Estimating nutrition-income elasticities in sub-Saharan African:Implication on health

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Abstract

The study estimates calories, proteins and fats-income elasticities in sub Saharan Africa (SSA). Annual time series data for 43 countries covering 1975-2009 that yields a balanced panel was employed for the analysis. The nutrient-income elasticities are estimated based on the aggregate Engel Curve framework using Feasible Generalized Least Square (FGLS) technique that is robust to autocorrelation and non-parametric plot. The empirical results show that a 10% increase in income will lead to about a 0.90%, 0.87%, and 0.73% rise in fats, proteins and calories supply, respectively in the region. This shows that the estimated nutrient-income elasticities are of small size. Other results show that the relationship between calorie and protein-income was found to be non-linear at higher income and diminished, as revealed by the estimated aggregate Engel Curve and non-parametric plot.

Key words: Nutrition, health, income elasticity, cross-country, and SSA

JEL Classification: C33, I31, O47, O55

1. Introduction

The variation in the level of food consume (henceforth defined in this paper as per capita nutrient supply) across countries can be linked to dissimilar levels of available food production, socio-demographic characteristics and in particular differences in cross -country growth performance or pattern of economic growth among others (Angulo et al., 2001). Income inequalities across countries could also dictate wide differences in food consumption patterns, which explain why availability and accessibility, over space and time, to sufficient nutrition for healthy and active life is necessary to ensure global food and nutrition security as noted by Ogundari (2014). Arcand (2001) also noted that inadequate nutrition, especially calories that measures total energy supply could lead to loss in global annual growth of gross domestic product (GDP), which explain why combating malnutrition is not only an urgent task for humanitarian reasons, but also a critical component for economic development.[1]

According to Ogundari and Abdulai (2013), analysis of society wellbeing measured in terms of the response of nutrient intakes to income (i.e., nutrient-income elasticity) has attracted interest among researchers over the years. This is because knowledge of how nutrition responds to income is vital in the design of policies to combat malnutrition in poor countries and to improve diets in both rich and poor countries (Tiffin and Dawson, 2002). In respect of this, Honfoga and van den Boom (2003) noted that, estimates of the calorie-income elasticity are considered an important parameter both in the literature and in the policy arena. For example, calorie-income elasticity with small size could be an indication of limited scope for income enhancing economic policies; as such policies could not alone decrease malnutrition or poverty (Ogundari and Abdulai, 2013). The elasticity could also be use to gauge implicitly the health implications of increasing consumption of certain macronutrients, especially calorie at higher income levels (Salois et al., 2012).

As revealed by Salois et al., (2012), the calorie-income elasticity at higher income has always been used to monitor consumer health behavior. In view of this, studies have

[1] It is important to mention that majority of energy (calorie) supply is sourced from carbohydrate in SSA.

shown that the relationship between nutrition and per capita income is not linear as demonstrated by Ohri-vachaspati et al., (1998), Skoufias et al., (2009), Banks et al., (1997), and Salois et al., (2012). This is because, the non-linear relationship has always been used to cast light on consumer health implications of consumption of certain nutrients at higher income levels. For example, if calorie-income/fat-income elasticity shows no indication of decreasing at higher income is a signal for need for public health programs that would influence diets in a given population (Salois et al., 2012). In this context, at higher income levels, calorie-income elasticity estimates could help health and food policy analysts understand health implications of increase in consumption of calories in reference to diseases such as obesity and diabetes.

