ESTIMATING EFFECTS OF CONSTRAINTS ON FOOD SECURITY IN MALAWI: POLICY LESSONS FROM REGRESSIONS QUANTILES

MATCHAYA, Greenwell C*
CHILONDA, Pius

Abstract
This paper examines food insecurity in Malawi. Conceiving food security as tri-dimensional, it is shown using Quantile, logistic, and OLS regressions that food security in Malawi is a function of both supply and demand factors. Specifically, food security as proxied by dietary diversity, reported food security, and food end time is a function of farm level production as proxied by farm level incomes. It is also a function of credit accessed, age and sex of a household head, while access to the markets, extension information, radio ownership, assets such as housing and adoption of a cash crop (tobacco). Education and consumer worker ratio are also important signifying the role that knowledge and labour play in deciding household level food security. The results also show that the impact of the regressors on food security depends on the level of food security in question such that in general factors with a positive effect on food security have a greater impact on food insecure households than on households that are better off. Given the preponderance of evidence in this paper it appears that policies that seek to enhance market access, improve market opportunities, enhance extension services, enhance informal education, encourage cash cropping, and support household level consolidation of assets would be useful for enhancing household level food security.
Keywords: Food security, Malawi, Farm income, Market access, Regression Quantiles
JEL Codes:

1. Introduction

Each year a considerable amount of households in Malawi suffer incidences of malnutrition, food scarcity or general low food production. The national burden created by food insecure households can only be hypothesised to be negative as they may be unable to fully participate in economic development of the country, while the possible ailments arising from insufficient nutrition could likely impose pressure on state health resources. Food security is hence an issue of importance both at the microeconomic and macroeconomic levels. In other countries such as the United States, huge resources are transferred from the government to food insecure households. In 2006 alone, for example, federal costs for food assistance programs nearly reached $51 billion in 2006 (see Guo, 2010). Although clear figures may not be readily available for Malawi, it is evident from the donor, civil society and government rhetoric that food insecurity is a problem whose fight drains national resources.

Amartya Sen's (1981) claims that food insecurity is more of a demand concern, affecting the poor's access to food, than a supply concern, affecting availability of food at the national level (Feleke *et al.,* 2004). Based on results of a test of full/reduced model and the magnitude of changes in conditional probabilities of food security, they concluded that the supply-side variables were more powerful determinants of food security than

*Greenwell C. Matchaya, IWMISA, 141 Cresswell Road, Silverton, Pretoria; email: E-mail: g.matchaya@cgiar.org /greenwellmatchaya@yahoo.com, Pius Chilonda, Head-International Water Management Institute-SA, 141 Cresswell Road, Weavind Park, Pretoria, South Africa

demand-side variables (Feleke *et al.*, 2004). However, despite the favourable supply conditions and low food prices after the mid-1970s, the incidence of food insecurity remained high in many developing countries (Sijm, 1997) implying that food security is an issue beyond simple food supply hence motivating the study of food security determinants.

People may suffer from food insecurity because of a lack of "entitlements" or access to food, implying that food insecurity should be analysed in terms of the decline or failure of food entitlements of different socioeconomic groups (Feleke *et al.*, 2004). But supply side factors are also very important and neglecting them would be at policy's own peril. The objectives of this paper are to (1) identify the determinants of food security in Central Malawi at the household level, (2) assess the relative importance of the determinants of food security, and (3) suggest possibilities for future research.

2. Quantitative analysis of food security in Malawi

Food Security in Malawi

Food security issues in Malawi have become of more relevance post 1993 upon embracing democratic politics. Food availability has been erratic and food scarcity related deaths have been recorded in some years following erratic rainfall. The period 2001 through to 2004 stand out as examples of worst years.

Malawi is among the poorest and most food-insecure countries of the world. It has a Human Development Index (HDI) of 0.4 and an HDI rank of 171 making it one of the poorest and unequal countries in the world (UNDP, 2011). Agriculture is the anchor of Malawi's economy, employing approximately 85 per cent of the labour force, generating about 40 per cent of GDP and 90% of export earnings (of which tobacco accounts for circa 60%; tea, sugar and coffee for a about 20% (GOM, 2002)). Food security in the country is determined by both supply and demand factors.

The agricultural sector in Malawi is dualistic with an estate sub-sector and a smallholder sub-sector. The dualistic nature does not imply that there are no inter-linkages. The estate sector gets labour from the large smallholder sub-sector. The smallholder sub-sector comprises about 2 million farmers farming on customary land. The customary farming counts for 80 per cent of agricultural GDP and the smallholder sector occupies about 72 per cent of agricultural land while the estate sector and government land accounts for the remainder (Mutangadura, 2007). The smallholder sector has over time, due to population pressure, seen a reduction in land per capita from around 1 hectare at the turn of independence to a point where about 55 per cent of smallholder farmers had less than 1 hectare at the turn of the 1990s [Harvard Institute for International Development (HIID), 1994]. The smallholder sector has mainly produced food crops such as maize and groundnuts. Maize has generally been the major food crop produced, constituting over two-thirds of total smallholder agricultural production. Maize export is possible where rainfall is not erratic because irrigation is in its infancy. For example Malawi has been cited as a success story due to bumper harvests of 2007 and 2008. In the said two years good rainfall and fertilizer subsidies have brought back food sufficiency to Malawi and countries like Zimbabwe and Swaziland have benefited from Malawi's harvest through trade and aid. Today, almost all fertilizer used is imported as Malawi does not manufacture its own and the government is calling for high concentration fertilizers to curb transport costs which inflate fertilizer prices and is the reason, together with poor

access to credit, why only less than 45 per cent of smallholder farmers use fertilizer (see Kherallah and Govindan, 1999).

