Identification and Estimation of Quadratic Food Engel Curves: Evidence from Cameroon

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Abstract

In this paper we estimate quadratic food Engel curves using data from the 2001, 2007 and 2014 Cameroon household consumption surveys. To address potential mismeasurement of regressors, we employ the heteroscedasticity-based identification strategy. Exploratory non-parametric analyses suggest quadratic forms for the food Engel curves. The regression results in this study confirm these patterns. At lower spending levels, unit increases in total spending increase the food budget share, while at levels above the spending thresholds, unit increases in total spending reduce the food budget share. We also find evidence of major shifts in the quadratic food Engel curves over time. These findings suggest that reducing taxes on food items would be more beneficial to poor households.

Key words: Quadratic food Engel curve, Foodshare, Non-parametric, Heteroscedasticity, Cameroon

1. Introduction

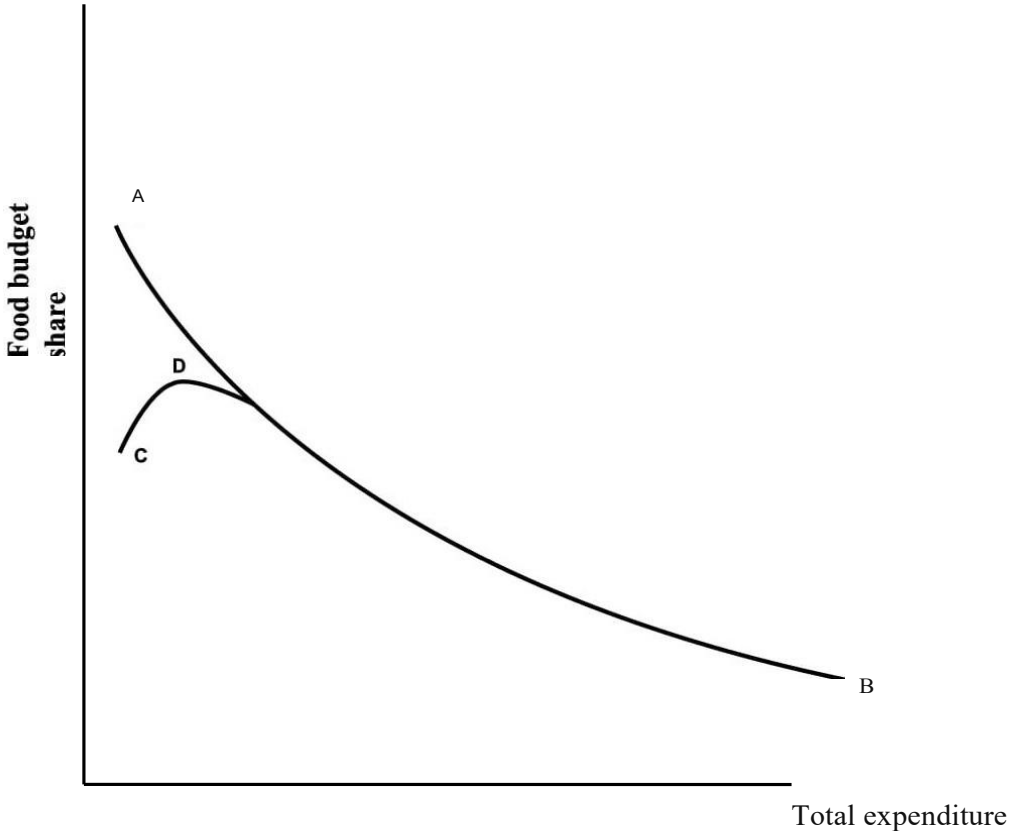
Household expenditure is an essential element of aggregate demand when modelling household consumption behaviour. The major components of household expenditure are food and non-food, with clothing, education, housing and fuel as the key components of non-food spending. Household food expenditure is a very important component of household total expenditure. On average, food expenditure accounts for about 50% of the total expenditure of households in low-income countries (USDA, 2011). Deaton (2018) indicates that the essential role of food expenditure in gauging household levels of welfare is evident from its huge share in the household total budget among underprivileged households. Zereyesus et al. (2017) corroborate this claim by indicating that resource-poor households in Northern Ghana spend 66%, of on average, of their expenditure on food.

Therefore, the share of household food expenditure can be used as an essential measure in gauging household welfare. The link between food expenditure and income was first studied empirically by Engel (1857), a German statistician. He observed that the income elasticity of demand for food was relatively low; an observation that became the basis of the famous Engel law. Engel's law stipulates that *as the income of a household increases, the proportion of the income devoted to basic necessities such as food decreases*, stating that the elasticity for food is always positive but less than one. In this context, if Engel's law is verified, poorer households will be vulnerable to price shocks. That is, poorer households are likely to witness greater welfare losses from food price hikes as food constitutes a greater portion of their budget, and these poor households have fewer substitution options (Wood et al., 2009). Robles and Keefe (2011) use data from Guatemala to corroborate this view by observing that households in rural settings were more vulnerable to food price shocks compared to their urban counterparts.

Household responses to income changes in terms of food budget shares are useful to both economists and policy stakeholders. It is an essential element in designing tax and transfer policies (Deaton, 1992; Jappelli and Pistaferri, 2010). In developing countries, it can inform the design of consumption support policies and other targeted interventions (Luseno et al., 2014; Fenn et al., 2015). A key reason for the importance of such responses is that they provide information about the potential sources of possible poverty traps. If households show a strong response to income changes in terms of food consumption, a nutrition-based poverty trap is plausible (Banerjee and Duflo, 2011; Schofield, 2014). Kedir and Girma (2007) also confirm that the Engel curve is an essential tool in understanding welfare dynamics.

The food insecurity status of a household is likely to be linked to the budget the household devotes to food consumption. High income households are expected to spend a low proportion of their income on food, which is usually greater than the minimum amount needed for a nutritious and healthy diet. Conversely, households with limited resources devote a greater share of their income to food, which would usually be less than the minimum amount required for a nutritious and healthy diet, leading to forms of food insecurity such as reduced food intake and disrupted eating patterns. Therefore, the amount of income spent on food by a household can provide an insight into the household's food security status. This suggests an Engel curve depicting a negative relationship between the household food budget share (proportion of income allocated to food) and household total expenditure (proxy for income), as illustrated by the AB curve in Figure 1.

Figure 1: Two possible Engel curves



Source: Adapted from Edirisinghe(1987)

However, researchers have raised the possibility that ultra-poor households are likely to defy this standard Engel relationship (Edirisinghe, 1987). This defiance is illustrated by the CDB curve in Figure 1. The implication of this behaviour for abjectly poor households is that, following a positive income shock, they are likely to first

increase household food spending, leading to an increase in the proportion of income devoted to food up to a saturation point, beyond which the standard Engel relationship starts to manifest. These turning points can be used to define poverty lines.

Grigg (1994) provides a plausible explanation for the defiance of the standard Engel relationship. First, ultra-poor households, unable to meet their nutritional requirements, usually devote almost all of their additional income to food. Second, with a growth in income, households are likely to shift from cheap staples to costly food items like eggs, milk, fish and meat. Such shifts among households at the lower tail of the income distribution are likely to be minimal. Even if such shifts in preferences occur, they do not explain why the food share begins to relate inversely to income after point D in Figure 1. These possibilities suggest the likelihood of quadratic food Engel curves for developing countries. Identifying the positive segment of the Engel curve is important for food security, as well as other welfare policies. Households with total spending within this segment are likely to be those highly in need of targeted social welfare interventions, such as cash transfers or work-for-cash public works programmes.

Most earlier empirical studies used the Working-Leser specification in which food shares are perceived as a linear function of total expenditure (Leser, 1963; Deaton and Muellbauer, 1980). This linear functional form of the Engel curve cannot depict the positive segment of the Engel curve, which can be used in identifying the proportion of food-poor households that should be targeted through interventions such as conditional cash transfers. In the 1990s, a great body of empirical work provided evidence of non-linear Engel curves for non-food items (Lewbel, 1991; Hausman et al., 1995; Banks et al., 1997). Empirical work on non-linear food Engel curves is still minimal. The few studies that have endeavoured to model and estimate quadratic food Engel curves in developing countries include Bhalotra and Attfield (1998) for Pakistan, Kedir and Girma (2007) for Ethiopia, and Moss et al. (2016) and Nsabimana et al. (2020) for Rwanda. To the best of our knowledge, no published work has estimated quadratic food Engel curves using Cameroonian data.

