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RESEARCH ARTICLE

CLIMATE CHANGE AND LIVESTOCK FARMING IN CAMEROON: Impacts and Implications for Poverty Reduction

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ABSTRACT

The objective of this paper is to investigate; first, the effects of livestock income on poverty and second, the impact of global warming on livestock farming and the way farmers adapt. Based on a 2004 household farm-climate data set generated by Global Environment Facility, Center for Environmental Economics and Policy in Africa and the World Bank we simulate the impact of livestock income on household poverty in Cameroon. Use is made of the Heckman's two-step estimation procedure to identify the factors that influence livestock income in Cameroon. We estimate a structural Ricardian model of net livestock income which not only reveals how net income changes with climate, but also reveals how livestock farmers adjust to the changing climatic conditions. Our findings reveal that livestock income is poverty reducing. Also, livestock income is adversely affected by global warming.

INTRODUCTION

The potential of livestock to reduce poverty is enormous. In Cameroon, livestock are important livelihood means for the poor especially in the drought prone areas of the Adamaoua and Northern Regions. It is said that that the poorest of the poor who do not have livestock, if acquire animals, can help start a pathway out of poverty (HPI, 2001). Livestock make a significant contribution to food production through the provision of high value protein-rich animal products; they indirectly support crop production through draught power and manure; and finally, they are the most significant source of income and store of wealth for smallholders (Swinton, 1988; Fafchamps *et al.,* 1998).

In Cameroon, livestock contributes over 15% to GDP and forms about 45% of the agricultural GDP. More than 64% of the land in Cameroon is arid to semi-arid lands characterized by low unreliable and poorly distributed rainfall and is mainly used for extensive livestock production and wildlife (NIS, 2001). The Adamaoua and Northern regions have the highest incidence of poverty (about 65%) and very low access to basic social services such as infrastructure and education facilities (Njong, 2008). In these regions the livestock sector accounts for 90% of employment and more than 95% of family incomes (NIS, 2001). NIS (2001) reports that per capita livestock production and productivity in Cameroon have been stagnant over the last two decades. This has been attributed to a number of production and

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productivity constraints including, inadequate and inefficient infrastructure, lack of farm credit, inadequate funding for research and extension, etc. Outbreak of major animal diseases has also been a major factor affecting productivity. While the Ministry of Livestock, Fisheries and Animal Industries is gearing up to address the above issues, performance and sustainability of the livestock sector is quite vulnerable to climate variations. Climate can affect livestock both directly and indirectly. Direct effects from air temperature, humidity, wind speed and other climate factors influence animal performance: growth, milk production, wool production and reproduction (Houghton *et al.,* 2001). Indirect effects include climatic influences on the quantity and quality of feedstuffs such as pasture, forage, grain and the severity and distribution of livestock diseases and parasites (Seo and Mendelsohn, 2006a). Further, climate change is likely to cause a rise in animal diseases that are spread by insects and vectors mainly due to temperature and humidity rise that favour their spread and growth. There has recently been increasing interest in the economic relationship between income sources and the welfare of households. Households may depend quite heavily on livestock farming activities to sustain their livelihood. The potential importance of livestock farming for the livelihood of poor rural households has long been recognized but seldom quantified and analyzed (especially in the Cameroon context). On another note the effects of climate change on crops have been studied frequently, but there are very few analyses of its effects on livestock (see Seo and Mendelsohn 2006a; 2006b; McCarthy and Di Gregorio, 2007). A study of climate change impacts on agriculture must include an analysis of livestock impacts. This study is, first, an exploration of the extent to which livestock income affects our understanding of poverty. Second, the study investigates the effects of changing climatic conditions on livestock income. In a nutshell, the study seeks to answer the following questions: To what degree is livestock income poverty increasing or reducing? What are the determinants of livestock income in Cameroon? What are the impacts of climate change on livestock income and how do livestock farmers adapt? These are the core research questions that this study attempts to address.

REVIEW OF THE LITERATURE

A large number of agricultural studies on the effect of climate change have focused on crops (see Molua and Lambi, 2006; Sene *et al.,* 2006). However, a large fraction of agricultural output is from livestock. Yet there is still very limited literature on the economic analyses of climatic effects on livestock. According to Adams *et al.,* (1999) American livestock appear not to be vulnerable to climate change because they live in protected environments (sheds, barns etc.) and have supplemental feed (e.g. hay and corn). In Africa, by contrast, the bulk of livestock have no protective structures and they graze off the land. There is every reason to expect that African livestock will be sensitive to climate change. Seo and Mendelsohn (2006a; 2006b and 2008) are among the rare studies that have analyzed the impact of climate change on livestock adaptation and selection of livestock species in Africa. In Kenya, some studies have investigated the response of livestock production to climate change (see Kabubo-Mariara 2008), land pressure and drought (Campbell, 1999; Kabubo-Mariara, 2005; McCarthy and Di Gregorio, 2007).