Estate agricultural land occupies around 12 per cent of the total arable land and produces 20 per cent of agricultural GDP. Over the years estates have been permitted to produce and market produce without restrictions while the smallholder sub-sector has been restricted with respect to crop choice, input access, marketing and land access, allegedly on the basis that they do not have the skills to produce high quality agricultural produce.

Estates generally produce cash crops such as tobacco, tea, sugar and cotton and produce about 95 per cent of the total agricultural exports. Over the years adoption of burley tobacco has led to estate expansion. The estates do grow food crops such as maize and groundnuts only for home consumption. The smallholder sector has been marked as inefficient for a long time and policy makers and academics seem to think that it is mainly customary land ownership that is behind the observed low production and inefficiency. Poor performance of the agricultural sector directly creates supply problems and indirectly creates demand problems by denying the producers access to sufficient income. These problems are attributed to both policy and non-policy variables including erratic rainfall (Wolday, 1995).

A previous study of food security in Malawi developed a food demand system model with data from the Integrated Household Survey (IHS), and concluded that calorie consumption in Malawi could be increased through policies that reduce food prices or increase household income (Ecker, 2009). A study by Lewin (2011), examined household and community factors that are associated with food security, and by evaluating public policies that are currently being implemented in Malawi: irrigation schemes, fertilizer subsidies, and agricultural extension. Whereas the concept of food insecurity has been popularised widely in time and space, a number of problems appear to stand on the way for thorough research on its determinants. As Barrett (2010) puts it succinctly, the concept remains elusive with myriad definitions all coined to fit a particular purpose. In this paper the concept is constructed in terms of the food end time for the household, food security perception dummy, and dietary diversity. These are explained in the sections that follow.

2. Theoretical and empirical foundations

Availability, access and utilization are very important hierarchal pillars that ensure household level food security (Maxwell and Wiebe, 1999). Any of these pillars is necessary but not sufficient on its own for food security (Barrett 2010). Access to food either by own production or through exchange of other commodities and services (known as entitlements in Sen, 1981) depends on access to resources, production technologies, environmental conditions, market conditions, non-market food transfers and accumulated food reserves, including coping and adaptive strategies (Chavas *et al.*, 2005, Maxwell and Wiebe, 1999). Following the 1996 World Food Summit, the prevailing definition of food security agreed upon holds that it represents a situation when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (see Maxwell and Wiebe, 1999; Barrett, 2002). Such a broader definition covers more than simply household level nutritional status, capturing vulnerability to future changes in access to adequate and appropriate food as well (Barrett, 2010). The complex nature of food

security calls for constructs that are composite in order to capture the quality, quantity, vulnerability and sustainability aspects that show up often in studies.

Some indices that can be used include food expenditure at the household level, dietary diversity measure (considering that nutritional security is an integral part of food security), underweight, under-nutrition and malnutrition incidences, levels of reported consumption, levels of reported food insecurity, and levels of production at the household level. In most studies, the choice among indicators involves trade-offs, so that the objective necessitating measurement commonly drives the choice of indicator. Expenditure on food is an important indicator of food security too because it also captures the concept of vulnerability to food insecurity (see Farid and Wadood, 2010; Hendriks and Msaki, 2009). Higher expenditure proportions are essentially indicative of inter-temporal vulnerability to food insecurity (Farid and Wadood, 2010). To capture some of the food security dimensions mentioned above, the food security variable ought to be constructed as a scale that will proxy different levels of food security. Such a scale could be computed by aggregating household level responses to questions on malnutrition incidences, food deficit incidences, future availability worries, eating of balanced diets, diversity of foods eaten per week, and weekly expenditure on foods (see Guo, 2010; Bickel *et al.,* 2000). If deemed appropriate, these could be scored and aggregated into a composite index that would be monotonic where higher numbers represent food security and lower numbers represent food insecurity. Alternatively different measures can be used in estimation and results can be compared across estimation techniques.

3. Statistical and Econometric Analysis

The common practice in the study of food security is either to use economic theory of consumers to derive price and income elasticities for consumed foods based on reduced-form calorie demand equations or to identify the likelihood that a household is food insecure, based on home-energy production. When the later approach is followed, the next step is to estimate the determinants of food insecurity using reduced-form models, which in turn allows evaluation of the effects of household level as well as other factors (Lewin, 2011). In view of this, to estimate the factors that influence food insecurity at the household level in the areas under study, we first adopt the general household decision problem due to Sadoulet and de Janvry (1995) in which it is theorised as one which integrates production, labour and consumption decisions simultaneously. The standard optimisation results of the decision problem in Sadoulet and de Janvry (1995) includes a general household level reduced form food demand equation (assuming that households desire to maximize utility) of the form:

$$z_1 = Z(p, q_c, q_v, w, R, D_a, D_z) \quad (1)$$

Where z_1 stands for household level food demand, p, q_c, q_v, stand for a general price index in a region, local prices for agricultural outputs, local farm input prices, w, stands for wages, R, stands for non-labour income whereas D_a, and D_z stand for other factors not related to prices, but which could affect agricultural production, purchasing power and preferences (Lewin, 2011). Incorporating the household characteristics that shape its preferences is important in the study of the determinants of food security determinants.

