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Estimating the Optimal Livestock Choice of Rural Households Under Conditions of Climate Change for Nigeria

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ABSTRACT

The article used a profit choice model based on the link between conditions of climate and livestock choice to infer the adaptive behavior of human systems at a micro scale. The marginal effect of climate change on the livestock choice of rural households was estimated using multivariate probit specification and executed in STATA package. Projected probability impact of climate change in 2030 and 2050 was estimated using climate change forecasts from the Intergovernmental Panel on Climate Change (IPCC). Results revealed a unit change in baseline temperature brought about a fall in the probability of choosing dairy cattle (-62.9%) while it increased the probability of choosing Beef cattle (22.6%), small ruminant (0.1%) and Poultry (36.1%). Also a unit change in baseline precipitation reduced the probability of choosing small ruminants (0.01%) and increases the probability of choosing Dairy cattle (0.2%), beef cattle (0.6%) and poultry (0.6%). The projected percentage change in the probability of livestock choice revealed that by 2030, a unit change in temperature will bring about a fall in the choice for small ruminants, dairy, poultry and beef livestock by 11.6%, 6.1%, 6.0% and 5.9% respectively. However, by 2050, relative to other livestock types, the probability of choosing small ruminant will reduce by 67% with a unit change in temperature. Precipitation however increased the probability of choosing dairy animal in 2030 and 2050 by 5.3% and 6.7% respectively. Controlling for non-climate factors, the study showed that as climate changes, farmers will substitute livestock types that are beneficial and profitable as an adaptation strategy. Hence the need to embark on livestock improvement programme on specific livestock and farm management practices that can foster the resilience of livestock types to adverse climatic conditions.

Key words: Estimating, Global climate change, Livestock choice, Rural Households, Nigeria

INTRODUCTION

In many rural communities in Africa, livestock is a key asset of the poor, but it is highly vulnerable to climate variability and extremes (Easterling *et al,* 2007; FAO, 2007; Thornton *et al,* 2007; IFAD, 2010). In Nigeria the keeping of cattle, small ruminants and poultry as well as equines is common in rural Nigeria, most especially in the northern part of the country. It is the highest valued agricultural commodity in intra-regional trade in West Africa (Okike, 2004) and "provides up to 45% of cash income and 30 percent of income even for poor households" (FEWSNET, 2008).

Climate change is expected to heighten the vulnerability of livestock systems (Gill and Smith, 2008). Climate change implies changing conditions for livestock keeping. The indirect conditions include changes in feed-grain availability and price; pastures and forage crop production and quality; diseases and pests; and the direct effects of weather and extreme events on livestock health, growth and reproduction (Thornton *et al.,* (2009). Such changes come with outcomes such as death of animals or changes in livestock mortality, yield, profitability and income. Accordingly, it comes with challenges of structural changes in the type and number of livestock kept or reared by rural households. Addressing the vulnerability of livestock systems at a local scale requires understanding the responses of rural households to environmental changes. Shedding light on rural households adaptation is particularly important for sensitizing adaptation programming. Few studies exist that have examined the empirical relationship between climate change and farm crop choices of rural households in Nigeria.

The purpose of the study is to examine the relationship between climate change and the optimal livestock choice of rural households. The study specifically profiled the pattern of rural household livestock keeping, the probability response of livestock choice to changes in historical climate and the projected absolute change in the probability livestock choice as temperature and precipitation change.

MATERIALS AND METHODS

Theoretical framework

The most popular definition of adaptation is that given by the Inter-governmental panel on climate change (IPCC, 2007). It is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007). Climatic stimuli can be climate change, variability or just climate and other change such as policy or market stimuli or opportunities. Systems include people, social and economic sectors and activities, managed or unmanaged, natural or ecological systems, practices, processes or structure of systems (Smit and Pilifosova, 2001)