A review of the literature shows that a large number of studies have been used to raise policy discussion on the relationship between per capita nutrient supply and income across the globe (for detail see: Ogundari and Abdulai, 2013). But the debate on the relationship appears to be unresolved because of the wide range of elasticity estimates in the literature through which this study intends to contribute in a number of ways. **First**, it is very unlikely that country specific nutrient-income elasticities obtained from some countries where similar analysis has been carried at the national level in SSA, [such as the case in Nigeria by Ogundari and Nanseki (2014), Zimbabwe by Tiffin and Dawson (2002) and South Africa by Phiri and Dube (2014)] can be ensured or generalized at the regional level. **Second**, while most of the previous studies from the region focused on calorie as the single nutrient of interest, this study also considers protein and fat in recognition that calorie-income elasticity alone is not enough to guide policymakers.[2] **Third**, the present study focuses on macro analysis because it provides estimates that

[2] The present study follows priori literature that refers to calorie as nutrient to ease comparison of the present results with previous studies. Nevertheless, it is important to stress that calorie is a measure of total energy supply, while fat and protein are macronutrient supply. We thank reviewer for drawing our attention to this fact.

cannot only be generalized or vary at the macroeconomic level but also provide essential information that can be useful in making food and nutrition policy decisions at regional level in recognition of Salois *et al.,*' s (2012) argument.

Generally speaking, the aim of the study is to examine how per capita nutrient supply responds to per capita income at cross-country level in SSA. This is very useful in understanding regional consumption behavior represented by the nutrient-income elasticity. In addition, it could be use to deduce whether effective income-mediated policies are necessary to enhance welfare proxy by nutrient supply and to be able to understand health implications of increase in consumption of certain nutrients such as calories and fats as income rises in the region.

Our empirical findings however, show that the response of per capita nutrient supply to per capita income (defined in terms of nutrient-income elasticities) is significantly positive but very modest (small) judging by the size of the estimated elasticities. Specifically, the results show that a 10% increase in income will lead to about a 0.90%, 0.87%, and 0.73% rise in fats, proteins and calories supply, respectively in the region. The relationship between calorie and protein-income was found to be non linear at higher income. Nevertheless, further analysis shows that the results of both calorie and protein-income elasticities are significantly lower (i.e., diminished) at higher per capita incomes in the study.

The rest of the paper is organized as follows. The next section focuses on the data used for the analysis and analytical model, while section 3 present the results and discussion. Concluding remarks are provided in section 4.

3.0. **Methodology**

3.1 **Data**

The study employs annual time series that yields balanced panel data of 1505 observations for 43 sub Saharan African (SSA) countries for which data was available covering 1975-2009. The aggregated data on per capita nutrient supply [e.g., calories, proteins and fats] was obtained from the national food balance sheet of the Food and Agriculture Organization (FAO) database (FAOSTAT, 2013), while data on real per capita Gross Domestic Product–GDP adjusted purchasing power parity [PPP] at the 2005$ constant price per annum was taken from the Penn World Table [PWT] database (PWT 2013).[3] The data used for the empirical analyses are expressed in logarithms to ease interpretation of the results as elasticities.

The summary statistics containing the mean and standard deviation of the daily per capita calories, proteins, fats, and GDP adjusted PPP used in the analysis are presented in Table 1.

In order to ensure that the results are robust so as to make efficient reference for policy from the empirical findings, we investigate the time series property of the data using different panel unit root tests in the study. To this end, a varieties of panel unit root tests were carried out on the variables, which is presented in Table 1A of the appendix. Among the tests that assumes common unit root process, Breitung (Breitung 2000), Harris (Harris and Tzaralis 1999), and Hadris (Hadris 2000) test statistics show strong evidence that the variables are non-stationary at level but become stationary with first differences. Also, among the tests that assume individual unit root processes in the study, IPS (Im et al., 2003) indicates strong evidence that the variables are non-

[3] We employ PPP adjusted GDP because it eases international comparison of economic variables across countries.

stationary in levels, but stationary in first differences. The table also shows that LLU (Levin et al, 2002) and CADF (Pesaran, 2007) test statistics gave mixed results. For example, under the LLU test, calorie and protein intakes were found to be stationary at level, while calorie intakes were found to be stationary at level under CADF test.
Since four out of the six test statistics strongly indicate unit root at the level across the variables, we conclude that the series are integrated of order 1.

