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FOOD PRICES AND HOUSEHOLD CONDITIONAL FOOD EXPENDITURE PERSPECTIVES OF GREENHOUSE GAS EMISSION IN EDO STATE, NIGERIA

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ABSTRACT

Empirical studies on climate-warming greenhouse gas (GHG) emission from the perspectives of food consumer parameters are sparse in literature, and non-existent in Edo state. The study examined the outcomes of food prices and household conditional food expenditure changes on GHG in Edo State, Nigeria. It estimated a complete conditional GHG emission share system equation, the price and conditional expenditure elasticites of GHG emission due to food demand. Three-stage sampling procedure was used to select a cross-section of 252 households. The micro-data obtained were analysed using the Quadratic Almost Ideal Demand System (QUAIDS) model. The results show that 87.5% of the conditional GHG emission in the State is caused by protein foods consumption, consisting of meat (73.8%), fish (12.7%) and beans (1.0%). The results of the QUAIDS show that GHG emission in the state has inverse relationship with price. GHG emission is price and expenditure elastic. There is no strong complementarity and substitutability among the GHG emission due to food commodities consumption in the State. GHG emission from fish (1.112) and beans (1.029) consumption increase more than proportionate increase in household conditional food expenditure, but less than proportionate increase with household conditional food expenditure for plantain (0.889), rice (0.939), meat (0.993), potato (0.737) and tomato (0.667) consumption. Though, GHG emission due to beans (1.029) and meat (0.993) consumption will increase with increase in household conditional food expenditure, it decreases in share due to beans and meat consumption. Similarly, GHG emission due to fish consumption decrease with increase in household income, but increases in share due to fish commodities consumption. GHG emissions in the State are food prices and household conditional food expenditure related with conditional food expenditure having greater weight than food prices effects.

Keywords: food, greenhouse gas emission, prices, income, elasticity

INTRODUCTION

Food and agriculture sector contributes significantly to green-house-gas GHG emissions (Johnson *et al.*, 2014; Smith *et al.*, 2014; FAO, 2017). The food system is locked in a vicious-circle of rising demand, changing food-price and household income, unhealthy and unsustainable food consumption pattern (Garnett, 2008; Macdiarmid *et al.*, 2011; Macdiarmid, 2012). Though, authors opined that animal-based foods typically have higher GHG emissions than plant-based foods (Carlsson-Kanyama and González, 2009; Pathak *et al.*, 2010; Bellarby *et al.*, 2012; Berners-Lee *et al.*, 2012; Smith *et al.*, 2014), there are no empirical evidence on GHG with respect to food consumption parameters. Literature also has it that it is possible to create a diet that achieves dietary recommendations for health and has lower GHGE than the estimated current dietary intakes (Macdiarmid *et al.*, 2011, Noleppa and von Witzke, 2012), but not without the *ceteris paribus* assumption of the type of food, food prices and household food expenditure. Results of modelling of climate-change impacts on food prices vary considerably, depending on the underlying model parameters, climate scenarios, baselines, adaptation responses and data employed. However, in the vast majority of cases the models predict higher food prices (Audsley, 2009) without a corresponding causal relationship between GHG emission and consumption parameters (Horne, 2009).

Nigeria experienced 98.22 $MtCO_2e$ (25%) in greenhouse gas (GHG) emissions between 1990 and 2014. In 2014, per *capita* GHG emissions in Nigeria were 2.79 tCO_2e with total GHG emissions of 492.44 MtCO2e, representing 41.5% and 1.01% respectively of global GHG emissions (WRI CAIT 4.0, 2017). According to the World Resources Institute Climate Analysis Indicators Tool (WRI CAIT 4.0, 2017), GHG emissions in 2014 for Nigeria were primarily from the land-use change (38.2%) and forestry sector (32.6%) with 1.0% change in average annual total emissions. The country pledged to unconditionally reduce GHG emissions by 20% by 2030 through improving energy efficiency by 20%, among others without recourse to the contribution of food prices and household income and their attendant food consumption (Stoll-Kleeman and Schmidt, 2016; Jones *et al.*, 2016). The few data on climate impact from food consumption contains GHG emission from transport in the food life-cycle emission estimates (Williams, *et. al.*, 2006)**.**

