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COPING WITH THE HETEROSCEDASTICITY IN APPLIED RESEARCH – A COMPARISON OF THREE METHODS OF FOOD EXPENDITURE ESTIMATION IN NORTHERN GHANA'S RURAL HOUSEHOLDS

PROBLEM HETEROSKEDASTYCZNOŚCI W BADANIACH EMPIRYCZNYCH – PORÓWNANIE TRZECH METOD W OBLICZANIU WYDATKÓW NA ŻYWNOŚĆ W GOSPODARSTWACH ROLNYCH W PÓŁNOCNEJ GHANIE

Key words: food expenditure, socio-demographic factors, farm features
Słowa kluczowe: wydatki na żywność, czynniki socjodemograficzne, cechy gospodarstwa rolnego

Abstract. This study explores the determinants of food expenditures in northern Ghana's rural households, using a survey data collected in 2010 in the vicinity of Tamale, the capital of the Northern Region. Three estimation methods (OLS, OLS with robust error, and WLS) are used in empirical models to address the possible heteroscedasticity. Models indicate that socio-demographic factors such as income, owning a tractor, age, and household composition are important factors in determining food expenditure. Similarly, farm features such as cultivation of staple or cash crops, the field size of groundnuts, as well as buying dry goods in bulk are also found to be major determinants. Results provide useful information for both private and public sector decision makers, while supplying ample evidence of the importance of estimation method selection to generate most accurate quantified effects of individual explanatory variables on food expenditure.

Introduction

Ghana, a West African country, has experienced substantial economic growth in recent years. The average GDP growth rate was 5.8% between 2001 and 2010, and GNI per capita (in current international dollars) [*GNI per capita…* 2012] was $1600 in 2010 [*World Development…* 2012]. The World Bank has projected that Ghana will have the fastest growing economy in Sub-Saharan Africa [*Government of Ghana…* 2012]. The accelerated economic and disposable income growth significantly stimulate food consumption in Ghana. According to the projection of the African Development Bank, total food consumption will grow from 11 to 15 percent between 2011 and 2015 [*Hungry for investment…* 2012], and per capita food consumption is projected to reach $580 in 2015, twice the expenditure level in 2009. Because the risk of fluctuations in spending power is lowered by the growth projections, Ghana's anticipated economic development is encouraging international supermarket chain expansion. For example, a long-existing local supermarket chain, started in Ghana in 1946 [*Son of India* 2011] and operating 24 stores in 2011, has been joined by a South African chain [*The supermarket Boom…* 2012].

Although emerging markets usually generate a substantial portion of business growth for food conglomerates, international retailers are reluctant to enter a new area because they lack effective market research and necessary knowledge about the dynamics of local economies [*African chains…* 2012]. Based on a survey conducted in the vicinity of Tamale in 2011, the objective of this paper is to identify the determinants of food expenditure in urban households of Northern Ghana, while assuring the accuracy of quantified effects of individual factors on food expenditure. Three approaches (OLS, OLS with robust standard error, and WLS) are used to address the possible heteroscedasticity, frequently associated with cross-sectional data, to assure that coefficients are efficient and precise. The OLS estimator is the best linear unbiased estimator (BLUE), if the

classical model assumptions, including homoscedasticity, are held. If the homoscedasticity assumption is dropped, the OLS estimator is still linear unbiased and consistent, but is no longer efficient or best, namely, it no longer has the minimum variance. As a result, the confidence interval of parameters will be unnecessarily larger, and the t or F tests are likely to indicate insignificant coefficients, which may in fact be significant [Gujarati 2003]. Policymakers concerned with reducing regional disparities and food marketers within and outside the region need the most accurate quantitative information possible for making their decisions.

Previous studies

The purpose of this study is the identification of factors and quantification of their effects on expenditures on food in rural households in northern Ghana. Previous studies provide guidance with regard to the applied conceptual framework and the selection of variables for the suitable empirical model. The strong link between food expenditures and income is well demonstrated in consumer demand theory, and food spending is always used as an important index of household economic well-being [McDowell et al. 1997] and food consumption behaviour [Muhammad et al. 2011]. Numerous studies show that food consumption is determined by household preferences, shaped by socioeconomic factors [Bittencourt et al. 2007, Ricciuto et al. 2006, McDowell et al. 1997, Frazao 1992] and demographic factors [Quaye et al. 2009, Jolly et al. 2008, Vasdekis et al. 2001, Han and Wahl 1998]. Since rural households are the focus of this study, farm features also play a key role in food expenditure determination [Mertz, Reenberg 1999].