<----------------TABLE 1 HERE------------>

3.2. **Analytical model**

Aggregate Engel curve: Response of per capita nutrient supply to income

The study of how nutrient intakes responds to income is in the recognition that knowledge of nutrient-income elasticities is critical in the design of policies to combat malnutrition in poor countries (Salois et al., 2012; Ogundari and Abdulai, 2013). Conversely, it is a common and well-accepted practice for researchers to investigate the relationship between per capita nutrient intakes and income under the implicit assumption of a linear relationship. But, in line with the objective of the study, we first investigate the relationship using non-parametric plots following the previous studies such as Salois et al., (2012) and Abdulai and Aubert (2004). The plot is very useful in deducing whether the relationship is non-linear or not. Subsequently, we employ the econometric (panel regression) approach to further cast light on how per capita nutrient supply responds to per capita income in the study.

According to Ogundari and Abdulai (2013), the presence of nonlinearity often characterizes the nutrient-income relationship, as also demonstrated in many empirical studies (see for detail, Banks et al, 2007; Skoufias et al., 2009; Salois et al., 2012). Based on this, the present study relaxes the implicit linear assumption by modeling the response of nutrient supply to changes in per capita income using both the linear and nonlinear specifications, while providing appropriate econometric tests to investigate which functional form best fit the data for the study across the selected nutrients (i.e., calories, proteins and fats). Since linear and quadratic specifications of the relationship between nutrient supply and per capita income are nested in cubic specification, we specify the cubic functional relationship within the framework of aggregate Engel Curve for the study[4]. The choice of Engel curve is motivated by the fact that previous studies have shown that large changes in consumption patterns create difficulties in choosing appropriate weights for food prices (Dawson, 1997; Tiffin and Dawson, 2002). Besides, inclusion of weighted price index in previous studies is significantly not different from zero, which motivated many authors to estimate parsimonious Engel curve with real per capita GDP as sole determinants of calorie intakes (for detail see: Dawson, 1997; Tiffin and Dawson, 2002; Mustaq et al., 2007). Given this, the effect of income on nutrient supply at macro level has always been assessed also using an aggregate Engel curve framework in the literature (see for detail: Dawson, 1997; Tiffin and Dawson, 2002; Mustaq et al., 2007;Salois et al., 2012 Ogundari and Nanseki, 2014; Phiri and Dube, 2014). Thus, the study estimates the respond of nutrient supply to income using cubic-specification, which is specified below

$$NT_{i,t} = \phi_{1i} y_{i,t} + \phi_{2i} y_{i,t}^2 + \phi_{3i} y_{i,t}^3 + \tau_i + \mu_t + \varepsilon_{i,t} \qquad \textit{for } t=1,...T,\ i=1,...N \qquad 1$$

[4] An Engel curve describes how consumer-spending behavior varies with income level, holding prices fixed.

$NT_{i,t}$ represents per capita nutrient supply for i country at time t, which includes calories, protein and fats; $y_{i,t}$ represents per capita income for i country at time t; τ_i represents country specific fixed effect; μ_t represents time specific fixed effect; ϕ is the parameters to be estimated while $\varepsilon_{i,t}$ is the error term of the regression with $\varepsilon_{i,t} \sim N\left(0,\sigma^2\right)$.

The nutrient-income elasticity from the cubic functional form can be computed using the expression below:

$$Nutrient - elasticity = \phi_1 + 2\phi_2\left[\overline{y_t}\right] + 3\phi_3\left[\overline{y_t}\right]^2 \qquad 2$$

where, $\overline{y_t}$ is the mean of per capita income across the period. Thus, in reference to equations 1 and 2, if $\phi_2 = \phi_3 = 0$ and $\phi_3 = 0$, it implies that linear and quadratic are best-fit functional forms, respectively, for the data rather than the cubic specification in the study.