The study, therefore, examined the carbon footprint per *capita* of each food item consumed using CO_2 equivalent (CO_2e) emissions data. To achieve this, the study estimated a complete climate-warming greenhouse gas emission (CO_2e) share system as function of food prices and household food expenditure, and estimated the price and income elasticites of equivalent greenhouse emission of food consumption using micro-data. The study provides greater precision of estimated parameters to enhance information concerning climate-warming greenhouse gas emission with respect to food prices and household income in Edo State, Nigeria. This would create increased awareness of the impact that food prices and household food expenditure have on climate change with a view to bringing a shift to more widespread adoption of healthy, sustainable diets among people in Edo state in particular and Nigeria in general.

MATERIALS AND METHODS

Study Area

The study was conducted in Edo State, Nigeria. It lies within Latitudes 4^o 45' and 7^o 40' North of the Equator and Longitudes 5^o and 6^o 45' East of Greenwich meridian. It has boundaries with Kogi in the North, Delta in the South, Ondo in the West and, Anambra in the East. It occupies a total land area of 19,794 Km^2 with a population of 3,218,332 million people (National Population Commission, NPC, 2006). The State has 18 Local Government Areas delineated into three senatorial districts. The main ethnic groups in Edo State are Edos, Afemais, Esans, Owans and Akoko-Edos. The Bini speaking people who occupy seven out of the 18 Local Government Areas of the state constitute 57.54% while others are Esan (17.14%), Afemai comprising of Etsako (12.19%), Owan (7.43%), and Akoko Edo (5.70%). The Igbira speaking communities exist in Akoko-Edo as well as Urhobos, Izons, Itsekiris communities in Ovia North-east and South-west Local Government Areas especially in the borderlands. Also, Ika speaking communities exist in Igbanke in Orhionmwon LGA. 75% of the urban centres are local government headquarters while 25% of other centres that evolved as urban due to other factors such as natural increase, agricultural and commercial activities. The State is an agrarian State with farming as the dominant economic activity of the State. Several social and economic facilities are located, including electricity, industries, health and educational facilities, markets and transportation. However, most of these are located in the local government headquarters which are the major urban centres in the State. The traditional cuisine in the State is fairly representative of what obtains in most southern States of Nigeria. The target population for the study was food consumers who live in the urban centres.

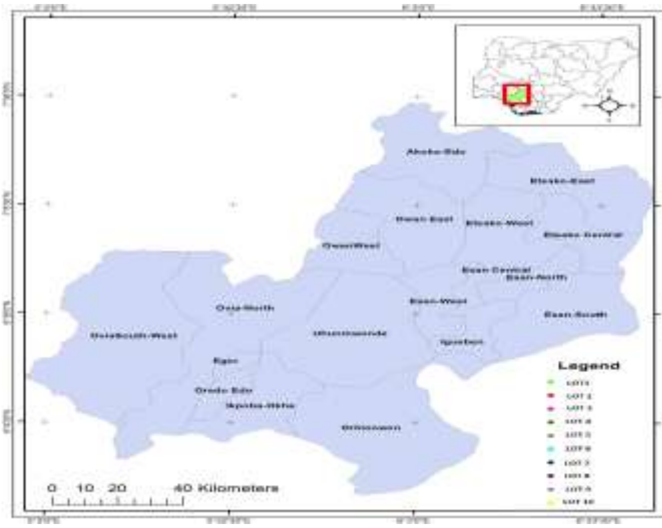

Fig. 1: Map of Edo State showing the Study Area

Experimental Design

A Multistage Sampling procedure was employed for the study. The first stage involved simple random sample of one Local Government Area (LGA) from each of the three Senatorial Districts of the State. The LGAs were Oredo in Edo-south, Esan-west in Edo central and Etsako-west in Edo-north. The second stage involved a purposive sample of the headquarters of the LGA as proxy for urban centres with Benin City for Oredo, Ekpoma for Esan-west and Auchi for Etsako-west. The third stage involved a simple random sample of two wards each from the headquarters. The sample size for the study in each ward was determined using the sample-size estimator adapted from Ojogho and Ojo (2017), given estimates of the expenditure variance for each ward, from a pilot survey, at 95 % confidence interval and a 0.03 margin of error. The sample-size estimator is given as:

$$n_i = \frac{z^2_{\alpha/2} s_i^2}{e^2 + \frac{z^2_{\alpha/2} s_i^2}{N_i}} \qquad \text{……….. [1]}$$

Where:

$z_{0.025} = 1.96$, s_i^2 is the expenditure variance of the i^{th} ward, N_i is the target population of the i^{th} ward and $e = 0.03$.

A simple random sample of households in each ward was then taken from the list of the target population in the region developed from the pilot survey. Using the estimator, 100 households were sampled from Edo-south, 75 households from Edo-central and 84 households from Edo-north out of a target population of 120, 80 and 100 households respectively. Data were collected between the period of November 2017 and April 2018. Only 252 households provided useful information for the analysis as only data from 7 or more in 10 respondents who consumed food commodities, at 3-5 times a week, under study were used in the final analysis. The prices of food commodities were measured as the sum of the transactions costs incurred by a household and the retail prices in ₦/Kg, while the quantity consumed of food commodities by a household was the quantities purchased at market price per Kg. The Kg CO_2/year per *capita* was computed by multiplying the quantity for human consumption in terms of kg/person/year and the median of emissions intensity in the world for j^{th} food item.

Model Specification

The study used the Quadratic Almost Ideal Demand System (QUAIDS) of Banks *et al.* (1997) to estimate a complete climate-warming greenhouse gas emission (CO_2e) system as function of food prices and household food expenditure. The study assumes prices are independent to the total quantity demanded. The study argues that the decision making process on the side of demand is not done by individuals but rather by the household as a whole. This can be a single person in case of single households but usually it is done by one of the parents or one of the couple hereafter called household head. Moreover, household is considered to be the best option of a unit for demand analysis. The study argues that there is an additive zero-mean error term associated with each of the *k* GHG emission share equations.

The QUAIDS model is given, in its GHG emission share form, as:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \left[\ln \frac{m}{a(p)}\right] + \frac{\lambda_i}{b(p)} \left[\ln \frac{m}{a(p)}\right]^2 \quad [2]$$

Where:

w_i is the share of climate-warming greenhouse gas emission of the i^{th} food commodity, m is total expenditure on the basket of food commodities, p_j is price of j^{th} food commodity, $a(p)$ is a price index of the basket of food commodities, homogenous of degree one in prices, defined as:

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{k} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \gamma_{ij} \ln p_i \ln p_j$$

$b(p)$ defined as $b(p) = \prod_{i=1}^{k} p_i^{\beta_i}$ is a function that is homogenous of degree zero in prices, n is the number of food items in the basket of food commodities entering the GHG emission share model, p is a vector of prices and, α, β and λ are parameters to be estimated.

An error term ϵ_i was added to the right-hand side of [2] for estimation purposes. In addition, $\epsilon \equiv [\epsilon_1, \epsilon_2, ..., \epsilon_k]$ was assumed to have a multivariate normal distribution with covariance matrix Σ. The adding-up condition implies that Σ is singular. Therefore, one of the *K*-GHG emission share equations was dropped from the system with the remaining (*K*−1) equations estimated by maximum likelihood, while the parameters of the final equation are recovered using the regularity conditions of adding-up, homogeneity and symmetry.