To understand the factors that influence food security at the household level therefore we propose to estimate a model of the form

$$Y^*_i = \beta_0 + \sum_{i=1}^{k} \beta_j X_{ij} + e_i \quad (2)$$

Where, Y^*_i, represents the household level food availability, e_i represents an error term whose distribution could follow any structure depending on the nature of the dependent variable Y. The linkage between (1) and (2) is such that if household level food needs falls below some minimum (z_{min}), then the household is food insecure. So the factors that determine Y_i also affect whether z_{min} is surpassed or not. In the estimation that follows later, in the X matrix,

*X*1 is income from farm sales per capita; *X*2 is credit accessed per capita; *X*3 is off farm income per capita; *X*4 is land holding per capita; *X*5 is radio ownership; *X*6 is good house ownership; *X*7 equals 1 if the main house is a poor house; *X*8 is consumer-worker ratio for the household; *X*9 is distance to the market or any good road; *X*10 is age of the respondent; *X*11 education of the respondent; *X*12 is the gender of the respondent; *X* 13 is tobacco adoption; *X*14 is bicycle ownership; *X*15 is extension services accessed by the household;

These variables are identified from the consumption and production behaviours of the household and hence they are selected to capture purchasing power, farming ability, household demand, and ability to access goods that are not produced by households. If Y^*_i is observed as a continuous variable, then food security can be analysed using continuous dependent variable models such as the Ordinary Least Squares (OLS) regression of the form in (2) assuming $E(e \mid X) = 0,$ no linear dependence and spherical errors ($Var(e\ ) = \sigma^2 I$)). In that case the betas are calculated using the familiar $\beta_{estimate} = (X'X)^{-1}X'y$

In literature, more often food security is constructed as a dummy variable comprising of a score of 1 when the household is food secure and 0 when the household is food insecure. This is often as a result of data limitations. The binary nature of Y_i motivates the use of discrete choice models such as the logit and probit models depending on whether an assumption is made that the e_i follows a logistic distribution or a standard normal distribution, respectively (Wooldridge, 2002).

It should be noted that while food security is of significant concern worldwide, estimated prevalence rates and patterns remain unconvincing because the concept remains elusive whereas its measurement remains difficult (Barrett, 2010). The dichotomy inbuilt in the food security dummy variables rampant in literature may be one reason why studies often get conflicting results on determinants of food security. The dichotomous nature could, for example mask some important information leading to a significant loss of statistical precision (Fedorov and Wu, 2007). Measurement of food security is hence just as important as estimation of what drives its incidence. Deriving conclusions from carefully chosen food security proxies would be more useful than relying solely on single proxies.

Again, national food availability measures of food security mask a lot of heterogeneity within the countries and studies that target information from households are very important (Barrett, 2010). Moreover it is also established in literature that food security measures based on household and individual data consistently generate higher estimates of food insecurity than those derived from more aggregate data apparently, not only in intra- and inter-household nutrient distribution but also in the resulting estimates of nutrient availability (Barrett, 2010).

Where the food security variable is dichotomous, the logit model is used in the analysis. The dependent variable in (2) is transformed such that $K_i=1$ if the household is food secure ($Y^*_i>0$) and $K_i=0$ for food insecure households ($Y^*_i=<0$).
The standard logit model used is summarized as follows

$$\Pr(K=1)=\Pr\left(\beta_0+\sum_{j=1}^{K}\beta_j X_{ij}+e_i>0\right) \quad (3)$$

So that the logistic model of food security in terms of conditional probabilities following Wooldridge (2002) can be written as

$$\Pr(K=1)=P=\left(\frac{Exp(\beta_0+\sum_{j=1}^{K}\beta_j X_{ij})}{1+Exp(\beta_0+\sum_{j=1}^{K}\beta_j X_{ij})}\right) \quad (4)$$

The marginal effects are then calculated as

$$\partial P_i/\partial X_{ij}=P_i(1-P_i)\beta_j \quad (5)$$

In models that use continuous constructs of food security, Ordinary Least Squares (OLS) and quantile regressions were used to estimate the determinants of food security. Unlike discrete choice models, Ordinary Least Squares and Quantile Regression (QR) models are more appropriate in this case because of the presence of a continuous dependent variable, whereas quantile regressions may further serve to reveal the differential impacts of explanatory variables at different quantiles of food security, while also being robust to the distributional assumptions that often bedevil estimation in OLS models (see Koenker and Basset, 1978). The latter should also be viewed as this study's strength as previous studies have been limited to discrete choice and OLS models which may not only be biased due to violation of normality and constant variance assumptions, but only estimate the mean, which may not *per se* give a good account of how variables affect food security at other levels of distribution. Below follows a discussion of the quantile regression technique employed herein.