Given the data generating process (DGP) of the time series nature of the balanced panel data used in the study, we perform Hausman test to ascertain which of the panel model best fit the data by comparing the random effect and fixed effect model. Thus, the results are presented in Table 2 with p-value less than 0.100, which is an indication that the differences between the random effect and fixed-effect coefficients are systematic with fixed effect model consistent across the data in the study. Also, another major problem associated with empirical analysis of equation 1 is the possible serial correlation between error terms across the period in the respective equations, which may likely bias the estimated parameters (Baltagi, 2001). Based on this, we perform the test for serial correlation between the error terms across the period using Wooldridge (2002) test statistic, which is also presented in Table 2. With p-value less than 0.001 from the test statistics across various specifications and nutrients considered, the results show that the null hypothesis of cross-sectional independence is strongly rejected.

Conversely, following the suggestion of Baitaigi (2001), we employ Feasible Generalized Least Square (FGLS) model that is robust to autocorrelation and cross-sectional contemporaneous correlation to estimate the parameters of equation 1 in the study. Subsequently, we perform an F-test for the FGLS two-way fixed effect model vs. FGLS one-way fixed effect model and the result yields a p-value of 0.000 across all the nutrients considred. This however, shows that both country and time fixed effect are significantly different from zero in the data. Based on this, the study employs FGLS two-fixed model for the empirical analysis of equation 1.

<----------------TABLE 2 HERE------------>

4.0. **Results and discussion**

Nutrient –income elasticities

The discussion on the relationship between per capita nutrient supply and per capita income in the study starts with the results of non-parametric plots presented in Figures 1-2. The non-parametric plots show that per capita nutrient responds to income to give an inverted U-shape, especially for calorie-income. This, however, is consistent with the argument in the literature that the relationship between calorie-income is non-linear. The non-monotonicity of the response of per capita calorie supply to changes in income suggests that as income rises, a percentage increase in income is likely to give different percentage changes in calorie supply in the region.

-----------<Figures HERE 1-2>------------

We explore further the nutrient-income relationship using regression approach with necessary tests carried out to ascertain the best-fit functional form for the data. In this respect, estimated parameters for the various functional specifications are presented in Table B of the appendix, while estimated elasticities used in the subsequent discussion are presented in Table 3 with preferred elasticities being the one in bold. To this end, we find that quadratic, cubic, and linear specifications represent the best-fit functional forms for calorie-income, protein-income and fats-income relationships, respectively in the study. [5] The result of calorie is consistent with the earlier result of the non-parametric plots that non-linear relationship characterized calorie-income nexus in the study. This indicates that per capita rise in income give rise to different calories supply. However, a look at the literature shows that the non-linear relationship between calorie-income and protein-income in the present study contradicts the work of Salois et al., (2012) who found a linear relationship for these nutrients. The differences between the present finding and that of Salois et al (2012) in particular can be linked to the fact that our sample is narrower since its focuses on SSA countries, while the authors' is broader, as it contains sample from both the developed and developing countries.

Conditional on the best-fit functional form, the estimated nutrient-elasticities show that the response of fat supply to income has the highest elasticity of about 0.090, followed by protein [0.087] and calories [0.073] as shown in Table 3. The implication of this is that, a 10% increase in income will lead to about a 0.90%, 0.87%, and 0.73% rise in fats, proteins and calories supply, respectively in the region. However, a look at the literature shows that the estimates, especially the calorie-income elasticity in the present

[5] Using F-statistics test, the results show that the most preferred specification for the response of nutrient intakes to changes in income vary significantly across the selected nutrients in the study.

study, are lower than the country specific results obtained at the macroeconomic level in some SSA countries. For example, Tiffin and Dawson (2002) obtained 0.35 from Zimbabwe, 0.33 from Nigeria by Ogundari and Nanseki (2014) and 0.15 from South Africa by Phiri and Dube (2014).[6] Also, the estimated calorie, protein and fat income elasticities are lower than the estimates obtained by similar cross-country studies for both the developed and developing countries, such as Salois et al., (2012). In a related development, we observe that the estimated calorie-income elasticity is higher than the estimate obtained by Dawson (1997) that employed cross-country data to analyse impact of per capita income, Gini-coefficient, and urbanization among others on calorie supply in developing countries. The differences in the findings between the present results and the results reported by Salois et al., (2012) and Dawson (1997) can be attributed to the fact that these studies contained a broader country sample beyond SSA, which is the focus of the present study.