Data and variable selection

The survey data were collected in July and August, 2010, with a total of 251 participating respondents in three districts (Savelugu Nanton, Tamale metropolis, and Tolon Kumbungu) and eighteen towns (including Kogni, Pigu, Wantugu, and others) in the vicinity of Tamale, the capital city of Northern Region of Ghana. The interview was conducted in the local language, Dabani, with the help of trained enumerators from Ghana's National Statistical Service. The surveyed households were asked to report their weekly food expenditure, personal information (e.g., income, age and education level), as well as farm features (e.g., crop type and farm size). After deleting incomplete records and two records with an unusually high reported income, 208 observations were used for estimating the food expenditure model.

Among the respondents, 82% received at least some formal education. The vast majority, 92%, were married. Only a small portion of respondents, about six percent, did not cultivate staple crops, while nearly three out of four households raised cash crops. One half of households reported buying goods in bulk, that is, they bought rice or other staples by the sack in the market or store. Only four percent owned a tractor, which is important for timely completion of some field practices. Finally, given the face-to-face interviews, it was not surprising that 83% of respondents were male. The average family was large (12 persons) and the respondent relatively young (39 years old).

The dependent variable is weekly food expenditure. The selection of explanatory variables includes those used in earlier studies (Section 2): gender, age, marital status, education, and household composition reflecting socio-demographic characteristics of the respondents; other variables such as "Income" and "Tractor" (measuring the income and wealth of the surveyed households); and four variables ("Staple crop," "Cash crop," total number of acres under groundnut cultivation, and buying dry goods in bulk) capturing farm features.

The log-linear functional form is chosen. First, after the transformation of the original dependent variable, the relationship between the logarithm of dependent variable and explanatory variables is linear, thus the model is easily estimated by the classic linear regression technique. Secondly, the slope coefficients of a log-linear model can be interpreted as semi-elasticities, that is 100 multiplied by the coefficient will give the percentage change in the dependent variable in response to one unit change of explanatory variable [Gujarati 2003].

Estimation method selection

Three tools, residuals plot, the White test, and the Breusch-Pagan test are used to detect heteroscedasticity. The results from these methods, however, are inconsistent. In the residuals plot (residuals plotted against the OLS fitted values), the points are randomly dispersed around the horizontal axis suggesting no heteroscedasticity. Given a 10% significance level, the White test supports the constant variance hypothesis, whereas the Breusch-Pagan test suggests that there may be heteroscedasticity in the error and, therefore, remedial measures are recommended.

In general, the OLS with robust standard errors and Weighted Least Squares (WLS) are the two main approaches for correcting heteroscedasticity [Gujarati 2003]. Wallace and Silver [1988] support using the regular OLS output as a comparison to check whether heteroscedasticity is a serious problem in the particular set of data.

OLS with robust errors minimizes the equally weighted sum of residual squares (Equation 1). The method adjusts the variance of t coefficients to be heteroscedastically consistent (Equation 2).

$$\sum \hat{u}_i^2 = \sum (Y_i - X_i \hat{\beta})^2 \tag{1}$$

$$Var(\hat{\beta}_{Robust}) = (X'X)^{-1} X' diag(\hat{u}_1^2, \hat{u}_2^2, \ldots, \hat{u}_n^2) X (X'X)^{-1} \tag{2}$$

WLS, a special case of the general least square (GLS), minimizes the weighted sum of residual squares (Equation 3) using the reciprocal of individual variance as weights,

$$\sum w_i \hat{u}_i^2 = \sum w_i (Y_i - X_i \hat{\beta})^2 \tag{3}$$

$$w_i = 1/\sigma_i^2 \ .$$

The variance of the coefficients is shown in Equation 4,

$$Var(\hat{\beta}_{WLS}) = (X'X)^{-1} X' V X (X'X)^{-1} \tag{4}$$

Coefficients and semi-elasticity comparison

Table 1 provides the estimation results of the three approaches (OLS, OLS with robust standard errors, and WLS). It is not surprising that the first two methods have exactly the same coefficients, because the robust OLS retains OLS coefficients, but adjusts the standard errors and affects the statistical significance. Staple crop cultivation has a positive significant effect in food expenditure in OLS, but not in the robust OLS. The WLS coefficients differ from OLS, and indicate the statistical significance of three additional variables such as "Age60," "Gnutacre," and "Education."