The quantile regression

As per Koenker and Basset (1978), a quantile regression is a method of estimating functional relationships between variables for all portions of a distribution function. The fact that it can be used to characterise the entire conditional distribution of a dependent variable conditional on a set of regressors is also often seen as an advantage over the OLS estimator (Buchinsky, 1998). In a quantile regression setting, a specified conditional quantile of the response variable is expressed as a linear function of subject characteristics (Austin *et al.,* 2004). It is better than a simple regression model which estimates such relations only at the mean. The advantage becomes conspicuous in the event of skewness in the data such that the mean does not represent values in the tail end of the distribution. Mosteller and Turkey (1977) also noted that it was possible to fit regressions to different parts of the distribution function although this was not being done at the time hence leading to results that did not give a representative picture of the effects of factors on response variables.
Quantiles are estimated through linear programming by an optimization function minimizing the sum of weighted absolute deviations where the weights are asymmetric functions of the quantile (Koenker and Basset, 1978; Koenker and d'Orey, 1987).

Focussing exclusively on the means as in OLS regressions, may underestimate, over-estimate or even fail to distinguish real nonzero changes in heterogeneous distributions (see Terrell *et al.*, 1996; Cade and Noon, 2003). The quantile regression (also called the least absolute value deviation model) becomes advantageous if other potentially useful variables have been left out in the model, yet this would simply yield inconsistent estimates with OLS regressions. The technique is useful too when the normality assumption does not hold, as well as in the face of outliers. The Median regression is an example of a quantile regression with Q=0.5 and it estimates the median and not the mean which can be wrong in the presence of outliers. The interpretation of the coefficients for the quantile regressions is not different from those from the OLS. The coefficients are interpreted as the change in the given percentile of the conditional distribution associated with a one-unit change in the given characteristic (see Austin *et al.*, 2004). It should further be noted that the quantile regression technique is semi parametric in that no distributional form is assumed for errors, although one can make some assumption about the deterministic part of the model i.e. the $\boldsymbol{a} + \boldsymbol{xb}$ portion (Cade and Noon, 2003).

This paper ultimately employs the following quantile regression

$$Q_{y_i}[\tau \mid x_{ij}] = \beta_0(\tau) + \beta_1(\tau)x_{1i} + \beta_2(\tau)x_{2i} + ... + \beta_k(\tau)x_{ki} \quad (6)$$

where $Q_{y_i}(\tau)$ denotes the tau-quantile of the conditional distribution of y_i. Thus, the regression parameter $\beta_k\tau$ denotes how the specified quantile changes with a one-unit change in x_k. The estimation of this model using the procedure in Koenker and Basset (1978) is said to underestimate standard errors when the errors have heteroscedastic distributions of error variances in which case one has to use bootsrap standard errors (see Koenker and de Orey, 1987).

Possible endogeneity/simultaneity of income, credit and cash crop production

To estimate the independent effect of, say, income on food security status, ordinary-least-squares (OLS) estimates may only be unbiased if auto-correlation between the error term and all explanatory variables is ruled out. For farm income in the food end time, dietary diversity and perception of food security regression, such a correlation may exist. For instance, some unobserved influence, such as farming ability, could influence both household food end time or dietary diversity and household income, and so the explanatory variable (farm income) would be correlated with the error term. Again, rural household behaviour when markets are perfect implies separability between production and consumption decisions (Singh *et al.*, 1986). Under such conditions the household can solve sequentially first its production problem, and then allocate the full income obtained to consumption choices (Vakis *et al.*, 2004). On the other hand, production and consumption decisions are non-separable in the presence of market failures. In the presence of market failures this case, factors that affect consumption decisions (for instance wealth, labour endowment, as well as household characteristics affecting consumption) also affect production decisions. Although the food security models are not per se, consumption models, they have elements of consumption decisions. Under imperfect markets, such decisions may be related to production decision through the factors that determine consumption and production-some of which may be similar. In the models estimated herein, cash crop decisions for example could be explained by labour endowments, land, wealth and other factors that may also affect consumption.

OLS without any instrumentation or any econometric precautions would yield biased and inconsistent estimates (Wooldridge, 2002). Using Durbin-WU-Hausman tests for endogeneity, these concerns are fortunately not established and hence results are presented based on real and not predicted values of farm income, credit income, tobacco adoption and assets. Models with predicted values of these variables were fitted and yielded identical results to the ones without predicted value of regressors. In other words predicted values of income, tobacco adoption and credit used to deal with potential endogeneity in all the estimated models (Garrett and Ruel, 1999) did not change any qualitative or quantitative conclusions drawn in this study. While this may imply absence of non-separability in farm household decision making, it is attributable to the fact that the dependent variable 'food security' is not entirely consumption, but is constructed such that it has other elements of food security apart from consumption.