Although adaptation can be analysed at various scales, this study focuses on the strand of literature that examines micro-level production adjustments of crop and livestock production systems. This strand of literature uses the profit model that emerged in an attempt to explicitly model systems adaptation behaviour by relaxing the assumed systems adjustment in the Ricardian model. Adaptation behaviour of agricultural households is seen as a decision process whereby climate and non-climate factors induce households to adjust their choices between and within livestock or crop types. Seo and Mendelsohn used the profit model to examine livestock choices of farmers in Africa and how choices condition the number of livestock kept and the profit. Kabubo-Mariara (2008) examined livestock choices of farmers in Kenya. These studies used the logit multinomial technique to model the profit choice behaviour of farmers. Arriagada (2005) used the mixed logit technique to specify the profit choice model of the relationship between climate and crop choice. Underlying these studies is the profit or utility maximization hypothesis that suggests profit as the defining motivation why a rural household would choose a particular type of livestock given climate constraints. This raises the endogeneity challenge of profit since it affects the livestock choice of rural households. In some studies, the Hackman two stage procedure is used to control for it while in others, farmers perceived adoption of an enterprise is assumed to reveal profitability and in the second stage the within choices are modelled. In other studies crop prices or input prices are included in the determination of choices. In some studies the effect of prices on profit is captured by set of fixed effect (Deschenes and Greenstone) while in others it is estimated (Seo and Mendelsohn, 2008).

Formally, rural households are assumed to operate in a perfectly competitive input and output markets with vector prices W and P respectively. Also have a well behaved production technology with output Q. Given expenditure function for inputs X, climate (F) and other variables (Z); farmer maximizes profit expressed as $\pi = PQ(X, F, Z) - WX$. The resulting solution to the optimization problem characterise the profit choice model. In which case farmers choose the most profitable livestock type and also the inputs that will maximize profit for that choice. The importance of discrete and binary choice models for the analysis of microeconomic problems is well established in literature (McFadden, 1976, Heckman, 1978). Therefore, estimation can be performed using discrete variables as dependent variable for the profit choice. The challenge however, is how to model profit choice. Seo and Mendelsohn (2008), Seo and Mendelsohn (2006) and Kabo-mariare (2008) documents three approaches. The first is the primary production approach whereby the livestock type that gives the largest profit is modelled. The second is the optimal portfolio approach whereby possible combination of livestock choices is considered. The third approach is the demand system in which livestock species choices are jointly considered. This study applies the demand system approach given the mix livestock and farming system predominant in Nigeria.

Two common discrete model specifications used in empirical studies are the multinomial logit (MNL) and the multinomial probit (MNP). In MNL, the errors are independent and identically distributed according to the type 1 extreme value distribution, whereas in MNP model, the errors are not necessarily independent and are distributed as multivariate normal (Greene 2003). The implication of MNL error term assumption is the assumption of the independence of irrelevant alternatives (IIA). The multivariate probit (MV) achieves both flexibility and computational practicability (Tse, 1989). Thus multivariate specification framework becomes relevant for this study. The model is able to test the null hypothesis that the covariance of the error terms across equations are not correlated and also provides insight on substitution or complementarity possibility across crop and livestock choices. With the aid of simulation as developed by Cappellari and Jenkins, (2003), three or more equations can be estimated jointly.

Model specification and estimation

This study models a system of livestock choices to be estimated jointly using a multivariate probit specification. Each equation is specified as a latent non-observable profit function with a quadratic formulation of the climate variables expressed as:

$\pi_{ij}^* = \beta_0 + \beta_{1i}F + \beta_{2i}F^2 + \beta_{3i}Z + \beta_{4i}S + \varepsilon_i\ ,\ = 1(\pi_1^* > 0)$ (1)

Where π^* represent unobserved potential benefit that takes the value of 1 for each livestock type jthat is observed and zero otherwise for household farmer i. The livestock types considered are dairy, cattle, beef cattle, small ruminants and poultry. F denotes the vector of climate variables representing the key explanatory variable of farmer's response pattern. Temperature and precipitation are specified as annual average from January to December as well as seasonal averages. For brevity only annual temperature and precipitation are used for this article. To control for climate variables, soil and socio economic characteristics are included denoted by Z and S respectively. The socio economic variables are meant to reflect other drivers of livestock preferences and also to control for the effect of climate variables. For example growth in wealth might influence more consumption of poultry for urban population. Population density and its squared term are used to capture urban –rural characterisation. For the environmental variables, clay, silt and sand content are included as rough proxies for soil quality for pasture. Other variables included are infrastructure index since it is a major determinant in explaining poverty and agricultural productivity in developing countries. The index was constructed using factor analysis. The correlation matrix of the error term across choices is estimated.