From the viewpoint of the policy-makers responsible for the long-term food policy decision to combat malnutrition in the society, the estimated nutrient elasticities in the present study are very modest in size (or small). The implication of this is that income enhancing economic growth policies could not alone decrease malnutrition or poverty but likely to alleviate malnutrition to a limited extent in SSA. In other words, attempt to improve nutrition in SSA countries cannot be confided to income growth only. Consequently, the joint influences of food prices, household demographic distributions, and household income have been identified as factors likely to enhance nutrient intakes in the literature by Abduali and Aubert (2004).

[6] But as noted by Salois et al., (2012), studies using aggregate data tend to obtain smaller elasticities than those using micro-level data.

Looking at the role played by a non-linear specification of the nutrient-income relationship in investigating whether nutrient supply may give different consumption patterns with increase in per capita income, we revisit health implications of increase in supply of certain macronutrients in the society, in particular calories, at higher income level in the study. In this respect, we test whether calorie-income with best fit quadratic specification and protein-income relationship with best fit cubic specification exhibit significant diminishing elasticities judging by the sign and significance of the second and third order term in the respective specifications. This is very important because, if nutrient-income elasticity estimates, especially that of calorie supply, shows no indication of decreasing at higher income, then it displays that there is need for public health programs that can influence diets of the populace (Salois et al., 2012). Guided by this, the results of the present study show that both calorie and protein-income relationships exhibit diminishing elasticities at higher incomes. The implication of this is that calorie supply at higher income is less likely to exacerbate problem of diseases such as obesity epidemic at cross-country level in SSA.

<----------------TABLE 3 HERE------------>

5.0. **Concluding remarks**

The study examined the response of per capita nutrient supply to income, which cumulates into nutrient-income elasticities estimates from SSA. The empirical analysis was based on annual time series that yields balanced panel data covering 1975-2009 from 43 countries.

The result of the relationship between nutrient supply and income was found to be non-linear for calories and protein but linear for fats. In addition, the response of per capita nutrient intakes to income (i.e., nutrient-income elasticities) is significantly positive but very modest (small) judging by the estimated elasticities. The implication of this is that policies such as income growth aimed at enhancing economic growth, may be insufficient at improving nutrition but likely to alleviate malnutrition to a limited extent in SSA. Other results show that estimated calorie-income and protein-income elasticities are significantly lower at higher incomes, which thus suggests that calorie supply at higher income is less likely to exacerbate problem of diseases such as obesity epidemic at cross country level in SSA.

We acknowledge the limitations associated with the data used in the study, especially the use of per capita GDP as proxy for income remains a complex issue, the use of FAO data for dietary intake viewed to be elusive, may underestimate the nutrient elasticity and aggregate nutrient supply in the study denotes the average availability of per capita food produce and import, which may not reflect actual food consumption. Nevertheless, we believe the results of the findings conform to the previous studies on the nutrient-income relationship, especially at macroeconomic level and perhaps similar studies carried out at micro level across the globe.

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TABLES

Table1: summary statistics of variables

Variable	*Variable description*	*Mean*	*Std. Deviation*
CALORIE	Per capita in kilocalorie	2192.93	308.05
PROTEIN	Per capita in gram	55.35	11.84
FAT	Per capita in gram	46.55	15.03
GDP [Income]	Per capita in PPP	2228.83	3616.19