3. Data Sources and variable measurements

Data for this research was collected through a survey by use of questionnaires (as tools for organizing interviews) in 2005 with mostly close-ended questions to permit collection of quantitative data for econometric analysis. Questionnaire administration was done with the help of enumerators from Bunda College of Agriculture, which is a constituent college of the University of Malawi.

Enumerators were given a weeklong training on how to administer the questionnaire, how to report any strange observations to the field supervisor (the author) and how to verify any suspicious information. The data collection instruments were pre-tested (piloted) on 10 randomly drawn households from the Kasungu central area to be able to avoid overlooking some important issues and this afforded the study an opportunity to make any necessary changes to the questionnaire. The sample used in the pilot study did not form part of the final sample.

The collection process followed focus group discussions and informal interviews with village level opinion leaders and officials from the Ministry of Lands and Physical Planning to enhance the authors' understanding of agricultural production issues as understood by those interviewed. In-depth interviews were conducted with farmers selected to represent as wide a range of different land tenure and social statuses as possible (see Broegaard, 2005 for maximum variation sampling). The implied sampling followed was purposive and organized in stages because, while theoretically attractive, completely randomized sampling does pose the risk of excluding other important aspects of the study (see Smith, 2004 and Place and Otsuka, 2001).

Multi-stage sampling was hence used to select the study units whereby the Kasungu district was purposively chosen because of its high agricultural potential. Specifically, within the Kasungu district, the areas of Chulu, Wimbe, Chamama and Lisasadzi were purposively chosen and censuses of households in all villages selected from these areas were obtained from village headmen secretaries and these formed the final sampling frame from which 25 households were selected at random from each village. To do this, names of each household (in most cases available from the village secretary or chief) were written on small papers. The small papers were then placed in a plastic container, and one of us would shake the container until it was felt that the papers were fully mixed. The required number of papers was then drawn from the container and these formed the sample. The list of variables is the following one, and a more detailed description is included in the Annex.

Food Security (y_i): In this paper food security indicators chosen are threefold: 1) Food security is constructed as a measure of dietary diversity whereby households were asked to recall and report the kind of foods they had eaten over the past week and the past two weeks. It was explicitly required of them to report on whether they ate roughly balanced diets in terms of whether they their consumptions included meat, beans, fish, vegetables, *Nsima* (thick porridge made from maize, Malawi's main dish), and fruits. They were also asked to report quantities of the foods in terms of number per individual for the case of fruits, number of fish and sizes, rough weight of fish, and quantity of nsima or rice or cassava and beans consumed. Data on consumption of pumpkins, groundnuts, sugarcane were also collected. These data were then aggregated into a monotone index spanning 0 to 2 where higher values implied a higher level of food security and lower values implied food insecurity. 2) Secondly, food security is indicated by the household's reported duration of own food. The rationale is that households whose food lasts early after harvesting will likely be food insecure in the months to come all factors being equal. This is constructed as a continuous variable in months and again, higher values are indicative of food security whereas lower ones are indicative of food insecurity. 3) Lastly, food security is proxied by household level own reported perception of food security. Households were asked whether they felt that they would face days without consuming food in the near or distant future, or whether they had already done so in the recent past. Those households that reported that they would or had spent a day without food or with too little food were coded as 0 (insecure) and the rest as 1 (secure). These three measures are then used to estimate food security using ordinary least squares (OLS), Logit models, and Qauntile regressions.

Household farm level income per capita: The farm level income is measured in terms of the household level income for the previous sales season.

Household access to credit per capita: Credit access is measured by the reported amount of credit the household gets formally or informally.

Household level off-farm income per capita: Off-farm work is measured based upon the household's reported amount of money they get from an off farm job. The expected effect on food security (*yi*) is positive.

Age of the respondent: Although young families may be associated with low dependency ratios, the dynamic nature of the youth considered with the fact that they are less experienced suggest that the effect of age of the respondent on household level food security is an empirical question

Sex of the respondent: Gender (male =1, female=0) of the respondent may be related to food security through access resources, as well as through knowledge. It is generally believed that women in Africa have poor access to resources, but studies have also shown that women do more to help their household meet basic food needs. They may be allocating a good share of resources to basic necessities at the household level and hence ensuring a health life. Women may have superior managerial skills (Chavas *et al.*, 2005), but are also burdened by child care, household maintenance, and economic production. It is hence expected that the relationship between gender and food security is an empirical question.

Education of the respondent: Educated (measured as 1 for schooling up to standard 8 and 0 for schooling up to standard 5) farmers will have good access to price, nutrition,

rainfall as well as farming information through newspapers and other sources unavailable to less educated ones. Education is expected to positively impact food security.

Asset ownership (bicycle): In rural areas transportation to distant places is difficult and bicycle ownership would ease travel to markets and other destinations of agricultural or nutritional importance. Bicycle ownership is hence expected to positively affect food security.

Asset ownership (radio): A radio is important in information dissemination and owning it would make the farmer more aware of issues in farming and marketing. It is hence expected that radio ownership is positively related to food security.

Asset ownership (main house is a good house with iron sheets): It is expected that ownership of a good house (bricks, cemented, corrugated iron sheets without any major leaking,) is indicative of asset and wealth holding of the household. Wealth would be expected to positively impact on food security (see Guo, 2010).