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdots \\ \varepsilon_m \end{pmatrix} \backsim N_m \begin{pmatrix} 0 \\ 0 \\ \cdots \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{12} & \cdots\rho_{1m} \\ \rho_{12} & 1\cdots & \rho_{2m} \\ & \cdots & \\ \rho_{1m} & \rho_{2m} & \cdots 1 \end{pmatrix} \quad (2)$$

Taking the derivative of the equations above with respect to F gives the probability of observing the mth choice expressed as

$\Pr(\pi_j = 1) = \Phi(F`\beta_i), for\ j = 1, \ldots, J$ (3)

The joint probability of observing all possible alternatives from a J-variate standard Normal distribution

$\Pr(\pi_j = 1, \ldots,\ \pi_J = 1) = \Phi(F`\beta_1, \ldots, F`\beta_J; \Sigma)$, (4)

The various equation groups are each jointly estimated in stata 11 using the mvprobit program developed by Cappellari and Jenkins (2003). To estimate the marginal effect on the probability of selection I used the formula as documented in Kabubo-Mariara (2008)

$$\frac{\partial P_j}{\partial F} = (1 - P_j) * P_j * [\beta_1 + 2\beta_2 F] \quad (5)$$

Where

$$\frac{\%\ change\ in\ probability\ of\ livestock\ choice\ P(U)}{\%\ change\ in\ temperature\ or\ precipitation(z)} = (1 - P_j) * P_j * [\beta_1 + 2\beta_2 F]$$

$(1 - P_j)$= Probability of livestock choice when π_j=0

P_j= Probability of livestock choice when π_j=1

β_1= linear specification coefficient

$2\beta_2$= quadratic specification coefficient

F= Average temperature or precipitation.

To operationalise this formula, the study adopted the approach as suggested in Anderson and Newell (2003). First all explanatory continuous variable were centred at the mean by taking deviations from the mean resulting in 0 value for the normalized variable.

When the linear term is negative and the quadratic term is positive, the function is U-shaped, and when the linear term is positive and the quadratic term is negative, the function is hill shaped. Estimated probability is recovered from the MV probit equations (probability of livestock choice) and used to multiply the parameter estimates to give the marginal effect (change in probability of livestock choice). Simulated impact is the percentage change in the probability of livestock choice defined as the difference between the future marginal estimates and the baseline multiplied by 100. Thus the output generated is the estimated probability, marginal effect and impact over two time slices of 2030 and 2050.

Data

Farm Household Economic Data

This study relies on secondary data collected by the National Bureau of Statistics (NBS). The data set is part of the existing data modules of NBS to help evaluate agricultural and socioeconomic development in Nigeria. Relevant to this study is the General Household Survey (GHS) collected in 2010. The sample frame includes all thirty-six (36) states of the federation and Federal Capital Territory (FCT), Abuja. Households were selected at the state level using a two stage stratified sample selection process. The sample size is 5,000 households. To answer the objectives of this study, the relevant agricultural data file was merged with the household data files. Farm households constitute 65% of the data amounting to about 3000 respondents. After data cleaning the sample size amounted to 1700 farm households.

Climate and Soil Data

The second data are climate and soil quality variables. They are aggregated data at the local and state levels. These were sourced from the WorldClim data base (Hijmans *et al.,* 2005,). The climate database contains both current and projected climate data developed from compiled monthly averages of climate elements from the 1950-2000 using the Thin Plate Smoothing Spline (TPS).

algorithm (Hutchinson, 1995). This climate data source was used rather than climate data from Nigerian weather stations because of the sparse weather network in Nigeria which comes with incomplete climate data for locations under consideration. The climate variables capture the average value over 60 years prior to the dependent variable (2010) as we hypothesize that 60 years is long enough to allow rural households to adapt to climate change. From the data set, seasonal climate measures were constructed for both current and projected. The annual is the average (January – December) while seasons are wet season (April – October), dry season (November – March) and quarterly seasons using the Excel spread sheet. Future climate projections for 2030 and 2050 by HADCM3 within the emission scenario A2 were used.

RESULTS AND DISCUSSION

Selected household characteristics and Livestock ownership by households.

Table 1 presents the socio economic characteristics of farm households and the nature of livestock ownership. From the table, the average age of household head was 51 years and 55% of these households were literate in the narrow sense of ability to read and write any Nigerian language.