Quantitative studies of the relationship between livestock farming income and poverty are scarce. To the best of our knowledge there has been little effort to estimate the impacts of livestock income on poverty, and also investigate the effects of climate variations on livestock income. The aim of this study is therefore to close this knowledge gap by providing new empirical evidence on these issues in Cameroon.

METHODOLOGY

The Impact of Livestock Income on Poverty

a) Poverty Measures

To investigate the impacts of livestock income on poverty, we resort to a modified Foster-Greer-Thorbecke (FGT) class of poverty indices. Following the notation of Foster-Greer-Thorbecke (1984), let $Y_d = (Y_1, Y_2, \ldots, Y_n)$ represent household incomes arranged in increasing order of magnitude and let $z>0$ denote the poverty threshold. We may define the FGT (1984) poverty measure by:

$$P_\alpha(Y_d; z) = \frac{1}{nz^\alpha}\sum_{i=1}^{q} g_i^\alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where n is the total number of households, q is the number of poor households, g_i = z-Y_{di} is the income shortfall of the i^{th} poor household and α is a weighting parameter that can be viewed as a measure of poverty aversion. Equation (1) takes the alternative values of α = 0, 1, 2 in the analysis we are about to carry out.

When α = 0, the index becomes $P_0 = \frac{q}{n}$ ……. (2)

Equation (2) shows the proportion of the population living below the poverty threshold. That is, the incidence or the headcount of poverty. The headcount measure of poverty does not change if the incomes of very poor households increase but not enough to put them above the poverty line. Similarly, the headcount measure does not increase if only those below the poverty line face a negative shock that decreases their income. To provide a more complete picture of how poverty changes under different scenarios, the poverty gap and sensitivity (poverty gap-squared) measures will be estimated in addition to the headcount measure. The poverty gap measure corresponds to α = 1 and is calculated using the formula:

$$P_1 = \frac{1}{nz}\sum_{i=1}^{q}(z - Y_{di}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Equation (3) reflects how far below the poverty line the average poor household's income falls (i.e., the depth of poverty). If the income of a poor household increases but not enough to take it above the poverty line, total poverty as measured by this index will decrease (even though the headcount measure does not change). When α = 2 we obtain the poverty severity index which is estimated with the help of the formula:

$$P_2 = \frac{1}{nz^\alpha}\sum_{i=1}^{q}(z - Y_{di})^\alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Like the poverty gap measure, it is sensitive both to the headcount and to changes in incomes of households that remain in poverty. However, it accords a greater weight to poor households who are further away from the poverty line.

Foster-Greer-Thorbecke (1984) presents a decomposition of the poverty index by population subgroup. In this study, we follow an alternative decomposition approach by Reardon and Taylor (1996) who propose a simulation method to decompose the FGT (1984) poverty measure by income source. To simulate the impacts of livestock income on poverty we decompose *P(Y_d, z),* by substituting the sum of income across the different sources for Y_{di} in the FGT poverty index. This gives:

$$P(Y_d; z) = \frac{1}{nz^\alpha}\sum_{i=1}^{q}(z - \sum_{k=1}^{K} y_k)^\alpha \quad \ldots\ldots\ldots\ldots (5)$$

The impact of a small percentage change in livestock income, *e*, on poverty, *dP(Y_d; z)/de*, is given by:

$$\frac{dP(Y_d; e; z)}{de} = \frac{1}{nz^\alpha}\left[\sum_{i=1}^{q_0} -\alpha g_i(e) - \sum_{q^-} g_i(e)^\alpha + \sum_{q^+} g_i(e)^\alpha\right] \ldots. (6)$$

where q_o denotes the number of households in poverty both before and after the change in livestock income, and *q- (q+)* denotes the number of households that leave (enter) poverty as a result of the income change. If livestock income is poverty reducing, the third term, $\sum_{q^+} g_i(e)^\alpha$ drops out, and the poverty effect is negative (i.e., poverty decreases). It would be interesting to empirically determine the extent of this poverty effect.

b) Determinants of Livestock Income

Use of farm data to estimate the determinants of livestock income may be complicated by the econometric problem of sample selection bias. Livestock income is observed only for those households who engage in livestock farming activities (it is unobserved for those who do not carry out this activity). We may be tempted to consider only those households rearing livestock. In this case the data would be non-randomly selected or incidentally truncated and we run the risk of encountering a sample selection bias problem which will generate unreliable parameter estimates. In order to correct for the sample bias problem, the Heckman's two-step estimation procedure would be applied, as suggested by Greene (2003).