Asset ownership (main house is thatched): If the main house for the household is only thatched without other features as discussed previously, such a household may be said to have lower levels of wealth and hence are likely to be food insecure.

Security of land tenure (in terms of size and expropriation potential): Security of land holding is a composite measure of an index of farm size held by the household and whether it is held uncontestably. Households with secure and larger farms should have a higher probability of being food secure, since farm size is positively associated with cash crop income (Tschirley and Weber, 1994). Security of land tenure is hence expected to be associated with food security, positively.

Extension services available to the household: Extension services are proxied by the number of visits that an extension worker has visited the household. It is expected that extension visits provide farmers an opportunity to get useful information on input and output prices, farming techniques, health consumption and other forms of farm and nutritional advice. It is expected that extension services would be positively related to food security.

Market proximity (Distance to markets/trading centre from the household): The longer the distance to the market, the less frequently the farmer visits the market and, hence, the less likely they are to get market information (Staal *et al.,* 2002; Fekele *et al.*, 2005). Lack of adequate information about prices, farmers may sell their produce at times when prices are low and buy when prices are high. It is expected that food security (*yi*) is negatively related to distance to the market.

Dependency (consumer worker ratio at the household): This is calculated as household size divided by number of people who contribute to the household's labour supply. The international dependency ratio formulation of dependants per worker can be derived from this definition by subtracting unity. The dependency ratio herein is defined as:

$$DR_c = \frac{w+d}{w} = 1 + \frac{d}{w}$$

where *DRc* is the dependency ratio and *w* and *d* are workers and dependants (children who are less than 10 years and older people who are over 65 years) respectively. The international definition is equivalent to DR_c *-1*. A higher dependency ratio implies that there is less production per individual in the household and consequently it is expected that dependency should be negatively related to food security.

Cash crop orientation (tobacco farming indicator): The effect of tobacco farming on household level food security is an empirical question because while tobacco farming has the potential to increase household incomes and boost household potential to purchase food, it also has the negative effect on food production.

4. Results and Discussion

Descriptive results: The sample had 46.5 % insecure households while 53.5% were secure. Considering food security in three categories namely very secure (for those who had the largest dietary diversity), secure for the second diverse group and insecure for those whose diets were undiversified, the means for selected variables are presented. Table 1 shows that secure and more secure households had generally larger values of credit accessed, farm income, land, off farm income, and labour force. They had lower values of distance to the market, age of respondent, and dependants.

Table 1: Variable means by food security (dietary diversity)

group variable	Mean	Std. Err.	group variable	Mean	Std. Err.
	Dependants			Land holding	
insecure	4.9	0.33	insecure	5.6	0.5
secure	4.9	0.45	secure	6.8	1.2
very secure	3.9	0.26	very secure	5.8	0.6
	Age of respondent			Credit amount	
insecure	39.8	1.85	insecure	2344.4	1105.1
secure	38.5	2.63	secure	2561.3	729.6
very secure	38.3	1.23	very secure	7949.7	1208.5
	Farm income			Food end time	
insecure	20497.7	3737.60	insecure	5.4	0.3
secure	34629.0	9216.49	secure	5.5	0.4
very secure	43082.3	6158.76	very secure	6.1	0.2
	Off farm income			Adults	
insecure	9855.2	1584.13	insecure	5.7	0.36
secure	7793.2	2722.00	secure	6.5	0.51
very secure	10016.3	1813.05	very secure	6.6	0.25
	Land holding per capita			Log of distance	
insecure	1.6	0.30	insecure	3.2	0.05
secure	1.9	0.26	secure	3.1	0.06
very secure	2.2	0.17	very secure	2.9	0.03

The data further show that 93 (46.5%) of the 200 households were food insecure as derived from the household's own reports of food security, whereas the remaining 107 (53.5%) were secure. Once food security is proxied by dietary diversity, the sample reveals that at the time of data collection (the data were collected from July i.e. soon after the harvest season), the data shows that 62 (31%) of the households were insecure, 31 (15.5%) were just secure whereas the remaining 107(53.5%) were very secure. Despite that this was a harvesting season, it is interesting to note that the self-reported food perceived security statistics correlates well with the one derived from the measures of dietary diversity. Again, once the duration of own food availability is used as a proxy for

food security, the data show that on average own produced food in the sample lasted for about six months after harvesting whereas the least time was 0 months (the household harvests nothing substantial) and the longest duration is calculated as 9 moths (with the potential that the food of the previous season coincides with harvest of the current season). Cross-tabulations show that households whose own food lasted 5 or fewer months amounted to 98 (49%) which is also close to the predicted food insecurity of 46.5% from the previous measures (if an assumption that any household whose own food lasts less than 6 months is insecure is made). While the results in Table 1 may be suggestive of the possible correlation between the variables under study and food security, to see the true effects of these variables on food security a multivariate analysis is important in order to control for many other variables that could influence the outcome of food security. The results that follow present estimates from multivariate analysis.

Multivariate Results

The data are analysed using STATA 11, a statistical package that, although is widely used in medicine, has now gained popularity among social scientists. The program routinely estimates many models including OLS, Logit and quantile regressions. The analysis results are presented below.