Table 1: Selected farm household characteristics and pattern of livestock activity

Farm and household characteristics	Mean	SD	Min	Max
Number of persons per household	6	1.	2	12
Age of household head	51.270	15.291	15	108
Literacy rate	0.553	0.497	0	1
Free hold land	10.03	30.06	0	1
Communal land	75.04	43.29	0	1
% sand top soil	58.131	8.483	39.542	80.763
% silt top soil	23.634	5.172	11.932	36.919
% clay top soil	18.234	4.077	2.511	26.990
Altitude	250.001	215.543	3	1341
Population density	19079.1	400502.7	1.41	1.30e+07
Wealth index	2.12e-10	1.1533	-3.015	9.188
Infrastructure index	-8.65e	10	1.47	-2.591
% household with Dairy cattle	12.75	33.24	0	1
% household with Beef cattle	15.65	36.35	0	1
% household with Small ruminant	44.74	49.76	0	1
% household with Poultry	24.12	42.77	0	1
% household with Other animal	2.74	3.64	0	1

Pattern of livestock activity by households across agro ecological zones

	North Central	North East	North West	South east	South West
Dairy cattle	12.71	20.00	22.95	1.32	4.17
Beef cattle	2.76	39.46	29.75	0	0
Small ruminant	50.28	34.05	40.23	55.82	22.22
Poultry	32.60	2.70	3.68	40.74	70.83
Other animal	1.66	3.78	3.40	2.12	2.78

Table 2: Coefficients estimates of multivariate analysis of livestock keeping

Variables	Dairy cattle	Beef cattle	Small ruminants	Poultry
Annual Temperature	-5.0269	1.4461	1.0844	1.5064
	(2.1569)**	(2.3152)	(1.7962)	(1.6709)
Annual Temperature	0.0970	-0.0310	-0.0180	-0.0292
Squared	(0.0412)**	(0.0443)	(0.0342)	(0.0320)
Annual Precipitation	0.0131	0.0360	-0.0197	0.0259
	(0.0223)	(0.0329)	(0.0120)***	(0.0136)**
Annual Precipitation	0.0000	0.0000	0.0001	-0.0001
Squared	(0.0001)	(0.0002)	(0.0000)	(0.0000)**
Altitude	-0.0413	0.2949	-0.0283	0.0209
	(0.0658)	(0.0864)*	(0.0419)	(0.0427)
Latitude	0.1442	0.6233	-0.0705	0.0066
	(0.2143)	(0.2667)**	(0.1329)	(0.1342)
% sand in top soil	0.4619	-1.1473	-0.0378	0.1705
	(0.3507)	(0.3915)*	(0.2151)	(0.2894)
% clay in top soil	1.0691	-0.7641	0.1724	0.2207
	(1.1508)	(1.3761)	(0.7613)	(0.8968)
Input price(fert)	0.0667	0.0365	-0.0356	-0.0269
	(0.0449)***	(0.0503)	(0.0673)	(0.0602)
Tpt cost(output mkt	-0.0042	0.0066	0.0010	0.0050
	(0.0035)	(0.0041)***	(0.0059)	(0.0050)
Wealth index	-0.0295	-0.0512	0.0794	0.0072
	(0.0480)	(0.0494)	(0.0312)*	(0.0351)
Infrastructure index	-0.0067	0.0033	0.0064	-0.0028
	(0.0043)***	(0.0045)	(0.0028)**	(0.0030)
Pop density	-0.0006	0.0001	0.0001	-0.0002
	(0.0003)**	(0.0003)	(0.0002)	(0.0002)
_cons	-2.6536	-14.8436	-0.2306	-0.6907
	(0.7603)*	(10.8224)	(0.0653)*	(0.0735)*
SML	Draws=5			
Log likelihood	-1474.9041			
Number of observations	1149			
Wald x2(132)	527.34			
Probability >x2	0.000			
Likelihood ratio test of p: Rho21=rho31=rho41=rho32=rho42=rho43=0				
X2(6)	234.412			
Probability > x2	0.000			

*1% ** 5% ***10% level of significance

The average number of persons in a household was 6. About 75% of households had access to community land. The average altitude for farms was 250m and ranges from as low as 3m to a maximum of 1341m. The percentage of sand in top soil ranges from 39% to 81% with a mean 58%. The average percentage silt in top soil was 23% and ranges from 12% to 40% maximum. The percentage clay in top soil was 18% and ranges from a minimum of 2.5% to a maximum of 27%. These values reflect rough proxies of soil quality. In the overall sample, 44.74% of farm households owned small ruminant animals. Small ruminants in this study refer to goats and sheep. This was followed by poultry (24.12%), beef cattle (15.65%) and dairy cattle (12.75%). In addition, 2.74% of households owned other forms of livestock such as pigs, donkey and Carmel. There is noticeable variation across agro ecological zones. Much of dairy cattle is concentrated in the hands of households in North West (22.95%), followed by North east (20.00%) and North central (12.71). There was little or no beef cattle selection in south east and south west but there was some ownership of small ruminants in south east (55.82%) and south west(22.22%)