To fix ideas we can express the household data in terms of a binary variable with 1 if household is engaged or participates in livestock farming, and zero otherwise. When the binary variable is 1, another variable, expresses the household's observed livestock income. In the simplest form, the model can be expressed simultaneously using a participation and valuation equations as follows: First, we define a binary variable, *Z,* for the participation/selection equation and *Y* for the valuation or income equation, conditional on two latent continuous variables *Z** and *Y** such that (see Fonta and Omoke 2008):

$$Z^* = x_i^{'}\alpha + \varepsilon_i$$

$Z_i = 0$ if $Z_i^{'} \leq 0$

Participation Equation ………………………. (7)

$Z_i = 1$ if $Z_i^{'} > 0$

$$Y^* = w_i^{'}\beta + \mu_i$$

$Y_i = Y^*$ if $Z_i^{'} = 1$

Valuation Equation …………………. (8)

Y_i is not observed if $Z_i = 0$

where, the latent variable Y^* is the observed household livestock income; x and *w* are matrices of demographic and other socio-economic covariates such as; educational attainment of household head, gender, age, livestock practices, household size, etc. α and β are vectors of parameters to be estimated. ε_i and μ_i are two error terms with joint cumulative density functions, and assumed to have a bivariate normal distribution with mean zero and correlation coefficient ρ. When ρ = 0, the two equations are independent and the parameters can be estimated separately (Strazzera *et al.,* 2003). The conditional expected value of Y_i conditional on Z =1 and on the vector w_i is expressed as:

$$E[Y_i / Z = 1, w_i] = w_i^{'}\beta + \rho\sigma_j\lambda(x_i^{'}\alpha) \text{ ….. (9)}$$

where $\lambda(x_i^{'}\alpha) = \varphi(x_i^{'}\alpha) / \Phi(x_i^{'}\alpha)$ is the inverse Mills ratio, and φ and Φ are the standard normal density and standard normal functions respectively. quations (7) and (8) would be estimated using the Heckman's two-step approach because of its computational simplicity. The Heckman's procedure (Heckman, 1979) is carried out in two steps. Step 1, a probit regression is computed to obtain a consistent estimator of α and then the estimated α is used to estimate the inverse Mills ratio (λ) for each household. Step 2, the estimated λ is used as an instrument or regressor in Equation (9) and allows us to estimate *w* and ρ consistently by OLS method.

Impact of Climate Change on Livestock Income

a) Theoretical Framework

Studies of the impact of climate change on agriculture and animal husbandry employ the Ricardian analysis (Mendelsohn *et al.,* 1994). The approach is a cross-sectional model that takes into account how variations in climate change affect net revenue. Following Seo and Mendelsohn (2006a), we start by assuming that the farmer maximizes net income by choosing which livestock to purchase and which inputs to apply:

$$Max\,\pi = P_{qj}Q_j(L_G, F, L, K, C, W, S) - (P_F F + P_L L + P_K K) \cdots (10)$$

where: π is net income; P_{qj} is the market price of animal j; Q_j is a production function for animal j; L_G is grazing land; F is feed; L is a vector of labour inputs; K is a vector of capital inputs; C is a vector of climate variables; W is available water; S is a vector of soil characteristics; P_F is a vector of prices of each type of feeds; P_L is a vector of prices for each type of labour; P_K is the rental price of capital. The farmer chooses the species *j* and the number of animals that maximizes profit. The resulting net income can be defined as:

$$\pi^* = f(P_q, C, W, S, P_F, P_L, P_K) \text{ ………. (11)}$$

The Ricardian function is derived from the profit maximizing level of equation (11) and explains how profits change across all the exogenous environmental factors, such as temperature and precipitations, facing a farmer. The change in welfare (Δ*U*) resulting from climate change from C_0 to C_1 can be measured using the Ricardian function as follows:

$$\Delta U = \pi^*(C_1) - \pi^*(C_0) \text{ …………………….. (12)}$$

The change is beneficial if it results in an increase in net income and harmful otherwise.

b) Model Specification

In this study we estimate a reduced form Ricardian model for net livestock income as follows:

$$\pi = \alpha_0 + \alpha_1 T + \alpha_2 T^2 + \alpha_3 R + \alpha_4 R^2 + \alpha_5 Z + \varepsilon \;\ldots\ldots\; (13)$$

where T and T^2 capture levels and quadratic terms for temperature, R and R^2 capture levels and quadratic terms for precipitation. Z is a vector of socio-economic variables and ε is a random disturbance term. The quadratic terms for temperature and precipitation are expected to capture the nonlinear shape of the climate response function. From equation (13), we can derive the expected marginal impact of temperature and rainfall changes on livestock income as in equations (14) and (15) respectively:

$$E\left[\frac{\partial \pi}{\partial T}\right] = \alpha_1 + 2\alpha_2 E(T) \;\ldots\ldots\ldots\; (14)$$

$$E\left[\frac{\partial \pi}{\partial R}\right] = \alpha_3 + 2\alpha_4 E(R) \;\ldots\ldots\ldots\; (15)$$

