	Vitamins	Fish farm	Energy efficient bulb
Air ventilation	1							
Water ventilation	0.243** (0.122)	1						
Litter spreading	0.536*** (0.089)	0.548*** (0.122)	1					
Traditional practices	-0.245*** (0.090)	-0.288** (0.115)	-0.368 (0.064)***	1				
Medicines	0.080 (0.086)	0.251 (0.180)	-0.303 (0.061)***	0.230 (0.059)***	1			
Vitamins	0.077 (0.085)	0.268* (0.146)	-0.291 (0.060)***	0.279 (0.057)***	1.906 (0.110)***	1		
Fish farm	0.008 (0.098)	-0.185 (0.234)	0.224 (0.086)***	0.067 (0.081)	-0.037 (0.069)	-0.122 (0.069)*	1	
Energy efficient bulb	1.042*** (0.145)	0.584 (0.115)***	0.288 (0.066)***	-0.226 (0.065)***	0.276 (0.063)***	0.260 (0.060)	-0.092 (0.085)	1

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The correlation matrix (Table 4) from the multivariate probit model is also informative, as it indicates the complementarities and trade-offs between the various adaptation strategies. A negative correlation coefficient between two practices suggests that the poultry farmers consider these practices to be substitutes or perceive that one practice is more suitable for adapting to climate change than the other. Conversely, a positive correlation indicates complementarity between the adaptation options. We observe positive and statistically significant correlations between the use of air ventilation, water ventilation, litter spreading and energy efficient bulbs, suggesting that these modern adaptation practices complement each other. These four adaptation practices are, however, negatively correlated with the use of traditional practices, indicating possible trade-offs between modern and traditional adaptation practices.

Table 5. Determinants of the adoption of multiple adaptation strategies

	Poisson	Fractional response
Experienced loss from weather event (0/1)	0.663*** (0.109)	0.090*** (0.011)
CV of temperature	0.348* (0.180)	0.046*** (0.013)
Farm size is in tercile 2	0.686*** (0.136)	0.071*** (0.012)
Farm size is in tercile 3	1.114*** (0.150)	0.133*** (0.014)
Male (0/1)	0.110 (0.130)	0.014 (0.012)
Education (0/1)	0.114 (0.156)	0.015 (0.013)
Number of years in poultry farming	0.004 (0.006)	0.001 (0.001)
Received training in chicken production (0/1)	0.287*** (0.102)	0.039*** (0.010)
Member of poultry association (0/1)	-0.069 (0.118)	-0.009 (0.013)
Job other than farmer (0/1)	0.250 (0.160)	0.031** (0.015)
Own well or borehole (0/1)	0.100 (0.131)	0.009 (0.011)
Bookkeeping (0/1)	0.633*** (0.110)	0.077*** (0.011)
LGA[a] is Igabi	-0.614*** (0.135)	-0.080*** (0.014)
LGA is Kaduna North	0.060 (0.352)	0.034 (0.031)
LGA is Kaduna South	0.715 (0.845)	0.111*** (0.027)
LGA is Akinyele	-1.200*** (0.319)	-0.151*** (0.034)
LGA is Egbeda	0.327 (0.244)	0.044** (0.018)
LGA is Ido	-0.506** (0.219)	-0.068*** (0.022)
LGA is Lagelu	0.191 (0.257)	0.028 (0.018)
LGA is Oluyole	-0.205 (0.251)	-0.028 (0.020)
Observations	1,284	1,284

Reported coefficients are average marginal effects. Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
[a] Akinleye, Egbeda, Ido, Lagelu, Oluyole, Ona Ara and South west are in Oyo state while Chikun, Igabi, Kaduna North and Kaduna South are in Kaduna state. Chikun is base for LGAs.

CONCLUSION

This paper examines the climate change adaptation strategies of poultry farmers in Nigeria. We focus on a set of modern and traditional strategies highlighted by actors along the poultry value chain in Nigeria to be effective at responding to heat stress. We adopt a multivariate probit analysis to explore the determinants of adaptation accounting for the likely correlation in the decision to adopt any one strategy with the decision to adopt other strategies. We supplement this with a poisson and fractional response models to explore the extent and determinants of adoption of multiple strategies by different kinds of poultry farmers.

Farmers in the study sample are concerned about changes related to temperature as 68% of them believe that temperature has increased overtime while almost 50% expressed concerns for an increase in the length of the heat stress. Medium and large farms were more likely to report being affected by a loss related to heat stress than small farms. The descriptive analysis indicated that there are heterogeneities in the types of strategies adopted at different scales of operation. The medium and large farms adopt modern strategies while many small farms stick to traditional practices. Regression results on the determinants of the adoption of adaptation strategies confirm this and further reveal that farmers who have experienced climate related losses are more likely to adopt water ventilation, pay for litter spreading, buy medicines and vitamins or use energy efficient bulbs. On the other hand, experiencing loss due to extreme heat does not affect the adoption of air ventilation and traditional practices. We further find that on average farmers who have personal experience of loss due to extreme heat are more likely to adopt multiple adaptation strategies at a time.

These findings have important implications for policy makers and practitioners including poultry farmers and extension agents. The fact that the adoption of modern strategies appears limited to medium and large scale farms requires further attention. There is room for innovation as some of the costly strategies such as ventilation adopted by the larger farms can be modified to suit the financial constraints of the small farms. For example, changing water more frequently to keep water cool compared to having a cooling pad or fan. Such strategies should be developed and communicated to farmers. Where modern strategies are inappropriate due to farm size, efforts to breed faster growing more adaptable breeds (as it relates to the tolerance of heat stress) could be helpful.

Given that membership in a poultry farmer association is an important determinant of investment in strategies such as combining poultry production with a fish farm, our findings suggest that medium and large-scale farmers may benefit from efforts that facilitate farmer to farmer learning events across geographic regions. Finally, we find positive synergies between the modern adaptation strategies, and thus policies and programs aiming to promote climate adaptation measures in poultry farming must consider the complementarities between these adaptation strategies.

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