Adding up

$\sum_{i=1}^{k} \alpha_i = 1$, $\sum_{i=1}^{k} \beta_i = 0$, $\sum_{i=1}^{k} \lambda_i = 0,$ and $\sum_{i=1}^{k} \gamma_{ij} = 0, \ \forall j$

Homogeneity

$\sum_{i=1}^{k} \gamma_i = 0, \forall j$

Slutsky symmetry

$\gamma_{ij} = \gamma_{ji}, \forall i,j$

The raw estimated parameters of the QUAIDS model have no closed-form interpretation. Thus, income and price elasticities were estimated. To achieve this, the geometric means of the price and expenditure variables were first computed and then the elasticities of the price and conditional expenditure elasticities were computed at the geometric means. The uncompensated own- and cross-price elasticites were estimated using:

$$e_{ij} = -\partial_{ij} + \frac{\mu_{ij}}{w_i} \quad [3]$$

Compensated own- and cross-price elasticites were estimated using:

$$e_{ij} = -\partial_{ij} + w_j \mu_i \quad [4]$$

Expenditure elasticites were estimated using:

$$e_i = 1 + \frac{\mu_i}{w_i} \quad [5]$$

Where:

$$\mu_i = \beta_i + \frac{2\lambda_i}{b(p)} . \ln\left(\frac{m}{a(p)}\right) \quad [6]$$

$$\mu_{ij} = \gamma_{ij} - \mu_i\left(\alpha_j + \sum_{k=1}^{n} \gamma_{jk} \ln p_k\right) - \frac{\lambda_i \beta_j}{b(p)} \left[\ln\left[\frac{m}{a(p)}\right]\right]^2 \quad [7]$$

δ_{ij} is the Kronecker delta, $a(p)$ and $b(p)$ are as defined above, p_k is the price of the k^{th} commodity.

RESULTS

Table 1 presents the summary statistics of the variables used in the QUAIDS model. The results show that in the broad categories of household food expenditure, the monthly per *capita* expenditure share on rice was 25% of the total monthly per *capita* expenditure of the household heads on food in Edo state. This was followed by meat (20.5%), fish (15.7%), and beans (14.2%), and least with potato (5.1%). However, more than half of the household food expenditure share was spent on protein foods (50.4%), followed by carbohydrate foods (39.7%) and least with vegetable (10.0%).

Table 1: Summary Statistics Variables of QUAIDS Model for GHG emission in Edo State

Equivalent Green House Gas			Food Expenditure		Food commodities	
Variables	GHG (tCO_2e)	share (ω)	Expenditure (₦)	Budget share (ω)	Prices	Mean
Plantain	685.977	0.010	1,570.00	0.096	Plaintain	111.78
Rice	6,406.458	0.090	4,091.68	0.250	Rice	391.08
Potato	63.229	0.001	811.76	0.051	Potato	121.57
Tomato	2,060.667	0.028	1,656.37	0.100	Tomato	183.67
Meat	5,8533	0.738	3,465.20	0.205	Meat	1282.27
Fish	9,614.811	0.127	2,666.18	0.157	Fish	777.28
Beans	720.131	0.010	2,306.72	0.142	Bean	425.55

The corresponding GHG emissions were 6406.46tCO_2e, 58533.00tCO_2e, 9614.81tCO_2e, 720.13tCO_2e and 63.229tCO_2e respectively for rice, meat, fish, beans and potato consumption given the market prices of the food commodities. The largest share of GHG emission was from spending ₦1282 per Kg on meat consumption (73.8%). This followed by expenditure of ₦777 per Kg on fish (12.7%), then ₦391 per Kg on rice (9.0%) and least with ₦122 per Kg on potato (0.1%).

The resulting coefficients and their associated standard error from the last iteration of the QUAIDS model are presented in Table 2. The squared log expenditure coefficient for beans, meat and fish were -0.0026, -0.016 and 0.018 respectively while the log expenditure coefficients were respectively -0.03, -0.19 and 0.23. The price variables were less statistically significant $p < 0.1$ than the income variables $p < 0.05$ except for the own-price of plantain, rice and potato. The squared log expenditure coefficient for beans, meat and fish were significant at $p \leq 0.1$ with value -0.0026, -0.016 and 0.018 respectively. The resulting Engle curves for beans (-0.00261), meat (0.01798) and fish (-0.01595) are non-linear. This implies that the QUAIDS model better fits the system of GHG emission shares against the Almost Ideal Demand System (AIDS) model. The log expenditure coefficients were also significant at $p \leq 0.1$ with value respectively -0.03, -0.19 and 0.23.