Quadratic food Engel curves may have important implications for the design of tax policies. For example, a higher tax on food items compared to non-food items implies that a higher proportion of the tax burden is borne by low-income households. The formulation of government tax and transfer policies relies on the nature of the Engel curve to a great extent (Deaton and Muellbauer, 1980; Blundell, Duncan and Pendakur, 1998; Banks, Blundell and Lewbel, 1997). Within this, a wrong specification of the Engel food curve is likely to limit its usefulness by generating misleading policy advice. The curvature of the Engel food curve is likely to be important for countries such as Cameroon, where a significant percentage of households still have subsistence income levels. Since the 2008 food crisis, the Government of Cameroon has implemented policies aimed at reducing import taxes on food items such as rice, flour and fish. Also, little attention has been devoted to the evolution of Engel food curves over time. This is surprising as the shifts in food Engel curves over time, even during periods of stable prices, are likely to provide researchers and political entrepreneurs with

essential information on changes in household welfare. Thus, estimating Engel food curves over time is expected to empirically contribute to the research on household consumption behaviour.

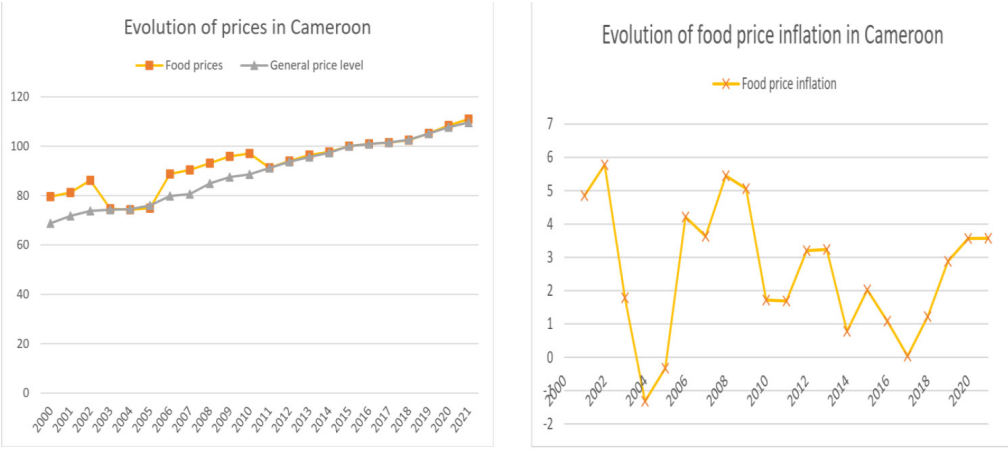
This study contributes to the empirical literature by estimating quadratic Engel food curves over time, which can be key inputs into public policy debates on household welfare and food security. Based on this, the research questions that need to be addressed are: (i) What is the nature of Engel food curves using data from the three most recent waves of Cameroon household consumption surveys?; and (ii) What income range defines the turning points of the Engel food curves, if any? The objectives of the study are to: (i) examine the nature of Engel food curves; and (ii) explore the income range defining the turning points of Engel food curves, if any. To address these issues, the study uses the 2001, 2007 and 2014 Cameroon household consumption surveys data, and an augmented heteroscedasticity-based identification strategy.

The rest of the paper is organized as follows: Section 2 presents the background to the Cameroon economy, while Section 3 reviews empirical studies on the Engel food curve. Section 4 outlines the theoretical framework and the modelling strategy adopted for the study. Section 5 looks at the data. Section 6 presents and discusses the empirical findings, and Section 7 presents the conclusion and policy implications.

2. Background Information on the Cameroon Economy

In the past 20 years, the economy of Cameroon has witnessed several shocks, including price rises in essential household expenditure items that reduced the purchasing power of households. The increase in the general price level is predominantly driven by the increase in the prices of food items. The soaring prices of food items appear to be higher than the increase in the general price level, as shown in Figure 2. This figure also shows great volatility in food price inflation over the period 2000–2021. In a country where the food budget share is over 50%, rising food prices have detrimental food security implications. The current global price inflation of almost all food items affects several developing countries, including Cameroon, that rely on food imports.

Figure 2: Evolution of prices in Cameroon, 2000–2021



Source: Author, using data from Food and Agriculture Organization of the United Nations. (2022) .

In 2002, annual food price inflation stood at about 5.8%. This spike in the prices of food items can be attributed to the depreciation of the exchange rate. The depreciation of the exchange rate is expected to have been the cause of food price inflation based on the idea that in Cameroon, most food items, such as wheat, vegetable oil and rice, are mainly imported. Real exchange rate depreciation increases the prices of food

items by increasing the cost of importing food items and, equally, the cost of importing fertilizer and other finished products relating to agricultural commodities, leading to rising domestic market prices. This was coupled with the high local prices of grains following a poor harvest. Prices stabilized later in 2003 as a result of the appreciation of the FCFA/USD, and we observe a sharp drop in food price inflation, only for it to regain momentum in 2005.

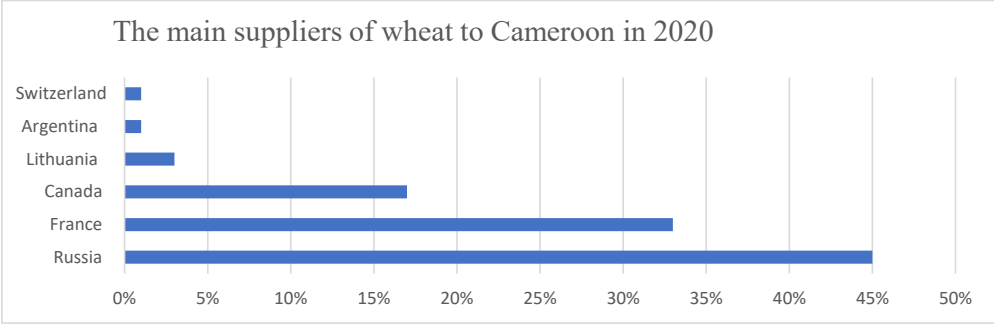
Another significant peak in food price inflation is observed in 2008, which corresponds to the 2008 food crisis. At the time, Cameroon was one of the countries in the world that were greatly affected by soaring food prices in world markets. This crisis was so damaging because it led to social unrest as the food security of households was threatened. Similar to the prevailing inflation in almost all global regions, the 2008 food price hike was mainly due to the "spike" in international commodity prices that led to price increases of almost 80% between early 2006 and mid-2008, before dropping sharply in 2009 (Davidson et al., 2012). Cameroon was seriously affected because the majority of Cameroon's imports consist of rice, frozen fish and wheat flour. The famous February 2008 riot in Cameroon indicates the damaging effects of price hikes. As a response to this riot, the Government of Cameroon put in place policies aimed at increasing the purchasing power of households. In particular, the Government of Cameroon slashed customs duties on basic necessities such as rice, wheat flour and fish, and the prices of petroleum products were reduced at the pump.

Following these measures, food price inflation in Cameroon decreased from 2009 to 2011, but did not return to the level observed in 2004. From 2011 to 2021, there was a similar and continuous rise in the general price level and food prices in Cameroon. However, the evolution of food price inflation appears to be very volatile. Food price inflation was perceived to have moved from an average of 1.7% in 2011 to an average of 3.2% in 2013, then decreasing in 2014. Another interesting episode of food price inflation in Cameroon occurred in the period 2017–2021. We observe a continuous rise in food price inflation in Cameroon: food price inflation rose from about 0.04% in 2017 to an average rate of about 3.6% in 2021. Multiple factors can be attributed to this continuous rise in food inflation in Cameroon. According to the Institute Nationale des Statistiques du Cameroun [INS] (2022a), the continuous increase in prices of local food items could be attributed to the contraction in supply resulting from the Anglophone crisis that affected the English-speaking regions of Cameroon, climate change and the disruption in market supply chains due to the COVID-19 pandemic. Regarding the increase in prices of imported products, the persistent increase can mainly be attributed to the disruption caused by the pandemic, particularly the restriction of imports, the energy crisis and the increase in maritime transport costs.