The application of the log-linear form assures the coefficients are semi-elasticities, which can be interpreted as the percentage change of the food expenditure in response to a one-unit change of explanatory variable. For continuous variables, the percentage change of the dependent variable is easy to compute (multiply the coefficient by 100) [Gujarati 2003]. For example, the semi-elasticity of the variable "Age3" is 10 in the WLS results indicating that an additional child (3 years or younger) will bring about a 10% increase in weekly food expenditures. Because semi-elasticity of continuous variables is directly based on the coefficients, most semi-elasticities have similarities but not identical values. For instance, the semi-elasticity of "Age61" is -22.8 in WLS, while -21.2 in the OLS or robust OLS, suggesting an additional elder (61 years old or older) will decrease the weekly food expenditures by 22.8% in WLS and 21.2% in the OLS and robust OLS. However, among these three methods, only the WLS reconfirms the crucial role of household size and groundnut planting in determining food expenditure. An additional adult (between 19 to 60 years old) will increase the weekly household food expenditure by 2.6%. Also, an additional acre under groundnut cultivation will bring a 45.2% increase in the weekly food expenditure. The differences in the size of semi-elasticities and their statistical significance have large practical effects.

Table 1. OLS, Robust OLS and WLS estimation results for the expenditure on food
Tabela 1. Wyniki obliczeń modelu wydatków na żywność metodami NK, NK ze skorygowanymi błędami i ważonej metody NK

Variable name/ *Zmienna*	Methods/*Metoda*					
	OLS/*NK*		OLS with robust std. errors/*NK ze skorygowanym błędem*		WLS/*WNK*	
	coefficient/ *współczynnik*	std. error/ *błąd stand.*	coefficient/ *współczynnik*	std. error/ *błąd stand.*	coefficient/ *współczynnik*	std. error/ *błąd stand.*
Intercept/*Przejęcie*	1.072***	0.349	1.072***	0.334	0.906***	0.307
Income factors/*Czynniki dochodu*						
Income/*Dochód*	-0.001***	0.000	-0.001***	0.000	-0.001***	0.000
Tractor/*Traktor*	0.460*	0.255	0.460**	0.179	0.483***	0.179
Socio-demographic factors/*Czynniki socjodemograficzne*						
Gender/*Płeć*	-0.219	0.166	-0.219	0.201	-0.241	0.153
Age [years]/*Wiek [lata]*	0.008*	0.005	0.008*	0.004	0.008**	0.004
– age 3/*wiek 3*	0.123***	0.033	0.123***	0.035	0.100***	0.029
– age 12/*wiek 12*	-0.006	0.027	-0.006	0.027	0.011	0.025
– age 18/*wiek 18*	-0.022	0.027	-0.022	0.025	-0.014	0.023
– age 60/*wiek 60*	0.018	0.016	0.018	0.020	0.026*	0.014
– age 61/*wiek 61*	-0.212***	0.070	-0.212***	0.062	-0.228***	0.062
Married/*W związku małżeńskim*	-0.259	0.208	-0.259	0.174	-0.237	0.173
Education/ *Wykształcenie*	0.178	0.155	0.178	0.122	0.209*	0.122
Farm characteristics factors/*Charakterystyczne elementy gospodarstwa rolnego*						
Staplec/*podstawowe*	0.424*	0.253	0.424	0.291	0.422*	0.247
Casch/*gotówkowe*	0.299**	0.126	0.299**	0.121	0.272***	0.104
Gnutacre/*1 akr orzeszków ziemnych*	0.016	0.020	0.016	0.027	0.452***	0.089
Drygoods/*Dobra suszone*	0.421***	0.106	0.421***	0.102	0.906***	0.307

Explanations: *, ** and *** significance at 10, 5 and 1% levels respectively/*Objaśnienia: *,** i *** symbolizuje odpowiednio znaczenie na poziomie 10, 5 i 1%.*
Source: own study
Źródło: opracowanie własne

For dummy variables, however, the computation of percentage changes of the dependent variable is different, and they are calculated using the Halvorsen and Palmquist [1980] procedure. Both statistically significant dummy variable coefficients and the related percentage changes in food expenditure are shown in Table 2. The OLS and WLS have similar semi-elasticity of such variables as "Track," "Staple crop," and "Cash crop." However, the WLS also indicates the significant influence of the variables "Education" and "Drygoods." Well-educated households have 20.9% higher weekly food expenditures than their counterparts only according to the WLS results. Households buying dry goods in bulk are expected to spend about 147.4% on food purchases per week suggesting that this particular purchasing behaviour will significantly affect food purchasing of farm households in response to an income increase. The result is of particular importance to supermarket chains in considering their entry or expansion into the Northern Region.