Table 2 Factors that affect food security measured by a dietary diversity index (OLS)

Food security	Coef.	S.E. (White-Huber).	P>t	Mean
Log farm income per capita	0.24**	0.12	0.05	2.14
Log credit per capita	0.08***	0.03	0.01	1.93
Log off farm income per capita	0.00	0.01	0.85	6.25
Log Age of respondent	-0.01	0.00	0.19	38.55
Sex of respondent	0.08	0.16	0.61	0.86
Education of respondent	0.28**	0.12	0.03	0.67
Bicycle ownership	0.01	0.14	0.92	0.73
Radio ownership	0.32**	0.15	0.03	1.21
Log Land secure per capita	0.16	0.15	0.28	0.83
Poor thatched house	-0.06**	0.03	0.02	1.80
Extension	0.17*	0.10	0.09	0.57
Log of distance	-0.50***	0.16	0.00	3.02
Log Consumer –worker-ratio	-0.32**	0.13	0.02	0.79
Good house	0.04	0.09	0.67	0.95
Tobacco farming	0.08	0.20	0.68	0.84
_cons	1.80	0.64	0.01	
F(15, 184) =6.75, Prob > F=0.001;F(0, 189) =0.00, prob >F=.; Adj R-squared = 0.301; Adj R-square for restricted model=0.00. S.E.= Standard Error.				

The standard errors are based on heteroskedasticity robust standard errors (White, 1980). The *F* and Adjusted R-squared statistics are used to test the dependence of food security (measured as dietary diversity) on the selected variables in the model. Under the null hypothesis ($H0$) where there only one parameter, which is the intercept ($\beta 0$), the values of the restricted *F* and Adjusted R-squared functions are 0.00, and 0.00 respectively, while under the alternative hypothesis ($H1$) where the model has all the parameters, the value of the unrestricted *F* and *R*-squared functions are 6.75 and 0.30 respectively (Table 2). The implications of the parameter estimates are estimated below:

Household farm level income per capita: The coefficient of farm level income from sales of crops from the previous season has the expected sign and a value of 0.24 and is statistically significant at the 1% level. This implies that farm level incomes are important in explaining dietary diversity as a measure of food security. Farm incomes further indirectly proxy the effect of household level market access on dietary diversity (food security), which makes intuitive sense especially that some goods consumed by the household are market purchased. Well integrated households may be associated with higher incomes leading to an improvement in their food security status.

Household access to credit per capita: The coefficient of household's access to credit is 0.08. It has the expected positive sign and is statistically significant at the 1 % level. This implies that households that are not socially excluded (have access to credit) are likely to be characterised by diverse diets due to the augmenting effect that credit has to household level incomes. The positive and significant sign shows that social supports influence food security by providing access to food or production resources (Bernell *et al.,* 2005).

Off-farm income, gender, age, means of transport, tobacco, housing and land: While it would be expected that off-farm work, gender of the respondent, age of the respondent, an indicator of land holding, bicycle ownership, ownership of a good house and tobacco adoption would significantly affect diversity of household level diets, the data do not provide enough evidence to reject the null hypothesis that these variables are ignorable in the food security equation, a result that appear frequent in OLS based models in literature seeking to establish the relationship between food security and these factors. Interestingly, most of these factors are significantly different from zero in the models that follow below.

Education of the respondent and Asset ownership (radio): The coefficient of education has the expected positive sign and statistically significant. The coefficient of 0.28 implies that a discrete change of the education variable from low education to higher education is associated with a 0.28 increase in the food index. Educated farmers often have good access to price, nutrition, rainfall as well as farming information through newspapers and other sources unavailable to less educated ones, which impact their food access and consumption decisions positively. Assets such as a radio are important in information dissemination and owning them positively impact household level food security. The coefficient for radio ownership is 0.32 and is statistically significant.

Asset ownership (main house is thatched): Poor housing is an indicator of household level lack of wealth and as expected, the coefficient of thatched houses is negative (-0.06). The coefficient's sign and statistical significance shows that poor housing is negatively correlated with food security. This is in line with Guo (2010) who find that such wealth proxies would be expected to significantly impact on food security.

Extension services available to the household: The household's access to extension services boosts the household's food security (dietary diversity) as expected. Extension visits provide farmers an opportunity to get useful information on input and output prices, farming techniques, health consumption and other forms of farm and nutritional advice which could explain the positive and statistically significant coefficient of 0.17.

Market proximity (Distance to markets/trading centre from the household): Distance from the household to the nearest urban centre/trading centre, or some market/ or in case of absence of all these, distance to the nearest good road (all measured in kilometres), can proxy market goods and information access. The coefficient of distance to markets is -

0.50 and is statistically significant. The longer the distance to the market, the less frequently the farmer visits the market and, hence, the less likely they are to get market information and goods/commodities (Staal *et al.*, 2002; Fekele *et al.*, 2005) and the negatively food security is affected.

Dependency (consumer worker ratio at the household): A higher dependency ratio implies that there is less production per individual in the household and consequently it is expected that dependency should be negatively related to food security. The coefficient of this variable is -0.32 and is statistically significantly different from zero signifying that overburdened households face food insecurity. Food security is also proxied by the reported food security at the household level and it is of use to compare the qualitative results from the previous measure of food security and the subjectively reported measure which is evaluated via a different framework-a discrete choice model other than the previous OLS model.