The Russia-Ukraine crisis has led to financial sanctions and embargoes on Russia, which is expected to result in an import reduction from Russia and Ukraine, and soaring commodity prices across the globe. According to the INS (2022b), the Cameroon-Russia trade balance recorded a deficit of FCFA96.5 billion in 2020, following FCFA84.3 billion in 2019, an increase of 14%. With regard to global trade, the Russian Federation ranks

14th among Cameroon's trading partners in 2020. It ranks 8th in imports and 74th in exports. Over the period 2018–2021, the main imported goods to Cameroon from Russia were wheat flour and fertilizer. Russia contributes about 45% and 43% to the total import of wheat and fertilizer, respectively, and as such Russia is the main supplier of these products to Cameroon. Figure 3 illustrates the main suppliers of wheat flour to Cameroon, with Russia as the main supplier.

Figure 3: Main suppliers of wheat to Cameroon, 2020



Source: Authors using data from INS (2022b).

According to the INS (2022b), the Cameroon-Ukraine trade balance increased by 60% in 2020, amounting to FCFA64.1 billion against FCFA40.1 billion registered in 2019. As of 2020, Ukraine was ranked the 19th largest trading country with Cameroon. Regarding imports, Ukraine occupies the 15th position while in exports, it occupies the 93rd position. Iron and steel are the main products imported from Ukraine, constituting about 95% of imports.

The Russia-Ukraine armed conflict is already disrupting the supply chains of products to Cameroon, and is expected to lead to increases in import costs and, therefore, increased inflationary pressures in general on products from these two countries, specifically wheat flour and its by-products (such as bread and pasta), fertilizers and certain building materials.

3. Literature Review

Most studies on cross-sectional Engel curves have been based on the Working-Leser log-linear model, in which household food budget is expected to be a linear function of total expenditure (Leser, 1963; Deaton and Muellbauer, 1980). Some later works by Hausman et al. (1995), Lewbel (1991), Byrne et al. (1996) and Blundell et al. (1998) indicate that the quadratic specification of the Engel curve for non-food items is important. However, studies that estimate quadratic food Engel curves, especially for developing countries, are limited. In the following discussion, we look at documented research on food Engel curves. The review was carried out at the global level, followed by a focus on Africa and then Cameroon.

Using household consumption data, Hoyos and Lessem (2008) employed a quadratic specification to estimate food Engel curves for different regions. The results revealed that in East Asia (EAP) and Eastern Europe (ECA), per capita consumption and food share were negatively related at all consumption levels. For Latin America (LAC), South Asia (SAS), and sub-Saharan Africa (SSA), the relationship between per capita consumption and food share is quadratic: positive for low expenditure levels and negative for high expenditure levels.

Using Bangladeshi data, Hasan (2016) estimated Engel curves for some of the main expenditure categories, including food, with a focus on their specifications. Insights from a semi-parametric analysis reveal a quadratic food Engel curve, thereby providing additional support for the existence of quadratic food Engel curves for developing countries. Angelucci and Attanasio (2013) assessed the effect of conditional cash transfer (CCT) programmes in Mexico (PROGRESA/Oportunidades) on household food budget shares. The results from this study indicated that: (i) demand changes over time in areas where the programme had been implemented, but not in control areas; and (ii) the treatment effects on food and high-protein food consumption were found to be larger than the prediction of baseline Engel curves.

In Columbia, Attanasio et al. (2012) examined the food Engel curve among the poor that benefited from a conditional cash transfer. Findings from this study suggested that a 10% increase in consumption leads to a 1% decrease in food share. Schady and Rosero (2008) used a randomized control trial to analyze the effect of unconditional cash transfers to poor women in rural Ecuador on the food Engel curve share. Results from this study indicated that households in the treatment group witnessed significantly higher food budget shares compared to households in the control group.

For Pakistan, Bhalotra and Attfield (1998) estimated semi-parametric Engel curves for rural Pakistani households. The results of the semi-parametric analysis provided empirical evidence of a quadratic food Engel curve.

Concerning empirical works in Africa, Nsabimana et al. (2020) used the Rwanda household expenditures and demographic survey to estimate quadratic food Engel curves. The findings from their study indicate that, in a rural setting, the food Engel curve is quadratic in nature, while in an urban setting the empirical findings depicted a linear food Engel curve. Almås et al. (2019) examined the effect of large income changes on food budget shares among rural poor households in Kenya using data from a randomized controlled trial delivering unconditional cash transfers to poor households. They found expenditure and calorie elasticities of 0.78 and 0.60, respectively.

Moss et al. (2016) used Rwandan data and a quantile estimation technique to evaluate the distribution of food budget shares. The results of their study show that the food expenditure share was statistically different between provinces involved in growing coffee and those not involved in coffee cultivation. Using household budget data from 2008/2009 and 2010/2011 for Tanzania, Mbegalo and Yu (2016) quantitatively examined the welfare implications of rising food prices in rural Tanzania. To achieve this, they analyzed food Engel curves using a semi-parametric approach and found evidence of a quadratic parametric fit for food Engel curves. Using data from the 1994 Ethiopian urban household survey, Kedir and Girma (2007) estimated food Engel curves, accounting for measurement errors in household total expenditure and household food budget share. They found evidence of a quadratic relationship between household food budget share and household total expenditure.

Based on the empirical studies reviewed, it is clear that very few studies have attempted to estimate and identify quadratic food Engel curves in developing countries. The few empirical studies that are available confirm that quadratic food Engel curves are features of developing economies and are very useful in designing welfare policies. Despite the usefulness of quadratic Engel curves for public policy, to the best of our knowledge no published empirical study using Cameroon data has attempted to estimate quadratic food Engel curves over time. To fill the gap, this paper attempts to investigate the nature of Engel curves in Cameroon, while accounting for measurement errors in total expenditure, using the augmented heteroscedasticity-based identification strategy proposed by Lewbel (2012).

4. Theoretical Framework and Methodology

In this section, we present the analytical frameworks employed in the study and the empirical modelling underlying the methodology. In particular, the study presents a theoretical framework for the Engel curve and the modelling of quadratic Engel curves with mismeasured regressors.

4.1 Theoretical Framework of Engel Curve

The theory underpinning this study is the Engel curve. The Engel curve is a function that explains how household expenditure on a certain group of goods, such as food, varies with household income, all other things being equal. Mathematically, the Engel curve is expressed as:

$$E_i = f_i(y, m) \tag{1}$$

Where E_i represents the expenditure on good ii, yy denotes the household's income, which is usually proxied with total expenditure on goods and services, and m is the set of other correlates such as age and some demographic characteristics that are likely related to household expenditure on good ii.

Most often, the Engel curve is presented in terms of budget shares.

$$S_i = g_i[\mathrm{Ln}(y), m] \tag{2}$$

In the above equation, S_i represents the fraction of y that is spent on good i. These goods are usually aggregate commodities such as total food, clothing or transportation consumed over some weeks or months, rather than discrete purchases. Holding the prices of other goods constant, Engel curves can be defined as Marshallian demand functions.

The term Engel curve is also used to describe the empirical dependence of E_i on y, m within consumers sampled at a point in time (cross section). The empirical Engel curve is in line with the theoretical Engel curve if we assume the law of one price to hold. The law of one price entails that all consumers pay the same price for different

goods. For this to hold, all consumers are assumed to have the same preferences. However, in practice, it is vital to distinguish between these two definitions as this condition rarely holds.

This relationship between food expenditure and household income is well established as the Engel law, and has been found to hold in most economies and time periods, often with the function for food i close to linear in log(y). From Equation 1, Engel curves can be used to calculate a good's income elasticity, which is roughly the percent change in Ei that results from a one percent change in y, formally written as:

$$e = \frac{\partial Lnf_i(y,m)}{\partial \operatorname{Ln} y} \tag{3}$$

Consumer goods that have income elasticities below zero are called inferior goods, and elasticities between zero and one are considered necessities, while goods with elasticities above one are luxuries. Based on this, Engel (1857) found that food was a necessity.

4.2 Methodology

To achieve the research objectives, the methodology involves a set of econometric techniques. First, to determine the nature of the food Engel curve, we employ a non-parametric analysis. In order to achieve the second objective of computing the critical expenditure beyond which food shares start declining with expenditure, the study estimates quadratic food Engel curves where the measurement error is corrected using Lewbel's (2012) approach.