Table 2: Results of Hausman and Wooldridge tests

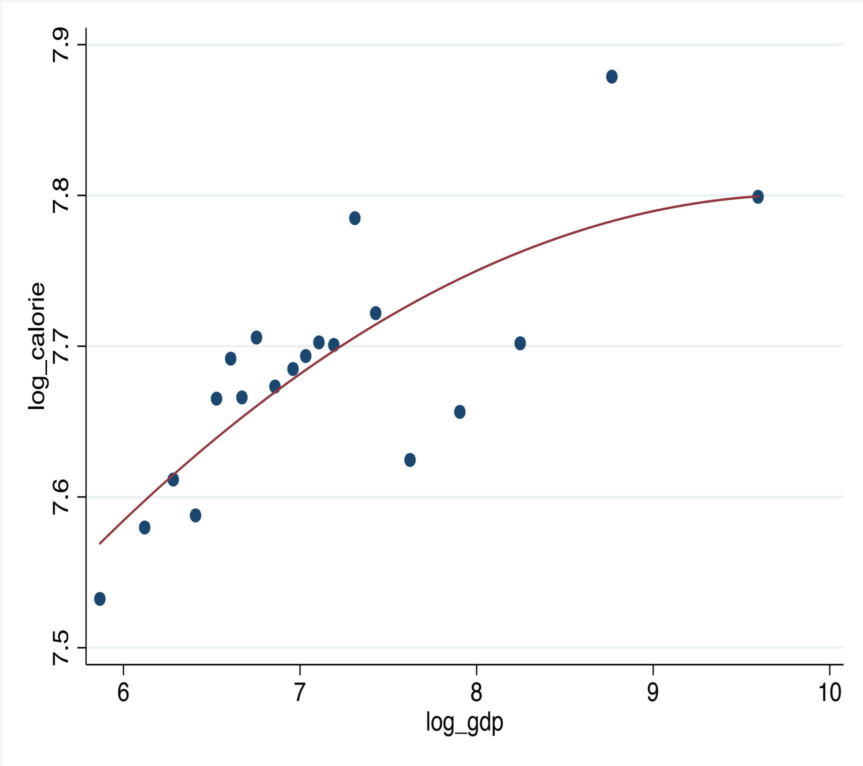
Various tests	Calorie-income	Protein-income	Fat-income
	Linear Specification		
Hausman [p-value]	0.002	0.034	0.078
Wooldridge [p-value]	0.000	0.000	0.000
	Quadratic Specification		
Hausman [p-value]	0.051	0.086	0.014
Wooldridge [p-value]	0.000	0.000	0.000
	Cubic Specification		
Hausman [p-value]	0.056	0.091	0.035
Wooldridge [p-value]	0.000	0.000	0.000

Table 3: Computed Nutrient-Income elasticities across functional forms

Functional Forms	*Calories-Income*	*Proteins-Income*	*Fats-Income*
Linear Functional form	0.0679*** [0.0026]	0.0875*** [0.0029]	**0.0900*** [0.0064]**
Quadratic Functional form	**0.0729*** [0.0024]**	0.0869*** [0.0030]	0.0929*** [0.0065]
Cubic Functional form	0.0733*** [0.0025]	**0.0873*** [0.0030]**	0.0995*** [0.0067]

*Figure in parenthesis represents standard error of the estimates; ***, **, and * imply significance at 1%, 5%, and 10%, respectively. Bold estimates correspond to the elasticities with best-fit functional form.*