To understand what is behind the impact estimates, we analyze the farmers' choice of animal species using a multinomial logit model (Seo and Mendelsohn, 2008). Following McFadden (1981) the probability to select a species *j* can be written as follows:

$$P_{ji} = \frac{e^{Z_{ji}\gamma_j}}{\sum_{k=1}^{J} e^{Z_{ki}\gamma_k}} \;\ldots\ldots\ldots\; (16)$$

The complementary analysis provided by Equation (16) measures how farmers alter their choice of animals depending on climate conditions.

DATA AND DESCRIPTIVE STATISTICS

Data

This study is based on secondary data obtained from a project entitled *Climate Change Impacts on and Adaptations of Agro-ecological Systems in Africa* which was funded by the Global Environmental Facility (GEF), Center for Environmental Economics and Policy in Africa (CEEPA) and the World Bank in 2004. The data are in two main sections: household farming and climate data.

a) Household data

The household dataset contains detailed information on farming activities in the 10 provinces of Cameroon. About 801 livestock farms were surveyed and the survey districts were chosen to ensure that the sample was representative of farms in different agro-climatic areas across the country. The questionnaire included questions on household characteristics, employment of household members and household use of electricity. In addition to farm crop information the survey provided detailed information with respect to the types of livestock owned, livestock product production and transactions, and relevant costs.

b) Climate data

In addition to the household data each farm surveyed was assigned a unique identifying code enabling it to be matched with spatially referenced satellites and ARTES (Africa Rainfall and Temperature Evaluation System) climate data. Temperature data came from satellites which measure temperatures twice daily via a Special Sensor Microwave Imager mounted on US Defense Department satellites (Basist *et al.,* 1998). The ARTES dataset was interpolated from weather stations by the National Oceanic and Atmospheric Administration based on ground station measurements of precipitation and minimum and maximum temperature (World Bank, 2003).

Descriptive Statistics

The key household variables of interest for this paper include diversified livestock types held by farmers, costs associated with livestock inputs and incomes from livestock products. The data indicate that the major types of livestock in Cameroon are beef cattle, dairy cattle, goats, sheep and chickens. Other less frequently recorded animals include breeding bulls, pigs, oxen, camels, ducks, guinea fowl, horses, bees, and doves. The major livestock products sold were milk, meat, eggs, wool and leather. Others included butter, cheese, honey, skins and manure. Though this study is based on livestock activities, most of the farmers earned income from both crops and livestock. The income sources captured in this survey may then be booked under one of three categories: farm crop income, livestock income and non-farm income (defined as income received from all wage/salary activities, transfers; etc). To calculated the net income derived from crop farming, the quantity of each crop sold was multiplied by the local market price of the crop *less* input costs (such as transportation cost, cost of hiring of equipments/pesticides, cost of man hours employed, etc). Net livestock income from livestock farming was computed by multiplying the number of each animal and quantity of livestock product by its unit sales price less the associated transaction costs respectively. The survey gives information about non-farm income (wages/salaries, pension, gifts, remittances, etc). This permitted us to compute total net household income as:

Total net household income= net farm crop income + net livestock income + non-farm income

The descriptive statistics for the 801 sampled households are displayed in Table 1.

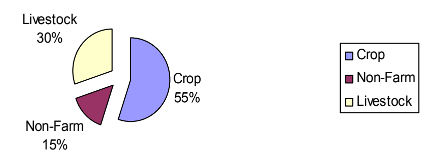
Table 1. Descriptive Statistics for the Sampled Households

Variables	Obs.	Mean	Std Dev.
Household size	765	6.27	3.72
Age	801	42.67	23.76
Distance to market (Km)	758	9.53	33.34
Electricity	795	1.23	0.42
Gender	801	1.18	0.38
Marital Status	797	1.36	0.71
Education (No. of years)	786	7.4	5.12
Farm Crop Income (Fcfa)	764	586699.48	849338.25
Non- Farm Income(Fcfa)	800	155802.28	218635.68
Livestock Income (Fcfa)	763	316682.28	959561.44
Total Household Income (Fcfa)	763	1064890.26	1525596.60

Source: Summarised by author from data base

Observe in Table 1 that the average age of household heads that participated in the survey was 42.67 years. In terms of distance from household units to the nearest market, the average distance was about 9.53 kilometres. By educational attainment, the average year of schooling for the sampled households was about 7.4 years (primary level). The average household size for the sample was about 6 members: with an average household income of about 1064890.26 Fcfa; derived from farm crops (586699.48F cfa), non-farm activities (155802.28 F cfa) and livestock farming (316682.28 F cfa). We display the distribution of total household income by income sources in Figure 1.