4.2.1 Modelling a Quadratic Food Engel Curve with Mismeasured Regressors

Several research studies have made use of the Working-Leser specification in which household food budget share is assumed to be a decreasing linear function of total expenditure. However, in a developing country scenario, this relationship is likely to be quadratic in nature, as demonstrated by Bhalotra and Attfield (1998) using Pakistani data, and Kedir and Girma (2007) using Ethiopian data. Therefore, we assume that the food Engel curve is likely to be quadratic in the context of Cameroon. Inspired by Bhalotra and Attfield (1998) and Kedir and Girma (2007), a quadratic food Engel curve is modelled as:

$$FS = \gamma_0 + \gamma_1 \operatorname{Ln} TE^* + \gamma_2 \operatorname{Ln} TE^{*2} + X'\beta_1 + V_1 \tag{4}$$

Where FS denotes household food budget share, $\mathrm{Ln}TE^{*}$ is the true log of household total expenditure proxy for income, $\mathrm{Ln}TE^{*2}$ is the square of the true log of household total expenditure, and X stands for the vector of other households and individual factors that correlate with household food budget shares. V_1 is the random error term with zero mean and independent of the covariates $X, \mathrm{Ln}TE^{*}$ and $\mathrm{Ln}TE^{*2}$. The regressors $\mathrm{Ln}TE^{*}$ and $\mathrm{Ln}TE^{*2}$ are without error, rather we observe that $\mathrm{Ln}TE$ $\mathrm{Ln}TE$ and $\mathrm{Ln}TE^{2}$ are mismeasured, as follows:

$$\mathrm{Ln}TE = \mathrm{Ln}TE^{*} + U_1, \qquad E(U_1) = 0, \qquad U_1 \perp X, FS, \mathrm{Ln}TE^{*} \tag{5}$$

$$\mathrm{Ln}TE^{2} = \mathrm{Ln}TE^{*2} + U_2, \qquad E(U_2) = 0, \qquad U_2 \perp X, FS, \mathrm{Ln}TE^{*2} \tag{6}$$

In Equations 5 and 6, U_1 and U_2 are classical measurement errors and are expected to have zero means and be independent of the true model variables, i.e., $\mathrm{Ln}TE^{*}$, $\mathrm{Ln}TE^{*2}$, X and V_1. All these assumptions are exactly the same as the hypotheses of the classical linear regression mismeasured regressor model. Let V_2 and V_3 represent the residuals of the linear projections of $\mathrm{Ln}TE^{*}$ on XX and $\mathrm{Ln}TE^{*2}$ on X, respectively, and we thus have:

$$\mathrm{Ln}TE^{*} = X'\beta_2 + V_2, \qquad E(XV_2) = 0 \tag{7}$$

$$\mathrm{Ln}TE^{*2} = X'\beta_3 + V_3, \qquad E(XV_3) = 0 \tag{8}$$

Substituting the unobservables $\mathrm{Ln}TE^{*}$ and $\mathrm{Ln}TE^{*2}$ in Equations 4, 5 and 6 gives the well-known triangular system linked with measurement error models:

$$FS = \gamma_0 + \gamma_1 \mathrm{Ln}TE + \gamma_2 \mathrm{Ln}TE^{2} + X'\beta_1 + \varepsilon_1, \qquad \varepsilon_1 = -\gamma_1 U_1 - \gamma_2 U_2 + V_1 \tag{9}$$

$$\mathrm{Ln}TE = X'\beta_2 + \varepsilon_2, \qquad \varepsilon_2 = U_1 + V_2 \tag{10}$$

$$\mathrm{Ln}TE^{2} = X'\beta_3 + \varepsilon_3, \qquad \varepsilon_3 = U_2 + V_3 \tag{11}$$

Based on the non-parametric regression, $\gamma_1 > 0$ and $\gamma_2 < 0$ indicate that the food budget share is likely to first increase before it starts declining. Thus, as the total expenditure proxy for income increases, household food budget shares increase until a critical point is reached where food sufficiency is assumed.

$$FS = \gamma_0 + [\gamma_1 + \gamma_2 \mathrm{Ln}TE]\ln TE + X'\beta_1 + \varepsilon_1 \tag{12}$$

This means that $[\gamma_1 + \gamma_2 \operatorname{Ln} TE] > 0$ up to some critical level of $\operatorname{Ln} \dot{TE}$. Beyond this critical point, $[\gamma_1 + \gamma_2 \operatorname{Ln} TE] < 0$ .. This construction is based on the information that $\gamma_1 > 0$ and $\gamma_2 < 0$.

The critical total expenditure level, where Cameroonian households are assumed to become food sufficient, is obtained as follows:

$$\frac{\partial FS}{\partial \operatorname{Ln} TE} = \gamma_1 + 2\gamma_2 \operatorname{Ln} TE = 0 \tag{13}$$

The turning point in log value is obtained by $\operatorname{Ln} \dot{TE} = -\frac{\hat{\gamma}_1}{2\hat{\gamma}_2}$, and in monetary value (FCFA) is given by $\dot{TE} = \exp(-\frac{\hat{\gamma}_1}{2\hat{\gamma}_2})$.

The income(expenditure) elasticity is derived from the quadratic specification of the food Engel curve in the following manner:

$$\hat{\eta} = \frac{\widehat{FS} + \hat{\gamma}_1 + 2\hat{\gamma}_2 Ln\, TE}{\widehat{FS}} \tag{14}$$

Where $\hat{\eta}$ is household expenditure elasticity, $\hat{\gamma}_1$ and $\hat{\gamma}_2$ are the estimated parameters of Equation 9, and $\widehat{FS}$ is the predicted household food budget share.

4.2 Identification of Quadratic Food Engel Curve with Mismeasured Regressors

The log of total expenditure and square of log of total expenditure that enter the food expenditure function may be endogenous due to measurement errors, as discussed when modelling the food expenditure. An estimation ignoring the potential endogeneity of the log of total expenditure and square of the log of total expenditure may lead to biased and inconsistent parameter estimates. However, it is usually a challenge in obtaining a valid and relevant instrument to employ in the Engel curve. The reliance on the standard IV approach in the identification of models requires valid and relevant instruments, usually through exclusion restrictions. In many applied economic contexts, the assumption that an instrument only indirectly affects the response variable is hard to verify. What could be done if there are no ordinary instruments available? In an article published in the Journal of Business & Economic Statistics, Lewbel (2012) proposed a novel method that could be used in the identification of models with mismeasured and endogenous regressors in the absence of standard identifying information such as external instruments or repeated measurements. According to Lewbel (2012), identification is achieved via the use of regressors that are not correlated with the product of heteroscedastic errors, which

is a characteristic of several models in which correlations of the error terms are mainly because of mismeasurement and unobserved common factors. In particular, this method uses heteroscedasticity in the data to estimate the IV regression. This technique may be employed in the absence of external instruments or, alternatively, applied to supplement external instruments in order to increase the efficiency of the IV estimator.

Lewbel (2012) suggests that a vector ZZ of observed exogenous variables can be used. Z could be a subset of X or equal to X. Lewbel (2012) further said that if Z is a vector of observed exogenous variables and the following moment conditions are met:

$$E(X\,\varepsilon_1) = 0, \qquad E(X\,\varepsilon_2) = 0, \qquad E(X\,\varepsilon_3) = 0, \qquad Cov(Z, \varepsilon_1\,\varepsilon_2\varepsilon_3) = 0 \tag{15}$$

and if there is some heteroscedasticity of $\varepsilon_j\varepsilon_j$, then the parameters of the structural equation (Equation 9) can be identified by using the vector $[Z - E(Z)]\widehat{\varepsilon_2}$ as instrument for total expenditure and $[Z - E(Z)]\widehat{\varepsilon_3}$. The intuition behind why $[Z - E(Z)]\widehat{\varepsilon_2}$ and $[Z - E(Z)]\widehat{\varepsilon_3}$ are vectors of instruments is that identification occurs by having regressors that are not correlated with the product of the heteroscedastic errors. The point is that the vector Z could either be a subset of X or equal to X. Using the above chosen set of instruments, one can use TSLS to estimate the IV regression, as one would do with conventional IVs. According to Lewbel (2012), supplementing the generated instruments with external instruments can help improve the efficiency of the IV estimator.