Table 2: Parameter Estimates of the QUAIDS Model and Associated Standard Errors for Climate-warming Greenhouse Gas Emission in Edo State

Parameter	Plantain $i=1$	Rice $i=2$	Potato $i=3$	Tomato $i=4$	Beans $i=5$	Meat $i=6$	Fish $i=7$
α_i	-0.004	0.051	-0.002	-0.008	-0.065	0.209	0.819***
	(0.024)	(0.102)	(0.002)	(0.016)	(0.043)	(0.178)	(0.103)
β_i	0.001	-0.002	-0.001	-0.002	-0.030**	-0.194***	0.228***
	(0.008)	(0.033)	(0.001)	(0.005)	(0.014)	(0.056)	(0.031)
λ_i	0.0002	0.0003	-0.00002	0.00013	-0.00261**	-0.01595***	0.01798***
	(0.0006)	(0.0027)	(0.00006)	(0.00042)	(0.00123)	(0.00417)	(0.00249)
γ_{1i}	-0.01018***	0.00345***	0.00024**	0.00054	0.00397*	0.00309	-0.00110
	(0.00117)	(0.00131)	(0.00011)	(0.00078)	(0.00155)	(0.00362)	(0.00374)
γ_{2i}		-0.03676***	0.00035	0.00182*	0.00720*	0.01909	0.00486
		(0.00583)	(0.00014)	(0.00098)	(0.00380)	(0.01531)	(0.01772)
γ_{3i}			-0.00065***	-0.00022	0.00029	0.00027	-0.00028
			(0.00013)	(0.00019)	(0.00020)	(0.00032)	(0.00034)
γ_{4i}				0.00071	-0.00328	0.00195	-0.00151
				(0.00140)	(0.00139)	(0.00243)	(0.00260)
γ_{5i}					-0.00906	0.01797*	-0.01710
					(0.00401)	(0.00662)	(0.00754)
γ_{6i}						0.03408	-0.07644
						(0.04940)	(0.04037)
γ_{7i}							0.09158
							(0.03236)

*Values in parentheses are standard errors; ***significant @ 1% level, **significant @ 5% level, *significant @ 10% level*

Table 3 shows the compensated own- and cross-price elasticities of a typical household in the State based on the QUAIDS model. The results show that the compensated own-price elasticities for all GHG emission due to food commodities consumption were non-positive and significant at $p < 0.05$. The own-price elasticity coefficients for all GHG emission due to food commodities consumption were greater than one in absolute term, except for tomato (-0.9241) and meat (-0.3596). This means that GHG emission due to food commodities consumption of these food items is piece elastic. . For plantain (-2.0484), rice (-1.3392), potato (-1.7225), beans (-1.3905) and fish (-1.2966), the elasticity coefficients were greater than one in absolute term. One percent increase in the price of plantain, rice and potato would cause a drop in GHG emission due to plantain, rice and potato consumption, on average, by 2.05%, 1.34% and 1.72% respectively, *ceteris paribus.*

Table 3: Expenditure and Compensated Own- and Cross-price Elasticities Coefficient Estimates for Climate-warming Greenhouse Gas Emission in Edo State