Table 2. The illustration of percentage changes in food expenditure in response to the change in a statistically significant variable by the described magnitude placed and replaced by variable and its change
Tabela 2. Wielkości zmian procentowych w wydatkach na żywność w reakcji na zmianę o podanej wielkości w statystycznie znaczącej zmiennej objaśniającej

Description/*Opis*	OLS (Robust Std. Err)/*MNK z korygowanym błędem*		WLS/*WMNK*	
	coefficient/ *współczynnik* *(c)*	example of effect/ *zmiana [%]*	coefficient/ *współczynnik* *(c)*	example of effect/*zmiana* *[%]*
Continuous variable/*Zmienne ciągłe*				
One tenth of the average income increase/ *Jedna dziesiąta średniego wzrostu dochodu*	-0.001	-1.3	-0.001	-1.3
10-year increase in age/*Wzrost wieku o 10 lat*	0.008	8	0.008	8
One additional child (3 years old or younger/*Jedno dodatkowe dziecko (trzyletnie lub młodsze)*	0.123	12.3	0.100	10
One additional adult (19-60 years old)/ *Jeden dodatkowy dorosły (19-60 lat)*	–	–	0.026	2.6
One additional elder (61 years old or older)/*Jedna dodatkowa osoba w wieku podeszłym (61 lat lub starsza)*	-0.212	-21.2	-0.228	-22.8
One additional acre of groundnut/ *Jeden dodatkowy akr orzeszków ziemnych*	–	–	0.452	45.2
Dummy variable/*Zmienne zero-jedynkowe*				
Owning a tractor/*Posiadanie ciągnika*	0.460	58.4	0.483	62.1
Having formal education/*Posiadanie oficjalnego wykształcenia*	–	–	0.209	23.2
Growing staple crops/*Uprawa podstawowych roślin uprawnych*	–	–	0.422	52.5
Growing cash crops/*Zarobkowa uprawa roślin*	0.299	34.9	0.272	31.3
Buying dry goods in bulk/*Hurtowy zakup dóbr suszonych*	0.421	52.3	0.906	147.4

Explanation: formula for calculating the effect for dummy variable pe = 100*[exp(c) -1]/*Objaśnienia: wzór na obliczenie efektu zmiennej zero-jedynkowej pe=100*[exp(c) -1]*
Source: own study
Źródło: opracowanie własne

Results

Comparing the three estimation methods presented above, the WLS is preferred over the other approaches in this particular study. Only the results from WLS are discussed because of space limitations. "Income" and "Tract" ownership are found to be significant, whereas the signals of the estimated coefficients are opposite (Tab. 1). One Ghanaian cedi (local currency) increase in income is found to decrease the weekly food expenditures by 0.1 percent. This result, negligible in terms of its absolute value, is less unexpected than it appears due to the specification of income and household type. The survey targets farm households, and the income is reported as the income earned in the month preceding the survey rather than the annual or monthly income that are commonly applied in consumer studies in post-industrial economies. Farm households, especially in lesser-developed countries, do not necessarily earn income every month, but only in the months when they decide to sell some farm production for cash. The reported income must suffice until the next sale of farm output-generating cash. Therefore, the link between the earned income and food expenditure is less obvious in the current study. However, the household wealth index, represented

by a dummy variable indicating whether the household owns tractors, is positively related to the weekly food expenditure. It appears that wealthier households do spend more on food purchases.

Among the socio-demographic factors, age, household member composition, and education are found to be statistically significant in the WLS results. Age of a respondent positively influences the weekly food expenditure. Older respondents may depend more on food purchases, because they are physically less able to raise crops, and they may receive some money in the traditional ways of interaction within households. Households with a large number of children (3 years or younger) have higher food expenditure, most likely because of the nutritional needs of growing children. However, food expenditure decreases as the number of older household members (over 61 years old) increases. Older people tend to seek less variety in foods and they are satisfied with foods raised on the farm. The number of adult household members (between 19 to 60 years old) positively affects the weekly food expenditure probably due to a large household size having a high household demand of food. The effect of "Education" of a respondent substantially increases food expenditure. Given that the variable measures any formal education, the importance of the link between education and food expenditure supports the education policy implementation by the government.