Lewbel's (2012) heteroscedastic-based instruments approach depend on some important hypotheses. The main hypothesis is that there is some heteroscedasticity in ε_i. Lewbel (2012) obtained the exact form of the heteroscedasticity requirement as $Cov(Z, {\varepsilon_2}^2)$ and $Cov(Z, {\varepsilon_3}^2)$. This requirement can easily be empirically verified by making use of the sample covariance between Z and the squared residuals from linearly projecting $\ln TE$ on X and $\ln TE^2$ on X. In econometrics, we can apply the Breusch and Pagan (1979) test for this form of heteroscedasticity to Equations 7 and 8. Second, the hypotheses outlined in Equation 11 are traditional hypotheses. As Lewbel (2012) puts it: "These are all standard assumptions, except that one usually either imposes homoscedasticity or allows for heteroscedasticity, rather than requiring heteroscedasticity". Hence, the non-traditional hypothesis posited by Lewbel (2012) is that of heteroscedasticity that can be empirically verified.

As indicated by Lewbel (2012), the efficiency of the estimator can be improved by complementing the generated instruments with external instruments; the present study employs the non-self-cluster identification approach. To derive external instrumental variables for total expenditure and total expenditure squared, we exploit the concept of social interactions to construct non-self-cluster means of log total expenditure and log total expenditure squared using cluster-level information and excluding the household in question. Therefore, in our study, the instruments employed are $[Z - E(Z)]\widehat{\varepsilon_2}$, $[Z - E(Z)]\widehat{\varepsilon_3}$, non-self-cluster mean of log total expenditure and non-self-cluster mean of log total expenditure squared.

5. Data

This study makes use of a pool of three recent waves of the Cameroon Household Survey on income expenditure and consumption (ECAM 2, 2001; ECAM 3, 2007; ECAM 4, 2014). The Cameroon household consumption surveys contain nationally representative data. Two types of sampling designs are employed based on the zone of residence. In the main cities of Yaoundé and Douala, two-stage sampling is adopted. For other areas, three-stage random sampling is used.

The 2001 wave of the consumption survey (ECAM 2) comprised 10,992 households and was carried out by the government's statistics office, the National Institute of Statistics, from September to December 2001. The main objective of this survey was to put in place a novel methodology of calculating poverty lines and also to correct the mistakes identified in the first survey (Institute Nationale des Statistiques [National Institute of Statistics], 2002). The data were obtained from 22 strata comprising 12 urban and 10 rural areas. The main cities of Douala and Yaoundé were employed as separate strata, while each region was partitioned into two strata: one urban and one rural.

The third wave of the consumption survey (ECAM 3) constituted 11,391 households and was carried out from May to July 2007. The major aim of this wave of the consumption survey was to evaluate efforts towards the implementation of the poverty reduction strategy paper and the millennium development goals (MDGs), and also to update the poverty profile for Cameroon. The 2007 survey was collected from 32 strata comprising 10 semi-urban strata and 10 rural strata, with a stratum extracted from each region, and 12 urban strata. The data consist of 742 primary sampling units of which 290 are in rural areas and 452 are in urban areas.

10,303 households were contacted for ECAM 4 in 2014. The 2014 survey aimed to update the poverty profile of 2001 (ECAM 2) and 2007 (ECAM 3), to assess the progress made in the fight against poverty and towards the achievement of the MDGs, and to guide the ongoing revision of the poverty reduction strategy paper. In order to render the three surveys comparable, the three data sets were intertemporally harmonized using price indices computed by the National Institute of Statistics. Indeed, the expenditures of 2007 and 2014 were deflated in terms of the 2001 prices. The consumer price indices (CPIs) were 174.8, 196.2 and 224.2, respectively, for 2001, 2007 and 2014, while the food price indices (FPIs) stood at 195.9, 218.1 and 259.3, respectively, for 2001, 2007 and 2014.

6. Empirical Results

In this section, we present the descriptive statistics in sub-section 6.1, parametric analysis of food Engels curve in 6.2 and the estimates of the quadratic food Engel curves in sub section 6.3

6.1 Descriptive Statistics

The descriptive statistics of the variables are presented for the 2001, 2007 and pooled surveys in section 6.1.1, while in section 6.1.2 we present the evolution of food budget shares by expenditure quantiles.

6.1.1 Descriptive Statistics for Variables

Table 1 provides pooled descriptive statistics for 2001, 2007 and 2014. Column 1, showing the descriptive statistics of the pooled records, reveals that, on average, household food expenditure per adult equivalent is 11.935 log points. The descriptive information further illustrates that the food share in total expenditure is 0.46. Equally, the results indicate that total expenditure per adult equivalent is 12.788 log points. Of the total number of households considered, 26.3% were found to have no level of education, 33.9% have a primary level of education, 31.8% a secondary level and 7.8% a tertiary level of education. The average age of the household head was found to be about 45 years. Concerning residency, the pooled results show that 37.1% of households reside in urban areas. The findings also show that 78.8% of households surveyed were found to be headed by men.

Columns 2, 3 and 4 provide descriptive statistics for the 2001, 2007 and 2014 surveys, respectively. Descriptive findings reveal that the average log food expenditure per adult equivalent is about 11.792 log points, 11.860 log points and 12.100 log points for 2001, 2007 and 2014, respectively. The share of food expenditure in total expenditure is 0.502 for 2001 and 0.455 for 2007 against 0.433 for 2014. This indicates that over the 15-year period, the household food budget share shows a declining trend among Cameroonian households. These findings are in line with those obtained by Issaka (2018) in Ghana, revealing that over the period 1999–2013, the food budget share of Ghanaian households decreased. The decrease in the food budget share from 2001 to 2014 in Cameroon can be translated as an improvement in the welfare of Cameroonian households.

Engel (1857) said that as the income of a household increases, the proportion of income devoted to basic necessities such as food decreases, indicating that the elasticity for food is always positive but less than one. Therefore, an Engel curve can be used to gauge the evolution of households' wellbeing by analyzing food budget shares over time. The implication of Engel's law is that poor households are expected to have higher food budget shares compared to rich households. As such, the decline in the household food budget share over the period 2001–2014 can be perceived as an improvement in the wellbeing of Cameroonian households over this period.

Table 1: Pooled descriptive statistics, 2001, 2007, 2014

Variables	Pooled Column (1)	2001 survey Column (2)	2007 survey Column (3)	2014 survey Column (4)
Ln(food expenditure)	11.935	11.792	11.860	12.100
	(0.686)	(0.650)	(0.598)	(0.742)
Food budget share	0.460	0.502	0.455	0.433
	(0.160)	(0.171)	(0.159)	(0.146)
Ln (total expenditure)	12.788	12.554	12.731	13.003
	(0.751)	(0.683)	(0.663)	(0.805)
No level of education	0.263	0.315	0.301	0.195
	(0.440)	(0.465)	(0.459)	(0.396)
Primary education	0.339	0.349	0.344	0.328
	(0.473)	(0.477)	(0.475)	(0.469)
Secondary education	0.318	0.274	0.292	0.371
	(0.466)	(0.446)	(0.455)	(0.483)
Tertiary education	0.078	0.060	0.060	0.106
	(0.269)	(0.237)	(0.238)	(0.308)
Age of household head	45.353	45.689	44.288	45.909
	(14.485)	(14.122)	(14.076)	(14.867)
Urban residency	0.371	0.348	0.353	0.403
	(0.483)	(0.476)	(0.478)	(0.491)
Male	0.788	0.816	0.791	0.764
	(0.409)	(0.387)	(0.407)	(0.424)
Sudano-Sahel	0.276	0.250	0.280	0.291
	(0.447)	(0.433)	(0.449)	(0.454)
High savanna	0.095	0.093	0.098	0.093
	(0.293)	(0.290)	(0.298)	(0.290)
Western highlands	0.204	0.236	0.207	0.178
	(0.403)	(0.425)	(0.405)	(0.382)
Monomodal humid forest	0.216	0.221	0.210	0.217
	(0.411)	(0.415)	(0.407)	(0.412)
Bimodal humid forest	0.210	0.200	0.205	0.221
	(0.407)	(0.400)	(0.404)	(0.415)
Observations	32686	10992	11391	10303

Source: Computed by author with data from ECAM 2, ECAM 3 and ECAM 4 using Stata 14. Values in parentheses are standard deviations.

The household average log of total expenditure per adult equivalent registered an intertemporal increase. For 2001, it is 12.554 log points, while for 2007 and 2014 the mean log of total expenditure per adult equivalent is 12.73 and 13.00 log points, respectively.