Parameter	Plantain $j=1$	Rice $j=2$	Potato $j=3$	Tomato $j=4$	Beans $j=5$	Meat $j=6$	Fish $j=7$	e_i
Plantain	-2.0484***	0.4433***	0.0258**	0.0660	0.4468***	1.0999***	-0.0334	0.8887***
$i=1$	(0.1217)	(0.1371)	(0.0118)	(0.0806)	(0.1550)	(0.1850)	(0.1572)	(0.1203)
Rice	0.0493***	-1.3392**	0.0049	0.0305***	0.1095***	0.9472***	0.1978***	0.9388***
$i=2$	(0.0153)	(0.0670)	(0.0015)	(0.0109)	(0.0283)	(0.0969)	(0.0679)	(0.0671)
Potato	0.2757**	0.4682**	-1.7225***	-0.2441	0.3078	0.7220***	0.1931	0.7369***
$i=3$	(0.1260)	(0.1453)	(0.1470)	(0.2056)	(0.2215)	(0.1893)	(0.1551)	(0.1216)
Tomato	0.0625	0.2593**	-0.0216**	-0.9241***	-0.3086**	0.8288***	0.1037	0.6668***
$i=4$	(0.0763)	(0.0930)	(0.0182)	(0.1367)	(0.1342)	(0.1255)	(0.1030)	(0.0805)
Beans	0.1551***	0.3417***	0.0100**	-0.1132**	-1.3905***	0.7954***	0.2015**	1.0291***
$i=5$	(0.0538)	(0.0884)	(0.0072)	(0.0492)	(0.1277)	(0.1209)	(0.1053)	(0.0775)
Meat	0.0144***	0.1111***	0.0009	0.0114***	0.0299	-0.3596***	0.1919***	0.9930***
$i=6$	(0.0024)	(0.0114)	(0.0002)	(0.0017)	(0.0046)	(0.0257)	(0.0162)	(0.0177)
Fish	-0.0025	0.1345***	0.0014	0.0083	0.0438**	1.1111***	-1.2966***	1.1127***
$i=7$	(0.0119)	(0.0462)	(0.0011)	(0.0082)	(0.0229)	(0.0936)	(0.0892)	(0.0701)

*Values in parentheses are standard errors; ***significant @ 1% level, **significant @ 5% level*

The resulting expenditure elasticities are also presented in Table 3. All conditional expenditure elasticities of GHG emissions due to food consumption were significant at $p < 0.001$ level of significance. The conditional expenditure elasticities for plantain (0.8887), rice (0.9388), potato (0.7369), tomato (0.6668) and meat (0.9930) were less than 1 in absolute term with GHG emission share due to tomato consumption being the least expenditure elastic. However, the shares of GHG emission due to beans (1.0291) and fish (1.1127) consumption were greater than 1 in absolute term, and GHG emission share due to their consumption would increase more than proportionate increase in income.

The results of the Mashellian own- and cross-price elasticities of GHG emission due are food consumption in the study area are presented in Table 4. The results show that the own-price elasticities of GHG emission due to are food commodities consumption in the State are negative and significant at $p < 0.001$ for all commodities. Based on the size of the own-price elasticities, the share of GHG emission due to plantain (-2.0570), rice (-1.4204), potato (-1.7232), fish (-1.4384) and bean (-1.4190) consumption are among the highly affected by changes in the own prices while the share of GHG emission due meat (-1.0921) is the least but one affected by change in the price in the area.

Also presented in Table 4 are the uncompensated cross-price elasticity coefficients. Most of the uncompensated cross-price elasticity coefficients were large but smaller than the own-price elasticities. These imply that there is no strong dependence among the GHG emission due to food commodities consumption in the State.

Table 4: Uncompensated Own- and Cross-price Elasticity Coefficient Estimates for Climate-warming Greenhouse Gas Emission in Edo State