Figure 1: Distribution of Total Household Income by Income Sources



Source: By author

Observe from Figure 1 that average livestock income accounted for about 30 per cent of average total household income. The data therefore makes it possible to test for the influence of livestock income on Cameroonian total household income. The data show that Cameroonian households hold a diversified portfolio of animal species and derived livestock products. The major livestock types, average endowments and prices are presented in Table 1A. The table shows that the largest livestock holdings are chicken, goats, sheep, pigs and beef cattle and dairy cattle. Consequently eggs, beef and milk and are the main livestock products. In Table 2A, we present the average sales of livestock products and prices. The large standard deviations in the number of livestock and product sales across all species portray high inequalities in livestock endowments in Cameroon.

RESULTS

Livestock Income and Poverty

To evaluate the potential poverty effects of a change in livestock income we calculate the three FGT measures for a 1% change in livestock income[1]. The simulation results show that when livestock income decreases by 1%, average national poverty increases by 0.043 percentage points (when $\alpha = 0$), by 0.156 (when $\alpha =1$), and by 0.256 (when $\alpha =2$) respectively. Our simulation results therefore suggest that ignoring livestock income when estimating poverty measures in Cameroon would substantially overestimate the impacts on household poverty. The impact seems to be greater on the poverty depth and severity measures than on the head count measure. This is all the more pronounced at the regional levels, especially at the northern Saharan part of the country where most households depend on livestock activities for their livelihood.

Determinants of Livestock Farming Income

Out of a total of 801 households, about 452 households (56.5%) reported deriving their income from livestock farming while 348 households (representing about 43.5%) reported having no livestock income. Ordinarily, in estimating the determinants of livestock farming income for the sampled households, the most convenient approach is to discard those with no livestock income and use only the selected sub-sample of households with livestock income. However, proceeding in this manner could lead to a sample selection bias. In the methodology section we expressed two types of equations to determine the factors that influence livestock income and correct the selection bias: the participation or selection equation (equation 7) and the valuation or livestock income equation (equation 8). The Heckman's two step correction technique is used to estimate the equations. Starting with the participation equation to explain included versus excluded households, we estimate a reduced form probit equation to identify some demographic and socio-economic variables of the sample that would likely influence a household's decision to participate in livestock farming, but are assumed not to influence the magnitude of the resulting livestock income. The dependent variable of the selection function is binary: it takes the value of 1 when the household participates in livestock activity and the value of 0 if it does not. Among the identified explanatory variables related to a household decision to participate in livestock farming are: education level; household size; livestock extension services; the land size of the household; and total household income per capita[2]. The results of the probit estimation are reported in Table 2.

Table 2. Probability of Participating in Livestock Farming

Dependent Variable : Participation=1 ; Non-participation=0

Variable	Coefficient
Constant	2.191***
	(13.59)
Education	-0.773**
	(-1.61)
Household size	0.010***
	(3.01)
Extension Services	0.256***
	(2.41)
Household income per capita	(0.051)***
	3.48
Land size of household	-0.269**
	(-2.02)
Pseudo R^2	0.085
% correctly predicted	83.4
Number of observations	801

Source: Computed by author using STATA 9.2

Note: The t-values are presented in parentheses.

**** indicates coefficient significant at 1% level; ** indicates coefficient significant at 5% level; * indicates coefficient significant at 10% level.*

Table 2 reports the probit estimates of the probability of a household participating in livestock farming. The signs of the coefficients of the variables in the participatory equation all make intuitive sense. The educational attainment of household head plays a negative role in its livestock participation decision. This is confirmed by its coefficient, in Table 2, which is negative and highly significant. Most educated household heads have greater wide-collar job opportunities, and are therefore less likely to engage in livestock activity. The larger the household size, the more the availability of labour and the higher the probability to participate in livestock farming. Households that received livestock extension services participate

[1] The analyses are based on the 2001 poverty line established by the National Institute of Statistics (INS, 2002) at 345535 F cfa per capita.