Regarding the level of education of Cameroonian households, the descriptive statistics depict a decreasing trend for no level of educationPrimary level of education also saw a decrease over the period 2001–2014. Conversely, there was a rise in

secondary level of education in Cameroon over the period 2001–2014: 27.4% in 2001, 29.2% in 2007 and 37.1% in 2014. The proportion of Cameroonians with a tertiary level of education stagnated between 2001 and 2007, while there was an increase between 2007 and 2014.

The descriptive results show that the average age of the household head was 45.69 years in 2001, in 2007 it was 44.29 years, and in 2014 it was 45.9 years. The results further show a decreasing pattern in the proportion of male-headed households over the 2001–2014 period.

6.1.2 Evolution of Household Food Budget Shares by Expenditure Quintiles

Table 2 reports descriptive statistics indicating the evolution of food budget shares across expenditure quintiles. According to Engel (1857), resource poor households are expected to allocate a greater share of their income to necessities like food. Thus, the proportion of income devoted to food can provide an insight into the welfare of Cameroonian households. In 2001, 2007 and 2014, the descriptive results indicate a decreasing pattern in the food budget share from the the 1st quintile up to the 5th quintile. The evolution of food expenditure shares across expenditure quintiles corroborates Engel's law, which stipulates that food budget share is a decreasing function of income(expenditure).

Gauging the evolution intertemporally, the trend seems to be different across the expenditure quintiles. Between 2001 and 2007, the results indicate a decreasing trend from the 1st quintile to the 5th quintile. However, the magnitude of the decrease in household food budget was found to increase monotonically from the 1st quintile up to the 4th quintile, then decreasing at the 5th quintile. This decrease in household food budget shares indicates an improvement in household welfare between 2001 and 2007.

Table 2: Evolution of food budget shares by expenditure quintile

Surveys	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
2001	0.5287 (0.0026)	0.5047 (0.0030)	0.4770 (0.0034)	0.4380 (0.0041)	0.3480 (0.0052)
2007	0.5137 (0.0027)	0.4578 (0.0029)	0.4027 (0.0031)	0.3431 (0.0032)	0.2940 (0.0038)
2014	0.4821 (0.0040)	0.4806 (0.0036)	0.4527 (0.0031)	0.4242 (0.0026)	0.3704 (0.0023)
	Intertemporal changes in household food budget shares				
Surveys	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
2001–2007	-0.0150*** (0.0037)	-0.0469*** (0.0042)	-0.0743*** (0.0046)	-0.0949*** (0.0051)	-0.0540*** (0.0063)
2007–2014	-0.0316*** (0.0023)	0.0228*** (0.0048)	0.0500*** (0.0045)	0.0811*** (0.0041)	0.0764*** (0.0042)
2001–2014	-0.0466*** (0.0048)	-0.0241*** (0.0048)	-0.0243*** (0.0047)	-0.0138*** (0.0049)	0.0224*** (0.0050)

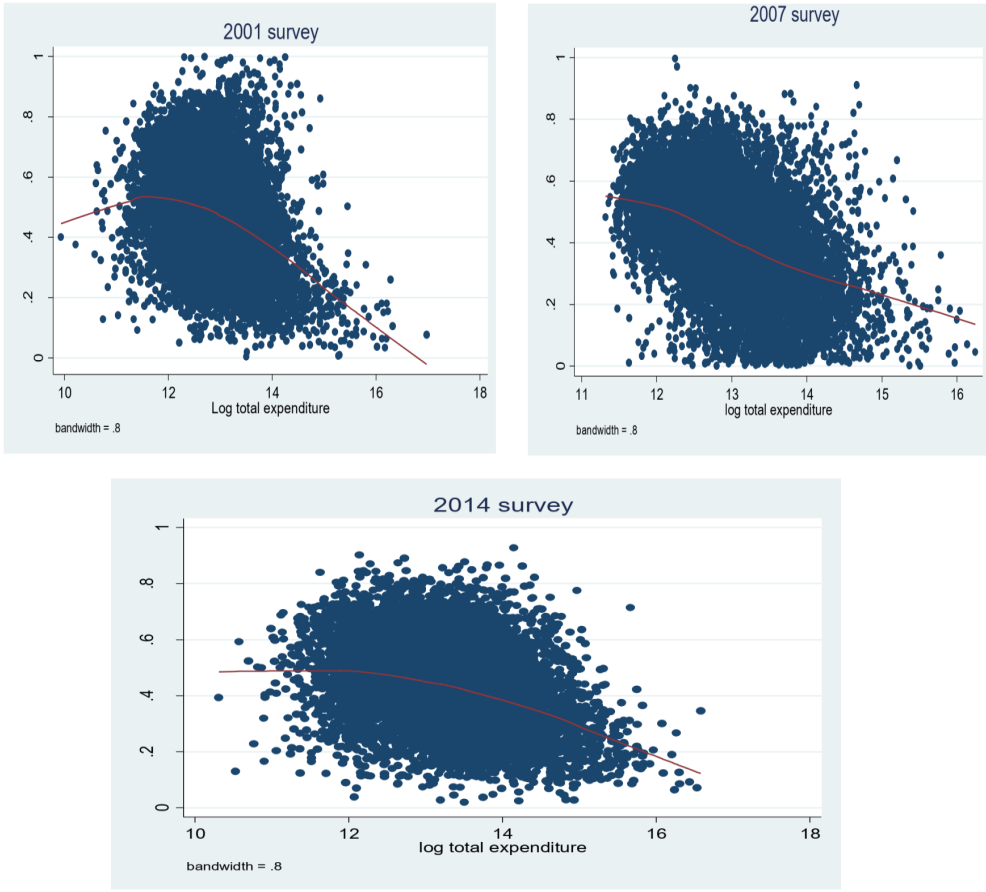
Source: Computed by author with data from ECAM 2, ECAM 3 and ECAM 4 using Stata 14. Values presented are mean values, while those in parentheses are standard errors.

Assessing the evolution between 2007 and 2014, the descriptive results report an increasing trend from the 2nd to the 4th quintile, and a decrease from the 4th to the 5th quintile. Considering the structural period 2001–2014, a fluctuating trend is revealed from the 1st quintile up to the 5th quintile of the income distribution.

6.2 Non-parametric Analysis of Food Engel Curves

We start by estimating non-parametric Engel curves for food in Cameroon for the separate surveys. This non-parametric exercise provides an insight into the nature of the Engel curves for each year. Specifically, the non-parametric analysis tells us whether we are dealing with a linear or a non-linear Engel curve for food. Figure 4 shows the smoothed food share values mapped against the log of total expenditures. The figure reveals the existence of a quadratic relationship between household food share and real total expenditure.

Figure 4: Non-parametric model of food share



Source: Authors with data from ECAM 2, ECAM 3 and ECAM 4 using Stata

The food Engel curve for 2001 shows an inverted U-shape, revealing that household food share first increases with the log of total expenditure up to a critical level of expenditure, beyond which food share starts declining with log of total expenditure.

The non-parametric analysis depicts the existence of a linear relationship between household food budget share and real total expenditure in 2007. In particular, the non-parametric analysis indicates that household food share is a decreasing function of the log of total expenditure. The figure also reveals the existence of a quadratic relationship between household food share and real total expenditure in 2014. However, the quadratic relationship is less pronounced in 2014 compared to the 2001 quadratic Engel curve.

6.3 Estimates of Quadratic Food Engel Curves

In this section, we estimate quadratic Engel curves for food using separate household consumption surveys and computing the turning points and expenditure elasticities. In particular, we present ordinary least squares (OLS) and two-stage least squares (2SLS) regression estimates of the food Engel curves for the 2001, 2007 and 2014 surveys. Before delving into the estimation of the quadratic food Engel curves using the Lewbel (2012) approach based on heteroscedasticity, we apply the Breusch-Pagan test presented in Appendix 1, which is a precondition to apply the Lewbel method. Using the three different surveys, the Breusch-Pagan test of heteroscedasticity rejects the null hypothesis of constant variance in each case.

Table 3 displays estimates of the structural forms of the food quadratic Engel curve under different assumptions. In particular, columns 1 and 2 host the OLS and 2SLS estimates of the 2001 quadratic food Engel curve, respectively. The OLS estimate of the 2001 survey indicates that the log of total expenditure exhibits quadratic behaviour, depicted by an inverted U-shape. In particular, total expenditure increases with food budget share up to the critical point calculated to be FCFA134,024. Beyond this critical point total expenditure starts declining with household food budget share (column 1 of Table 3).