FIGURES



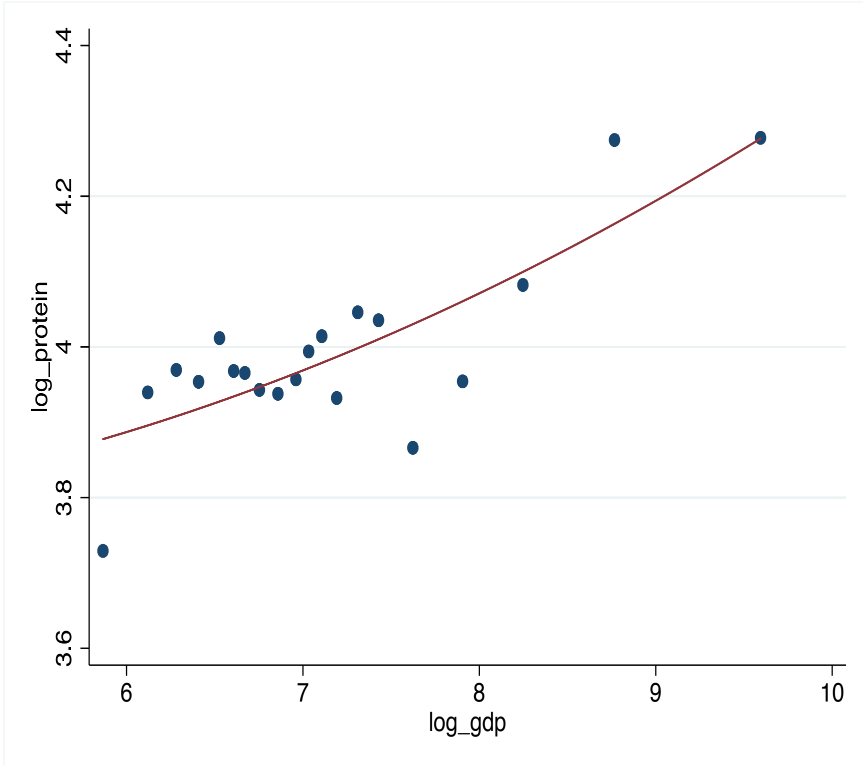


Figure 1: Log calorie supply vs. Log of income-GDP (LHS) and Log protein supply vs. Log of income-GDP (RHS)