Farm features also have a meaningful influence and the WLS results show a wider effect of the features than the OLS results. The households reporting the cultivation of staple crops have higher food expenditure than their counterparts. Facing the seasonal challenge, a household planting staples needs to buy some ingredients (e.g., spices or beans) that are not grown on the farm or not grown in sufficient volume. The significant and positive link between cultivation of staple crops and weekly food expenditures could be expected with a corresponding increase in food purchases, often at higher prices during the dry season [Burney et al. 2010]. Moreover, a household cultivating cash crops (such as vegetables and tobacco) has higher food expenditures, as income from selling cash crops can be used towards food purchases. The results also indicate that a household with a larger groundnut field has higher food expenditures. Groundnut is a major crop in the Northern Region of Ghana for both self-consumption and sales. The importance of this particular crop to food expenditure is, however, unique, but enlarging the field size is limited by labor available for cultivation and harvest and the competing crops. However, it does suggest that productivity improvement, e.g., the use of higher quality seeds or better yielding varieties, would improve the household situation.

Furthermore, households buying dry goods (e.g., rice, corn, and beans) in bulk are found to spend more on food purchases. Compared with buying dry goods in small quantities, buying in bulk tends to yield relatively lower prices per unit due to the large quantity purchase (sellers grant discounts), but requires more money than a purchase of the same foods in a small volume. Moreover, a household might economize on food purchases by choosing to buy bulk foods, as this is an economically feasible option compared to raising the same volume of dry goods on farms with such constraints as land, labor, climate, or natural resources (for instance, rice cannot be grown in the vicinity of Tamale due to lack of water). Because the households buying dry goods in bulk may have a larger demand for purchased foods and higher capability to afford foods, they tend to have higher spending on food than the households buying dry goods in small quantity.

Conclusions

In recent years, disposable income has substantially increased in Ghana. However, food expenditures of farm households in less developed regions continue to be a much-understudied field. This paper investigates the farm and farmer features affecting food expenditures in rural households, using cross-sectional data collected in 2010 in the vicinity of Tamale.

Results of the study emphasize the significant role of farm features in determining food expenditures in rural households. The study provides a comprehensive consumer profile of food purchasing. Food marketers need to consider providing specific foods that ease cooking or have functional properties appropriate for older consumers, meet the nutritional needs of growing children in households with toddlers, and offer more choices to households with educated adults.

Furthermore, the results suggest that food purchase behavior such as buying dry goods in bulk was also positively associated with food expenditures. Food marketers could effectively use such information to apply suitable merchandising techniques to increase the current volume of sales and to accurately anticipate changes in consumers' food expenditures.

Since a regionally-focused food expenditure analysis is rare due to the lack of data, this study is useful to anticipate the development in the future food expenditure trends in Northern Ghana among rural households. Results provide helpful information for food marketers to make decisions about their entry into the market or investment in retail capacity. Global food chains and supermarkets have important impacts on local and regional economies and on the environment [Friedmann 1999].

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Streszczenie

Celem badań było zidentyfikowanie determinantów wydatków na żywność w wiejskich gospodarstwach domowych w Ganie, na podstawie danych z ankiety przeprowadzonej w 2010 r. w okolicy Tamale, stolicy Regionu Północnego. Aby wykluczyć heteroskedastyczność do obliczenia modelu użyto trzech metod – MNK, MNK z poprawionymi błędami oraz WMNK. Otrzymane wyniki wskazują na czynniki socjodemograficzne (dochód, posiadanie ciągnika, wiek i skład rodziny), jako czynniki determinujące wydatki na żywność. Stwierdzono, że uprawa podstawowych roślin i tych przeznaczonych na sprzedaż (np. orzeszki ziemne) oraz niektóre inne zmienne, jak np. zakup produktów suchych w ilościach hurtowych, były statystycznie istotne. Wyniki dostarczały informacji o przydatnych w podejmowaniu decyzji zarówno w sektorze prywatnym, jak i publicznym, jednocześnie podkreślają wagę wyboru metody umożliwiającej najdokładniejszą ocenę wpływu poszczególnych zmiennych na wydatki przeznaczone na zakup pożywienia.

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