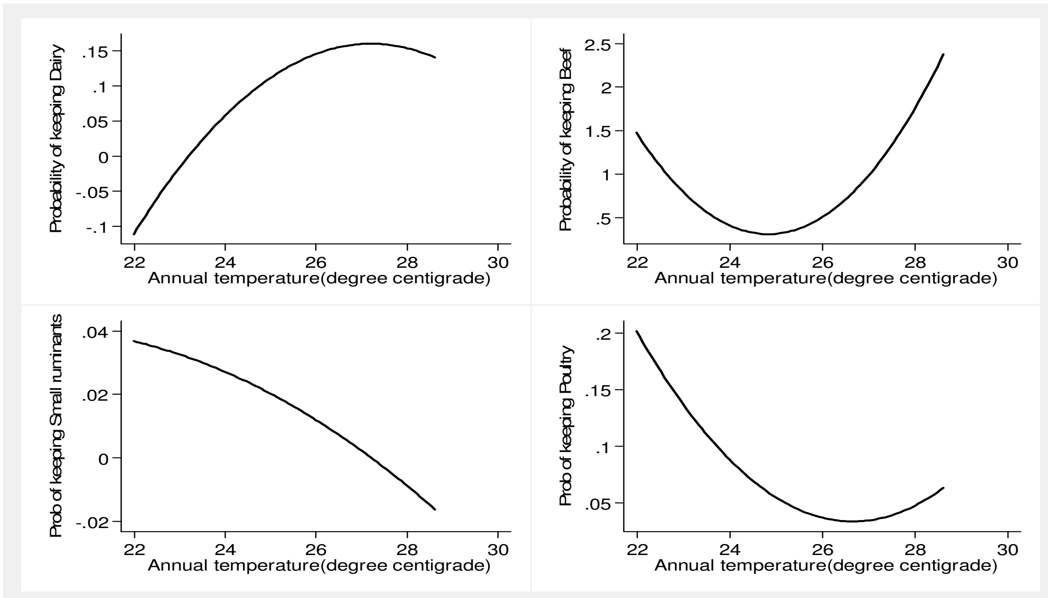

Figure1: Probability of livestock choice and changes in temperature

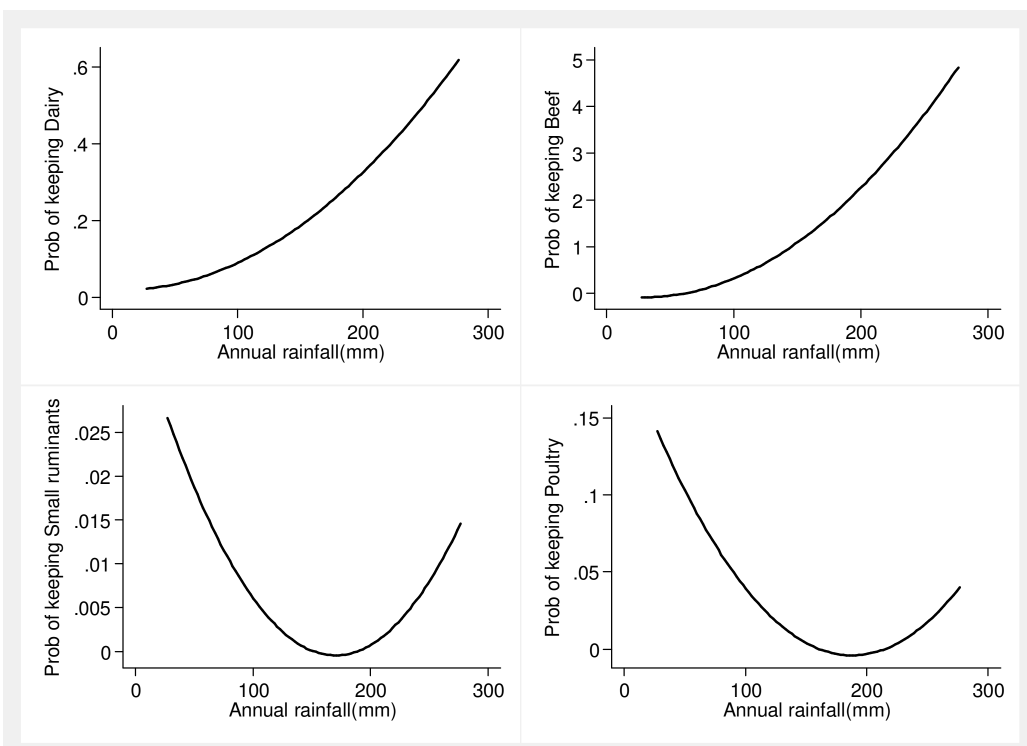

Figure2: Probability of livestock choice and changes in rainfall

Coefficient Estimates of Livestock Choice

This section presents the parameter estimates of livestock keeping under conditions of long term climate. The coefficients and their respective signs are presented in table 2. It should be noted that the coefficients from the multivariate probit analysis cannot be used to infer impact of climate change on livestock keeping but used to derive impact estimates. The signs are however useful indicators of the behavioral response of rural households under conditions of climate change. Figures 1 and 2 are used to show visually the response pattern of the probability of keeping livestock by rural households under the conditions of changes in temperature and rainfall. In figure 1, beef cattle and poultry are clearly U-shape reflecting a declining probability of rural households to keep livestock as temperature increases. While dairy and small ruminants are hill shaped. In Figure 2, all the livestock types reflect a U-shape response pattern reflecting a declining probability of keeping livestock as rainfall increases.

Marginal Effects of Annual Temperature and Precipitation on the Probability of Livestock Choice

This section presents the probability estimates of the livestock choice of households given changes in climate. That is by how much the probability of livestock choice falls or increases as a result of a change in temperature or precipitation. The estimates are shown in table 3 and are derived from the multivariate probit coefficients in table 2. As shown in the table, a unit rise in annual temperature reduced the probability of dairy cattle (-0.629) while it increased the probability of choosing Beef cattle (0.226), small ruminant (0.001) and Poultry (0.361). Also a unit change in precipitation reduced the probability of choosing small ruminants (-0.000) and increases the probability of choosing Dairy cattle (0.002), beef cattle (0.006) and poultry (0.0062). It is to be noted that change in precipitation had no effect on small ruminants.