[2] Some household characteristics such as age; distance to market; possession of electricity; marital status etc. that were not significant are not reported. It should be noted that we tested the selection variables to ascertain that they do not influence livestock income, but do affect the probability of a household to participate in livestock farming.

more in livestock farming than non-receiving households. The per capita household income coefficient is positive and significant which suggests that this factor would favour livestock rearing decision. On the contrary, the lack of household land reduces the likelihood of participation in animal husbandry especially on a large scale basis. This is confirmed by the negative and significant sign on its coefficient. In the income equation, the dependent variable is the natural logarithm of livestock income. We introduce the following into the income equation as independent variables: age, squared age, gender, households below the poverty line (poor households), and most importantly we introducing the inverse Mills ratio which comes from the probit estimation equation so as to correct the sample selection bias. The results of the estimation are displayed in Table 3.

Table 3. Log Livestock Income Equation adjusting for sample selectivity

Dependent Variable: Log Livestock Income

Variable	Coefficient
Constant	3.308***
	(7.532)
Age	0.035**
	(1.971)
Age^2	-0.041*
	(-1.731)
Gender (Male headed households)	0.162*
	(1.618)
Poor households	3.973***
	(6.308)
Mills lambda (λ)	-0.326**
	(-2.18)
Sigma (σ)	0.662
Adj. R^2	0.191
Log-likelihood	-210.109
Number of observations	801

Source: Computed by author using STATA 9.2

Note: The t-values are presented in parentheses.

**** indicates coefficient significant at 1% level; ** indicates coefficient significant at 5% level; * indicates coefficient significant at 10% level.*

The relation between livestock income and age is of the inverted U form: at the beginning, income increases with the increase of age, when age reaches its optimal level, income reaches its maximum, then as age continues to increase, income decreases. This result supports the findings of Agesa and Agesa (1999) who conclude that the relationship between age and income is hill shaped. We observe from Table 3 that households whose incomes are below the poverty line have a significant positive relation with livestock farming income. For such households, livestock farming activity is considered an important safety net required for overcoming poverty. The results also suggest that male-headed households have a significant positive relationship with livestock income than female-headed households. One possible explanation for this is that the males are more engaged in livestock rearing than the female. Finally, an important theoretical explanatory variable observed in Table 3, is the mills lambda (λ) variable, which explains the correlation between the participation decision equation and the livestock income equation. Since the coefficient on λ (i.e., λ = -2.18) is statistically significant, it implies that if we had excluded households with no livestock income from the estimation, the final estimates of the results would have suffered from a sample selection bias problem. Our use of the Heckman's sample selection model is then justifiable.

Climate Change Impact Analyses

a) Impact of Climate on Livestock Income

Table 4 shows the regressions of net livestock income per farm.

Table 4. Regression Estimates of Net Livestock Income Performance

Variable	Coefficient	
Constant	711.64**	(2.33)
Dry season temperature	-13.84*	(-1.72)
Dry season temperature sq.	359.45*	(1.69)
Wet season temperature	14.36*	(1.78)
Wet season temperature sq.	-356.78*	(-1.72)
Wet season precipitation	168.17**	(2.02)
Wet season precipitation sq.	-1.05**	(-1.99)
Electricity dummy	3.93*	(1.74)
Household size	-17.03**	(-2.05)
Pop. Density	35.31*	(1.70)
Pop. Density sq.	-0.19*	(-1.72)
% Muslim	-41.03**	(-2.01)
% grassland	11.80*	(1.73)
Adj R^2	0.21	
Obs.	801	

Source: Computed by author using STATA 9.2

Note: The t-values are presented in parentheses.

**** indicates coefficient significant at 1% level; ** indicates coefficient significant at 5% level; * indicates coefficient significant at 10% level.*

The net livestock income function is sensitive to the percentage of the population that is Muslim, the percentage of grassland and the population density variable. The more grassland in a district, the higher the livestock net income per farm. This variable measures the scarcity of land for grazing in a given area. Higher population densities would translate into higher net revenue because of the increased demand for livestock products leading to higher prices for output and probably also because of lower transport costs to the market. Household size is significant and negative. This means that large households tend to have lower livestock net incomes per farm. By contrast, households with electricity have higher net revenues. Electricity may be a dummy variable for higher technology (see Seo and Mendelsohn, 2008). Soil variables and household characteristics such as age, gender and education of the head of the farm, were also tested but were dropped because they were not significant. Table 4 also reveals that livestock net incomes are generally sensitive to climate variables. We may deduce from Table 4 that dry season temperatures exhibit a U shaped relationship with net revenue, while the response of net revenue to wet season temperature is hill shaped. High wet season temperatures will encourage growth of fodder and grass, holding precipitation constant and will therefore encourage farmers to increase their livestock holdings (Kabubo-Mariara, 2008). The hill shaped relationship suggests that excess wet season temperatures are however harmful to animal stocking levels. Wet season precipitation exhibits a hill shaped relationship. The quadratic term though negative, has a relatively small impact and suggests that excess wet season precipitation will be harmful. This is consistent with findings by Seo and Mendelsohn (2006a) which show that livestock production in Africa is quite sensitive to changes in precipitation. The quadratic terms show that both temperature and precipitation exhibit a nonlinear relationship with net livestock income.

b) Marginal Climate Effects and Elasticities

The marginal climate impacts on net livestock income are evaluated by calculating the change in mean net livestock income resulting from a unit change in temperature and precipitation. Table 5 displays the results of marginal impacts on livestock income.