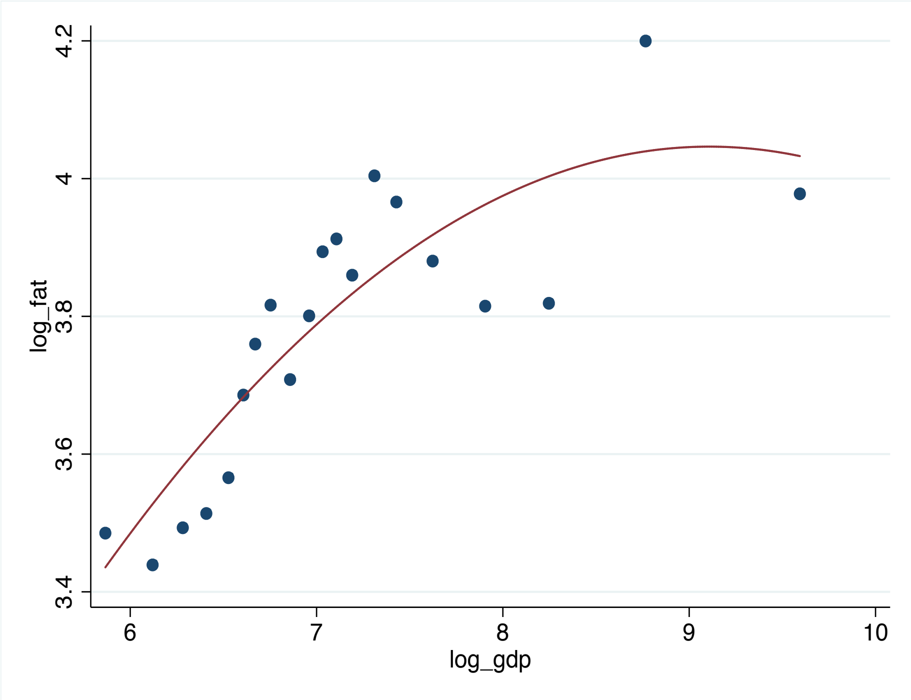


Figure 2: Log fat supply vs. Log of income-GDP

APPENDIX

Table 1A: Panel Unit Root Tests Statistics

Variables	Assume a common unit root				Assume individual Unit root	
	LLU H_0: Unit Root	Breitung H_0: Unit Root	Harris H_0: Unit Root	Hadri H_0: Stationary	IPS H_0: Unit Root	CADF H_0: Unit Root
	t-stat. [p-value]	t-stat. [p-value]	z-stat. [p-value]	z-stat. [p-value]	w-t-bar: stat. [p-value]	z:stat. [p-value]
	VARIABLE IN LEVEL					
CALORIE	-1.8432** [0.0326]	1.5404 [0.9383]	1.0285 [0.8481]	104.3753*** [0.0000]	0.5062 [0.6936]	-1.6240** [0.0520]
PROTEIN	-1.6508** [0.0494]	1.2573 [0.8957]	-0.6156 [0.2691]	97.1805*** [0.0000]	0.4299 [0.6663]	-0.4800 [0.3160]
FAT	-0.9155 [0.1800]	-0.7773 [0.2185]	-2.2940 [0.1109]	84.5192*** [0.0000]	0.1396 [0.5555]	-2.2640*** [0.0120]
GDP	0.6646 [0.7469]	1.9254 [0.9729]	1.9424 [0.9740]	96.6114*** [0.0000]	3.0239 [0.9988]	2.3600 [0.9910]
	VARIABLE IN FIRST DIFFRENCE					
CALORIE	-17.5431*** [0.0000]	-11.8565*** [0.0000]	-79.2613*** [0.0000]	-0.4244 [0.6636]	-20.3898*** [0.0000]	-15.5650*** [0.0000]
PROTEIN	-18.8083*** [0.0000]	-11.9336*** [0.0000]	-76.7923*** [0.0000]	-1.2744 [0.8987]	-21.0212*** [0.0000]	-17.8220*** [0.0000]
FAT	-18.6676*** [0.0000]	-14.1142*** [0.0000]	-76.1749*** [0.0000]	-1.7450 [0.9595]	-21.5531*** [0.0000]	-17.887*** [0.0000]
GDP	-16.5253*** [0.0000]	-9.9589*** [0.0000]	-66.3772*** [0.0000]	3.0091 [0.1301]	-18.6668*** [0.0000]	-15.1640*** [0.0000]

Notes: The results were estimated using "xtunitroot" command with exception of CADF, which estimated using "pescadf" command in "stata".
With exception of CADF that represents second-generation panel unit root, the rest of the statistics represent first-generation panel unit root tests.
There is no deterministic trend in the estimates, while maximum lag of one based on the AIC criteria was selected.
*Figure in parenthesis represents p-value as ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.*

Table B: Functional response of nutrient supply/available to per capita income across different functional specification in SSA

Variables	**Linear functional form**			**Quadratic functional form**			**Cubic functional form**		
	Calories	*Proteins*	*Fats*	*Calories*	*Proteins*	*Fats*	*Calories*	*Proteins*	*Fats*
Income	0.0679*** [0.0026]	0.0875*** [0.0029]	0.0900*** [0.0064]	0.2903*** [0.0197]	0.1042*** [0.0280]	0.1767*** [0.0527]	0.1638 [0.1249]	-0.3109* [0.1769]	-1.8409*** [0.3771]
$[\text{Income}]^2$	-	-	-	-0.0152*** [0.0013]	-0.0012 [0.0019]	-0.0059* [0.0036]	0.0021 [0.0169]	0.0559** [0.0239]	0.2694*** [0.0503]
$[\text{Income}]^3$	-	-	-	-	-	-	-0.0008 [0.0008]	-0.0026** [0.0011]	-0.0123*** [0.0022]
Constant	7.1497*** [0.0189]	3.3241*** [0.0214]	3.0325*** [0.0466]	6.3461*** [0.0728]	3.2674*** [0.1016]	2.7159*** [0.1934]	6.6485*** [0.3024]	4.2573** [0.4309]	7.5563*** [0.9324]
Cross section included	43	43	43	43	43	43	43	43	43
Time period	35	35	35	35	35	35	35	35	35
Time fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES
Autocorrelation	AR (1)	AR (1)	AR (1)	AR (1)	AR (1)	AR (1)	AR (1)	AR (1)	AR (1)

*Figure in parenthesis represents standard error of the estimates; ***, **, and * imply significance at 1%, 5%, and 10%, respectively.*