Projected Change in the Probability of Choosing a Livestock Type in Percentage

The projected percentage change in the probability of choosing a livestock type in 2030 and 2050 was undertaken using climate change forecasts from the Intergovernmental Panel on Climate Change (IPCC). As shown in Table 3, by 2030, a unit change in temperature reduced the probability of small ruminants, dairy, and poultry and beef livestock by 11.6%, 6.1%, 6.0% and 5.9% respectively. By 2050, relative to other livestock types, the probability of choosing small ruminant reduced by 67%. However, precipitation increased the probability of choosing dairy animal in 2030 and 2050 by 5.3% and 6.7% respectively. The probability of choosing Beef cattle, small ruminants and poultry also reduced with the greatest effect on small ruminants.

CONCLUSION

Long term changes in climate have a physical impact component in terms of benefit or loss on the value of the livestock kept by households and a behavioural component in terms of adjustment. The behavioural component can be seen as farm household rational adaptation response to changes in their environment and in our case climate. As climate changes, farmers substitute livestock types that are beneficial and profitable as an adaptation strategy. Results revealed the choice for poultry and beef over dairy cattle with a unit change in temperature and precipitation. The simulation results suggest that the probability of choosing livestock declines as temperature increases but milder for precipitation increases. There is the need to embark on livestock improvement programme on specific livestock appropriate to specific climate zones.

Table 3: Temperature and precipitation impact on livestock choice

	TEMPERATURE			PRECIPITATION		
Livestock types	Marginal effect	% change in 2030	% change in 2050	Marginal effect	% Change in 2030	% Change in 2050
Dairy cattle	-0.6289	-6.100	3.5978	0.0016	5.3455	6.6928
Beef cattle	0.2256	-5.930	11.9890	0.0056	-0.3459	-0.9673
Small Ruminants	0.0075	-11.594	-67.8265	-0.0001	-11.2850	-2.0473
Poultry	0.3607	-6.013	1.3840	0.0062	-1.1994	-2.0354

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