These OLS estimates could suffer from potential endogeneity bias originating from the mismeasurement of the variables of interest of log total expenditure and log total expenditure squared. Accounting for endogeneity using the Lewbel (2012) approach, supplemented with external instruments, affects the estimates of the log of real expenditure and the square of real expenditure (column 2 of Table 3). The inverted U-shape of the Engel curve is still present after correcting for endogeneity. However, the turning points will likely change. The empirical results reveal that correcting for endogeneity in the 2001 survey gives a turning point of FCFA129,428. Comparing this with the critical point when not corrected for endogeneity, the turning point decreased when endogeneity is accounted for. These findings are consistent with those obtained by Kedir and Girma (2007) using Ethiopian data. The implication of the findings is that households with expenditure below this critical point are considered to have insufficient income to meet minimum food requirements.

Table 3: Estimates of quadratic food Engel curves (dependent variable: food budget share)

	2001 survey		2007 survey		2014 survey	
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	OLS	2SLS	OLS	2SLS	OLS	2SLS
Ln(Total Expenditure)	0.545***	0.503***	0.369***	0.340***	0.350***	0.174***
	(0.032)	(0.039)	(0.041)	(0.057)	(0.029)	(0.044)
Ln(Total Expenditure)^2	-0.023***	-0.021***	-0.016***	-0.015***	-0.016***	-0.008***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
Primary	-0.042***	-0.042***	-0.014***	-0.015***	-0.010***	-0.010***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Secondary	-0.063***	-0.063***	-0.046***	-0.048***	-0.022***	-0.022***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Tertiary	-0.092***	-0.094***	-0.070***	-0.076***	-0.035***	-0.035***
	(0.006)	(0.006)	(0.005)	(0.006)	(0.004)	(0.004)
Age	-0.024***	-0.024***	0.027***	0.011***	0.009	0.011
	(0.008)	(0.580)	(0.008)	(0.007)	(0.007)	(0.007)
Household size	-0.003***	-0.003***	-0.003***	-0.002***	-0.004***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male	0.006**	0.006**	-0.012***	-0.011***	-0.012***	-0.013***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Urban	-0.095***	-0.096***	-0.094***	-0.097***	-0.059***	-0.064***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
High savanna	-0.018***	-0.018***	0.000	-0.000	-0.017***	-0.017***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Western highlands	-0.065***	-0.065***	-0.050***	-0.050***	-0.075***	-0.073***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Monomodal humid forest	-0.096***	-0.096***	-0.080***	-0.081***	-0.074***	-0.076***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
Bimodal humid forest	-0.070***	-0.070***	-0.055***	-0.056***	-0.070***	-0.072***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Constant	-2.570***	-2.316***	-1.478***	-1.331***	-1.380***	-0.305
	(0.206)	(0.250)	(0.262)	(0.358)	(0.186)	(0.276)
Observations	8,928	8,928	9,797	9,797	9,058	9,058
R-squared	0.530	0.530	0.538	0.537	0.418	0.414
Turning point [FCFA]	134,024	129,428	77,195	82,943	76,063	30,579
	(8,594)	(11,310)	(12,452)	(18,016)	(9,865)	(14819)
Expenditure elasticity	0.9071	0.9070	0.8806	0.8973	0.8699	0.8929

Source: Computed by author with data from ECAM 2, ECAM 3 and ECAM 4 using Stata 14.
Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

2SLS: Using internally-generated instruments $[Z - E(Z)]\hat{\varepsilon_2}$ and $[Z - E(Z)]\hat{\varepsilon_3}$, and external instruments non-self-cluster mean of total expenditure and non-self-cluster of total expenditure squared.

To treat outliers, the top and bottom 5% of households in terms of standardized residuals were omitted.

To investigate whether there is there a shift in the Engel curve between 2001 and 2007, we estimate the food Engel curve for 2007 and compare it with the curve for 2001. When estimating the food Engel curve for the 2007 survey, the OLS results depict that household total expenditure exhibits quadratic behaviour when endogeneity is not accounted for, as indicated in column 3 of Table 3. Specifically, the findings show that total expenditure increases with food budget share up to FCFA77,195, and after this critical point the real total expenditure starts declining with household food budget share.

Column 4 of Table 3 gives the 2SLS estimates of the quadratic food Engel curve. Taking into account the endogeneity issue in the Engel curve, the estimation reveals a quadratic food Engel curve using the 2007 household survey and shows, in particular, that total expenditure increases with food budget share up to FCFA82,943, which then starts falling above this critical expenditure point. Thus, based on these results, we can say that between 2001 and 2007 there was a shift in the food Engel curve in Cameroon as illustrated by changes in the turning points. Columns 5 and 6 of Table 3 provide the estimates of the food Engel curve using data from the 2014 household consumption survey. The results reveal that in 2014 the Engel curve for food is also quadratic in nature. In particular, the OLS results indicate that the log of total expenditure increases with household food budget share up to a critical expenditure point calculated as FCFA76,063. Beyond this critical expenditure point, household food budget share starts falling with the log of household total expenditure.

Column 6 of Table 3 shows the results of the estimates of the quadratic food Engel curve, which were corrected for endogeneity. Using the 2014 survey, the 2SLS results reveal a concave quadratic Engel curve for food. Specifically, the 2SLS results indicate that total expenditure has a diminishing effect on household food budget share. In particular, any additional expenditure below the critical expenditure of FCFA30,579 increases the food budget share, while any additional expenditure above this critical expenditure level reduces the household food budget share.

The findings further reveal that for 2001, 2007 and 2014, education correlates negatively and monotonically with household food budget share. That is, a higher level of education correlates negatively with household food budget share. Age registers a negative effect on household food budget share for the 2001 and 2007 surveys, while for the 2014 survey, the age of the household head was not significantly related to household food budget share. The results further show significant differences between male-headed and female-headed households in terms of food budget shares. In particular, based on the 2001 survey, male-headed households are found to have higher food budget shares compared to female-headed households, while based on the 2007 and 2014 surveys, households headed by men tend to have lower household food budget shares compared to households headed by women. This is an indication that for 2007 and 2014, households headed by men were better in terms of welfare compared to households headed by women. Compared with household dwellings in the Sudano-Sahel agroecological zone, households in other agroecological zones have lower food budget shares, ranging from 0.016 in the high savanna zone to 0.092 points

in the monomodal humid forest agroecological zone for the 2001 and 2014 surveys. Using the 2007 survey, the findings show that with respect to household dwellings in the Sudano-Sahel agroecological zone, households in the high savanna zone have no significant differences in terms of food budget shares, while households in the other agroecological zones have lower household food budget shares.

7. Concluding Remarks and Policy Implications

This study aimed to estimate food Engel curves for Cameroon while correcting for measurement errors using the three most recent Cameroon household surveys. Specifically, the study set out to: (1) examine the nature of the food Engel curves for 2001, 2007 and 2014; and (2) calculate the critical expenditure (turning point) beyond which households experience diminishing returns. Regarding the empirical strategy, the paper used a non-parametric analysis to examine the nature of the food Engel curves for the three surveys, and a Lewbel (2012) heteroscedasticity-based instrument supplemented by external instruments to identify and estimate quadratic food Engel curves.

Findings from the non-parametric analysis indicate that the food Engel curves are parabolic in nature for 2001 and 2014, and linear for the 2007 survey. Results from both the OLS and the 2SLS estimations of the food Engel curves reveal that total expenditure increases with household food budget share up to a critical expenditure point, beyond which this critical expenditure total expenditure starts declining with household food budget total share.

The shift in food Engel curves over the period 2001–2007 and 2001–2014 can be translated as a decrease in food poverty and an improvement in household welfare over these periods. This can be explained by the decrease in the responsiveness of household food budget share to total expenditure. This is supported by Engel (1857), who stipulated that richer households have lower income elasticities. Thus, the decrease in the magnitude of the effects of log of total expenditure and the log of total expenditure squared can be interpreted as welfare improvement.