Parameter	Plantain i =1	Rice i =2	Potato i =3	Tomato i =4	Beans i =5	Meat i =6	Fish i =7
Plantain	-2.0570***	0.3664***	0.0250**	0.0570	0.4222**	0.4444***	-0.1466
i =1	(0.12196)	(0.1358)	(0.0118)	(0.0808)	(0.1557)	(0.1655)	(0.1615)
Rice	0.0403***	-1.4204***	0.0040	0.0209**	0.0835***	0.2547***	0.0782
i =2	(0.0153)	(0.0679)	(0.0015)	(0.0110)	(0.0287)	(0.0938)	(0.0705)
Potato	0.2686**	0.4044**	-1.7232***	-0.2516	0.2873	0.1784	0.0992
i =3	(0.1261)	(0.1434)	(0.1470)	(0.2060)	(0.2218)	(0.1654)	(0.1586)
Tomato	0.0560	0.2016**	-0.0222*	-0.9309***	-0.3271**	0.3370***	0.0188
i =4	(0.0764)	(0.0918)	(0.0182)	(0.1369)	(0.1344)	(0.1096)	(0.1053)
Beans	0.14520***	0.2526***	0.0091	-0.1237***	-1.4190***	0.0363	0.0704
i =5	(0.0539)	(0.0878)	(0.0072)	(0.0493)	(0.1283)	(0.1082)	(0.1075)
Meat	0.0048**	0.0252**	-0.00001	0.0013	0.0024	-1.0921***	0.0654
i =6	(0.0024)	(0.0118)	(0.0002)	(0.0018)	(0.0047)	(0.0250)	(0.0169)
Fish	-0.0132	0.0382	0.0004	-0.0030	0.0130	0.2903**	-1.4384***
i =7	(0.0119)	(0.0465)	(0.0011)	(0.0083)	(0.0230)	(0.0923)	(0.0923)

*Values in parentheses are standard errors; ***significant @ 1% level, **significant @ 5% level, *significant @ 10% level*

DISCUSSION

Household monthly per *capita* food expenditure share on rice was highest in the State. This is followed by meat, fish, beans and least with potato with starchy food occupying a larger part of the budget. The highest budget share on rice in the area is in agreement with Ojogho and Alufohai (2010). However, most of the household food expenditure share was spent on protein foods followed by carbohydrate foods and least with vegetable. This is in line with Goodland and Anhang (2009). Within the food budget, expensive, more protein foods such as meat, fish and beans are predominant for households in the State, leading to more nutritious, more diversified diets. This may suggest some level of richness among the households in the State.

The GHG emissions given in Table 1 for rice, meat, fish, beans and potato consumption, given the market prices, suggest that for every 1Kg of rice, meat, fish, beans and potato consumed, 25,63MtCO_2e, 291.21MtCO_2e, 61.24MtCO_2e, 5.07MtCO_2e and 0.10MtCO_2e of GHG are emitted. The largest share of GHG emission is from consuming 1Kg of meat, followed by fish, then rice and least with potato. This suggests that households that consume a basket of food commodities containing less meat and fish are more climate-friendly in food consumption in the State, *ceteris paribus*. This agrees with the assertion of Garnett (2008) that livestock products, like meat, are the most contributors to GHG emission.

The resulting coefficients and their associated standard error from the last iteration of the QUAIDS model are presented in Table 2. The squared log expenditure coefficient for the food commodities are very low for all the equations especially potato where it is below 0.00003. The coefficients of beans, meat and fish statistically significant for at least 5% level of significance. The same is true of their log expenditure coefficient for beans, meat and fish. The price variables are less statistically significant than the income variables except for the own-price of plantain, cross-price of plantain rice and potato demand function, and own-price of potato. This implies that the QUAIDS model better fits the system of GHG emission share against the Almost Ideal Demand System (AIDS) as the resulting Engle curves of beans, meat and fish are non-linear. However, only beans and meat exhibit the inverse hump-shaped Engle curve as the coefficient at the log expenditure squared is negative while fish exhibits hump-shaped Engle curve. This implies that there is the possibility of a reverse in the direction of change in GHG emission share due to fish and bean consumption as conditional food expenditure increases.