Table 5. Marginal Impacts of Climate Change on Net Livestock Income

Marginal Impact	Coefficient
Dry season temperature	14.73*
Wet season temperature	11.94**
Overall temperature	17.55*
Temperature elasticity	10.39
Wet season precipitation	-13.21*
Overall precipitation	-7.87*
Precipitation elasticity	-8.04

Source: Computed by author
*Note: ** significant at 5 per cent; * significant at 10 per cent*

The results on Table 5 suggest that the marginal impact of an overall change in temperature is positive, and the change is much more significant for the wet season than for the dry season temperature. A unit rise in overall temperature would result in about 10.39 percentage point's increase in net livestock revenue. The reason for the large positive temperature elasticity is that farmers have the possibility to shift from crops to livestock production as temperatures increase. This finding agrees with Seo and Mendelsohn (2008) who have shown that small farmers have more substitutes than large farmers and so they are less vulnerable to climate changes. The marginal impact of an increase in precipitation is -8.04, suggesting that an increase in precipitation reduces net income from livestock farming. This may suggest an adaptation strategy available to the farmer: with high precipitation, farmers may switch to crop farming and therefore reduce their livestock holdings. The University of Georgia (2007) has explained that livestock farms have a negative elasticity with precipitation because heavy precipitation is often accompanied by an increased prevalence of animal diseases such as trypanosomiasis. Farmers can therefore adopt by shifting from livestock to crop production.

c) Farmer's Choice of Livestock Species

To understand how a farmer's choices of livestock species change with climate, we estimate a multinomial logit model. The results of the analysis are displayed in Table 6 which explains how exogenous variables affect the farmer's choice of one species from the five possible major animals captured in the survey. In making our analysis we assume that the choice of each type of animal is independent of the choice of any other animal; and that the probability of choosing each animal is a function of dry and wet season temperatures and precipitations.

Table 6. Multinomial Logit Animal Selection Model

Reference animal category is chicken

Variable	Coefficient			
	Beef cattle	*Dairy cattle*	*Goats*	*Sheep*
Constant	0.422	7.744***	47.19*	27.10**
	(1.392)	(16.12)	(1.76)	(2.04)
Dry season temperature	0.269**	-0.176***	-0.319**	-0.441*
	(2.02)	(-3.443)	(-2.17)	(1.869)
Dry season temperature sq.	-.0.026**	-0.041*	0.051**	0.023*
	(5.149)	(-1.73)	(2.452)	(1.21)
Wet season temperature	-0.123*	-0.184	-0.625***	-0.301**
	(-1.824)	(-1.09)	(-2.129)	(-2.003)
Wet season temperature sq.	-0.035*	-0.026*	0.070***	0.051**
	(-1.971)	(-5.149)	(4.107)	(2.452)
Dry season precipitation	0.061***	0.057***	0.013*	0.063*
	(4.096)	(3.357)	(0.953)	(1.961)
Dry season precipitation sq.	-0.001	0.016	0.011	0.007
	(0.09)	(0.289)	(0.120)	(0.045)
Wet season precipitation	0.035**	-0.046**	-0.079*	-0.091**
	(1.97)	(-3.192)	(-4.503)	(10.074)
Wet season precipitation sq.	-0.002*	0.009	0.004*	0.001
	(-1.330)	(0.332)	(1.031)	(0.010)
Likelihood ratio test		P < 0.0001		
Lagrange multiplier test		P < 0.0001		
Wald test		P < 0.0001		

Source: Computed by author using STATA 9.2

<u>Note:</u> The t-values are presented in parentheses.

**** indicates coefficient significant at 1% level; ** indicates coefficient significant at 5% level; * indicates coefficient significant at 10% level.*

We consider chickens to be the base outcome animal category. This may be justified on the grounds that chicken is the animal species commonly owned by the majority of Cameroonian households (see Table 1A). Observe from table 6 that livestock farmers are more likely to choose goats and sheep, but less likely to choose beef cattle and dairy cattle with climate variation. This is indicated by the quadratic dry and wet season temperature coefficients which are negative for beef cattle and dairy cattle but positive and significant for goats and sheep. This means that as temperature rises, farmers shift from beef cattle, dairy cattle and chickens to goats and sheep[3]. As precipitation increases, farmers shift away from the other animal species to goats and chickens This is indicated on Table 6 by the fact that the quadratic wet season precipitation coefficient is negative and significant for beef cattle; it is insignificant for dairy cattle and sheep; while it is positive and significant for goats. This change in the portfolio of animals helps explain how the farmers can adapt to changing climatic conditions.