The study's findings reveal that the food Engel curves for Cameroon are quadratic in nature. This is contrary to the food Engel curve typically found for developed countries, which appears to be Working-Leser(linear in nature). Our analysis thus provides additional evidence to support the hypothesis that quadratic Engel curves are a feature of developing countries. Importantly, in case of a negative income shock, misspecified models of the Engel curve underestimate expenditure variability. Based on the evidence of a quadratic food Engel curve (presence of an increasing segment in the Engel curve), a reformulation of policies aimed at reducing food insecurity and improving the welfare of ultra-poor households is crucial. Indeed, if taxes on food items are high, low income households will be most affected. Therefore, it would

be better if taxes are levied in such a way that the impact is lower on resource poor households. Policies such as reducing taxes on food items should be encouraged as the tax burden on food items is likely to be borne by low-income households. In particular, the Government of Cameroon can reduce custom duties on basic necessities such as rice, flour and fish that will, in turn, increase the purchasing power of households and thus increase food security. Another policy that the Government of Cameroon should consider in order to ensure food security of ultra-poor households is targeted transfer schemes. Transfer schemes are expected to compensate for adverse effects such as price hikes in some staple food items, which mainly affect ultra-poor households.

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Appendixes

Appendix 1: Breusch-Pagan test for heteroscedasticity in first-stage regressions

	2001 survey		2007 survey		2014 survey	
	$\ln TE$	$\ln TE^2$	$\ln TE$	$\ln TE^2$	$\ln TE$	$\ln TE^2$
Chi2(1) test statistics	91.58***	254.75***	14.66***	89.79***	13.07***	41.90***
P-value	0.0000	0.0000	0.0001	0.0000	0.0003	0.0000

Source: Computed by author with data from ECAM 2, ECAM 3 and ECAM 4 using Stata 14.
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix 2: Estimates of quadratic food Engel curve for 2001 under different assumptions

	(1)	(2)	(3)
Variables	2SLS_1	2SLS_2	2SLS_3
logexp1	0.932***	0.493***	0.503***
	(0.115)	(0.040)	(0.039)
logexp2	-0.039***	-0.021***	-0.021***
	(0.005)	(0.002)	(0.002)
primary	-0.041***	-0.042***	-0.042***
	(0.003)	(0.003)	(0.003)
secondary	-0.056***	-0.064***	-0.063***
	(0.004)	(0.004)	(0.004)
tertiary	-0.064***	-0.096***	-0.094***
	(0.010)	(0.006)	(0.006)
Age x10-2	-0.0019**	-0.0025***	-0.024***
	(0.000)	(0.000)	(0.000)
size	-0.004***	-0.003***	-0.003***
	(0.000)	(0.000)	(0.000)
male	0.006*	0.006**	0.006**
	(0.003)	(0.003)	(0.003)
urban	-0.087***	-0.097***	-0.096***
	(0.004)	(0.003)	(0.003)
high_savanah	-0.018***	-0.018***	-0.018***
	(0.004)	(0.004)	(0.004)
west_highlands	-0.066***	-0.065***	-0.065***
	(0.003)	(0.003)	(0.003)
mono_forest	-0.094***	-0.096***	-0.096***
	(0.004)	(0.004)	(0.004)
bimo_forest	-0.068***	-0.070***	-0.070***
	(0.004)	(0.004)	(0.004)
Constant	-4.894***	-2.261***	-2.316***
	(0.707)	(0.251)	(0.250)
Observations	8,928	8,928	8,928
R-squared	0.515	0.530	0.530

Source: Computed by author with data from ECAM 2 using Stata 14.
Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Notes:
2SLS_1: two-stage least squares using non-self-cluster mean of total expenditure and non-self-cluster of total expenditure squared as instruments.
2SLS_2: two-stage least squares using $[Z - E(Z)]\hat{\varepsilon_2}$ and $[Z - E(Z)]\hat{\varepsilon_3}$ as instruments.
2SLS_3: two-stage least squares using internally-generated instruments: $[Z - E(Z)]\hat{\varepsilon_2}$ and $[Z - E(Z)]\hat{\varepsilon_3}$, and external instruments: non-self-cluster mean of total expenditure and non-self-cluster of total expenditure squared.

Appendix 3: Estimates of quadratic food Engel curve for 2007 under different assumptions

	(1)	(2)	(3)
Variables	2SLS_1	2SLS_2	2SLS_3
logexp1	0.387	0.327***	0.340***
	(0.454)	(0.057)	(0.057)
logexp2	-0.019	-0.014***	-0.015***
	(0.018)	(0.002)	(0.002)
primary	-0.008**	-0.015***	-0.015***
	(0.003)	(0.003)	(0.003)
secondary	-0.029***	-0.050***	-0.048***
	(0.005)	(0.003)	(0.003)
tertiary	-0.024	-0.080***	-0.076***
	(0.016)	(0.006)	(0.006)
Age x 10-2	0.033***	0.0026***	0.0026***
	(0.000)	(0.000)	(0.000)
size	-0.005***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)
male	-0.014***	-0.011***	-0.011***
	(0.003)	(0.002)	(0.002)
urban	-0.069***	-0.099***	-0.097***
	(0.005)	(0.003)	(0.003)
high_savanah	0.006	-0.000	-0.000
	(0.005)	(0.004)	(0.004)
west_highlands	-0.045***	-0.050***	-0.050***
	(0.005)	(0.003)	(0.003)
mono_forest	-0.068***	-0.081***	-0.081***
	(0.005)	(0.003)	(0.003)
bimo_forest	-0.045***	-0.057***	-0.056***
	(0.005)	(0.003)	(0.003)
Constant	-1.260	-1.275***	-1.331***
	(2.858)	(0.358)	(0.358)
Observations	9,797	9,797	9,797
R-squared	0.499	0.536	0.537

Source: Computed by author with data from ECAM 3 using Stata 14.

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

Notes:

2SLS_1: two-stage least squares using non-self-cluster mean of total expenditure and non-self-cluster of total expenditure squared as instruments.

2SLS_2: two-stage least squares using $[Z - E(Z)]\hat{\varepsilon_2}$ and $[Z - E(Z)]\hat{\varepsilon_3}$ as instruments.

2SLS_3: two-stage least squares using internally-generated instruments: $[Z - E(Z)]\hat{\varepsilon_2}$ and $[Z - E(Z)]\hat{\varepsilon_3}$, and external instruments: non-self-cluster mean of total expenditure and non-self-cluster of total expenditure squared.

Appendix 4: Estimates of quadratic food Engel curve for 2014 under different assumptions

	(1)	(2)	(3)
Variables	2SLS_1	2SLS_2	2SLS_2
logexp1	1.548***	0.170***	0.174***
	(0.579)	(0.044)	(0.044)
logexp2	-0.063***	-0.008***	-0.008***
	(0.024)	(0.002)	(0.002)
primary	-0.012***	-0.010***	-0.010***
	(0.004)	(0.003)	(0.003)
secondary	-0.023***	-0.022***	-0.022***
	(0.003)	(0.003)	(0.003)
tertiary	-0.039***	-0.035***	-0.035***
	(0.004)	(0.004)	(0.004)
Age X10-2	0.004	0.012	0.012
	(0.012)	(0.007)	(0.070)
size	-0.005***	-0.004***	-0.004***
	(0.002)	(0.000)	(0.000)
male	-0.011***	-0.013***	-0.013***
	(0.003)	(0.002)	(0.002)
urban	-0.050**	-0.064***	-0.064***
	(0.021)	(0.003)	(0.003)
high_savanah	-0.030***	-0.017***	-0.017***
	(0.010)	(0.004)	(0.004)
west_highlands	-0.093***	-0.073***	-0.073***
	(0.008)	(0.003)	(0.003)
mono_forest	-0.082***	-0.076***	-0.076***
	(0.015)	(0.004)	(0.004)
bimo_forest	-0.081***	-0.071***	-0.072***
	(0.014)	(0.003)	(0.003)
Constant	-8.942**	-0.281	-0.305
	(3.534)	(0.276)	(0.276)
Observations	9,058	9,058	9,058
R-squared	0.299	0.414	0.414

Source: Computed by author with data from ECAM 4 using Stata 14.

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

Notes:

2SLS_1: two-stage least squares using non-self-cluster mean of total expenditure and non-self-cluster of total expenditure squared as instruments.

2SLS_2: two-stage least squares using $[Z - E(Z)]\hat{\varepsilon_2}$ and $[Z - E(Z)]\hat{\varepsilon_3}$ as instruments.

2SLS_3: two-stage least squares using internally-generated instruments: $[Z - E(Z)]\hat{\varepsilon_2}$ $[Z - E(Z)]\hat{\varepsilon_2}$ and $[Z - E(Z)]\hat{\varepsilon_3}$ and external instruments: non-self-cluster mean of total expenditure and non-self-cluster of total expenditure squared.

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