The results in Table 3 show that the compensated own-price elasticities for all GHG emission due to food commodities consumption are non-positive. This is in line with economic theory. The own-price elasticity coefficients for all GHG emission due to food commodities consumption are greater than one in absolute term, except for tomato and meat. This means that GHG emissions due to consumption of these food items are price elastic. For plantain, rice, potato, beans and fish, the elasticity coefficients are greater than one in absolute term. This implies that the GHG emissions due to consumption of plantain, rice, potato, beans and fish are price elastic, having relatively high effects (decrease) in the GHG emission share in the State. The value of the own-price elasticity for tomato is less than one in absolute term. This means that a one percent increase in the price of tomato and meat would cause less effect on GHG emission share, *ceteris paribus* than for plantain, rice, potato, beans and fish. Thus, one percent increase in the price of plantain, rice and potato would cause a drop in GHG emission due to plantain, rice and potato consumption, on average, by 2.05%, 1.34% and 1.72% respectively, *ceteris paribus.* The drop in GHG emission due to consumption of these food commodities is higher, on average, with plant-based non-protein food items than with animal-base food commodities. The implication is that an increase in consumption of these food commodities has attendant relatively significant decrease in greenhouse gas emissions. This supports the predictions of von Witzke *et al.,* (2011), Noleppa and von Witzke (2012), Alexandratos and Bruinsma (2012) and Clark and Tilman (2017). Reducing GHG emission share can be achieved, therefore, through deliberate price-oriented policies. However, the less effect in the drop of GHG emission due to meat consumption is in line with expectations of increased GHG emission from producing meat. The possible explanation is that meat is a luxury food item among poor households with higher income effect.

The second set of parameter in Table 3 is the compensated cross-price elasticity coefficients for GHG emission due to food consumption. Most of the compensated cross-price elasticity coefficients were high. This implies that there is a strong dependence among the GHG emissions due to consumption of these foods. This is expected as there is both complementary and substitution dependence among food commodities consumption, even with weak separability.

The resulting expenditure elasticities are presented in Table 3. All conditional expenditure elasticities of GHG emissions shares due to food consumption were significant at 1% level of significance and greater than zero. The implications are that conditional expenditure of households has effects on GHG emissions share, and an increase in expenditure on the food items would lead to an increase in GHG emission shares. The conditional expenditure elasticities of plantain, rice, potato, tomato and meat are less than 1 with tomato being the least expenditure elastic. The implication is that GHG emission shares resulting from the consumption of these food commodities are necessities to their expenditure. Hence, the shares of GHG emission due to plantain, rice, potato, tomato and meat consumption is invariant to income level of households. GHG emission only decreases with increase in food expenditure on plantain, rice, potato, tomato and meat but with less than proportionate increase in food expenditure. However, the conditional expenditure elasticities of bean and fish are greater than 1. This implies that the GHG emission share due to consumption of these food commodities are income dependent while GHG emission share due to beans and fish consumption increase more than proportionate increase in household expenditure in the State. However, the GHG emission share resulting from the consumption of these commodities can be made to decrease with increase in household income as in the case of beans and meat with inverse hump-Engel curve in the State.

The results of the Mashellian own- and cross-price elasticities of GHG emission due are food consumption in the study area are presented in Table 4. The results show that the own-price elasticities of GHG emission due to food commodities consumption in the State are negative for all commodities, as expected. Based on the size of the own-price elasticities, the GHG emission shares due to plantain, rice, potato, fish and bean consumption are among the most affected by changes in own-prices of these food commodities while the GHG emission share due meat is the least but one affected by change in the price in the State. Also presented in Table 4 are the uncompensated cross-price elasticity coefficients. Most of the uncompensated cross-price elasticity coefficients are large but smaller than the own-price elasticities.

These imply that there is no strong dependence, with respect to complementary and substitution, among the GHG emission share due to food commodities consumption in Edo State.

CONCLUSION

The study estimated ~~a~~ complete GHG emission share equations system due to food consumption in the study area and estimated the conditional price and income elasticites of GHG emission. It analysed micro-data from 252 household using the Quadratic Almost Ideal Demand System (QUAIDS) model. Household's protein foods consumption in the area caused more than 85% of the GHG emissions. The GHG emissions were price inelastic, had inverse relationship with price, and a strong complementarily and substitutability due to food commodities consumption in the State. The GHG emission due to consumption of protein staple foods consumption, like fish, beans and meat in the area follows the 'hump-shaped' Engel-curve relationship.

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