CONCLUSION AND POLICY IMPLICATION

The paper examines the distributional implications of income derived from livestock farming on poverty, and assesses the impact of climate change on livestock income in Cameroon. The analyses are based on primary data collected from a sample of 801 households in 2004. The primary data were enriched with secondary climate data, which reflect long term climate change in Cameroon. The impact of climate change on livestock income is analyzed using the Ricardian approach. It comes out of the analyses that households whose incomes are below the poverty line have a significant positive relation with livestock income. This implies that for such households, livestock farming activity is considered an important safety net required for overcoming poverty. This finding highlights the importance of income from livestock farming for the alleviation of poverty in the country. Livestock farming is an important source of income for many Cameroonian households. Without it, many households' ability to satisfy their basic needs would be jeopardized. The simulation results reveal that ignoring this income source when estimating poverty measures in Cameroon would substantially overestimate the impacts on household poverty, which is all the more pronounced at the regional levels, especially at the northern parts of the country where most households depend on livestock activities for their livelihood. The policy implication here is that policy makers (especially the Ministry of Livestock, Fisheries and Animal

[3] We note here, however, that the adaptation of the farmers may not be automatic due to cultural and geographical factors.

Industries), Non Government Organizations (such as Heifer Project International–Cameroon) and agricultural research stations (such as Institute of Zoo-technical Research) should promote and intensify livestock extension services and formulate locally relevant programs that have the greatest impact on poverty alleviation. The northern Saharan regions of the country should be especially targeted. Another result emanating from the study is that livestock production in Cameroon is sensitive to global warming. We may deduce that the economic viability of large livestock operations is more vulnerable to warming. This is because they depend more on cattle. Global warming will force reductions in beef and dairy cattle, critical to many commercial livestock activities. On the other hand, small farmers have many substitutes. If it gets warmer, they can shift to heat tolerant animals such as goats and sheep. In these circumstances, small farmers are actually better able to adapt to climate change than their larger more commercial counterparts. Providing subsidies or other enticements may not solve the problem. Instead, governments should encourage farmers to change the composition of animals on their farms and practice mixed farming.

The estimated marginal impacts of climate change on net income reveal that the overall impact of rising temperatures will be a significant increase in livestock income. The reason for the large positive temperature elasticity is that farmers have the possibility to shift from crops to livestock production as temperatures increase. This finding agrees with Seo and Mendelsohn (2008) who have shown that small farmers have more substitutes than large farmers and so they are less vulnerable to climate changes. The marginal impact of an increase in precipitation reveals a reduction in net revenue from livestock farming. This suggest that the adaptation strategy available to the farmer may be a switch to crop farming and thereby a reduction in livestock holdings.

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APPENDIX

Table 1A: Average Livestock Holdings and Prices

Livestock Type	No. of Households	Livestock Holdings		Price per Animal (Fcfa)	
		Mean	*Std Dev.*	*Mean*	*Std Dev.*
Beef Cattle	60	53.85	31.64	106444.54	18407.87
Dairy Cattle	63	59.71	21.33	117893.11	18997.32
Bulls	17	32.50	15.93	120974.06	193007.14
Goats	178	13.34	10.88	26453.95	6123.28
Sheep	113	18.29	23.59	28322.92	8092.22
Pigs	49	20.53	79.15	58018.94	29824.90
Oxen	29	61.59	52.17	114354.84	25972.48
Chicken	194	471.5	144.32	2708.04	614.80
Others	18	181.5	703.52	4190.91	3800.38

Source: Computed by author from data base

Table 2A. Average Livestock Product Sales and Prices

Livestock Product	No. of Households	Sales		Price per Product (Fcfa)	
		Mean	*Std Dev.*	*Mean*	*Std Dev.*
Milk (kg)	23	665	983.20	1200	400
Beef (kg)	41	761.95	659.76	1782.93	258.99
Sheep (kg)	46	221	146.14	2069.59	370.51
Goat (kg)	57	205.18	109.87	2350.88	109.87
Chicken (kg)	45	578.41	1101.06	2500	3455.36
Eggs	48	2534.90	7441.65	241.02	131.17
Wool	5	92.32	87.20	1975.53	658.09
Leather	16	409.56	198.34	806.89	531.19
Other	12	132.33	76.18	300.5	177.07

Source: Computed by author from data base