Table 3 Reported Food Security (Logit results)

Food security	Coef.	S.E.	P>z	dy/dx	S.E.	P>z	X
Log farm income per capita	0.76*	0.40	0.06	0.19*	0.10	0.06	2.14
Log credit per capita	0.29***	0.09	0.00	0.07***	0.02	0.00	1.93
Log off farm income per capita	0.00	0.05	0.98	0.00	0.01	0.98	6.25
Log Age of respondent	-0.03*	0.02	0.09	-0.01*	0.00	0.09	38.55
Sex of respondent	0.18	0.54	0.73	0.05	0.13	0.73	0.86
Education of respondent	0.67*	0.40	0.09	0.17*	0.10	0.09	0.67
Bicycle ownership	0.19	0.44	0.67	0.05	0.11	0.66	0.73
Radio ownership	1.26**	0.50	0.01	0.31**	0.12	0.01	1.21
Log Land secure per capita	0.52	0.47	0.27	0.13	0.12	0.27	0.83
Poor thatched house	-0.22**	0.09	0.01	-0.05**	0.02	0.01	1.80
Extension	0.49*	0.12	0.10	0.12*	0.05	0.10	0.57
Log of distance	-1.62***	0.51	0.00	-0.4***	0.13	0.00	3.02
Log Consumer–worker-ratio	-0.75	0.55	0.17	-0.19	0.14	0.17	0.79
Good house	0.48*	0.29	0.10	0.12*	0.07	0.10	0.95
Tobacco farming	-0.10	0.67	0.88	-0.02	0.16	0.88	0.84
_cons	2.15	2.03	0.29				
Log likelihood	-138.139	Model $\chi 2$ Statistic for LR test			72.57,		P<0.00

The results from the latter model are discussed below: The likelihood ratio $\chi 2$ statistic is used to test the dependence of food security on the selected variables in the model. Under the null hypothesis ($H0$) where we have only one parameter, which is the intercept ($\beta 0$), the value of the restricted log likelihood function is -138.139, while under the alternative hypothesis ($H1$) where we have all the parameters, the value of the unrestricted log likelihood function is -101.854 (Table 3). The model $\chi 2$ statistic amounts to 72.57 and is highly significant ($p < 0.001$) with 15 degrees of freedom, indicating that the log odds of household food security are related to the independent variables. The pseudo r-square calculated is 0.26 which is high for cross-sectional data too. Based on a simple correlation analysis, there are no strong correlations among the independent variables as most of the correlation coefficients are statistically insignificant implying that multicollinearity is not a problem in the model. With regard to the predictive efficacy of the model, of the 200 sample households included in the model, 155 or 77.5% are correctly predicted. Of the

200 observed households in the sample, 107 are food secure (53.5%) of which 86 or 80.37% are correctly predicted by the model. The other 93 households are food insecure (46.5%) of which 69 or 74.19% are correctly predicted by the model. The coefficients from the logistic regression have the predicted signs and most of them are statistically significant from zero. Marginal effects calculated as previously discussed are more useful as they may offer some information about the per cent changes in the food security variable following a 1% change in the regressor. The marginal effects from the logistic regression are reported in the 5th column under the title dy/dx. The discussion below is based on these.

Household farm level income and Household access to credit: The marginal effects show that a 1 % increase in farm level incomes yields a 0.19 % increase in household level food security. This implies that there is no one-to-one relationship between farm level income and food security status of the household and in fact strictly speaking, food security is farm level income inelastic as income has to increase more to yield a lower increase in food security. This makes intuitive sense and supports the very definition of food security which encompasses not only means to food acquisition (purchasing power), but includes utilization as well. Incomes are however important in the food security equation and other factors being equal, income rich household may be more food secure than otherwise. This is also the case with household level access to credit, which is associated with an elasticity of 0.07 providing further support to the role of social support in influencing food security by providing access to food or production resources (Bernell *et al.,* 2005). An index for off farm income is however not significant again in this model hence the hypothesis that off farm income may not be important for food security is not rejected.

Age of the respondent: In all the model experiments that included age a non-linear variable age-squared was also entered to examine the nonlinear effects that age could have on food security. However, only age in its linear form gave significant results. In this model, young farmers appear to be more food secure. The food security elasticity of age of a respondent is 0.01 implying that a 1% increase in age from the average age of 38.55 years is associated with a 0.01% reduction of household level food security. This in some way provides support to the human capital thesis that young farmers may be dynamic and energetic which makes it easy for them to access markets and information. This implies that despite their low experience about certain agricultural operations, young farmers still tend to be food secure. Interestingly, sex of the respondent appears ignorable in the food security status of the household and so are bicycle ownership, land holding, consumer worker ratio, and tobacco adoption.

Education of the respondent, Asset ownership (radio) and Extension services: A discrete change from poor education to good education is associated with a 0.17% increase in food security status of the household whereas radio ownership is associated with a 0.31% increase in food security and other means of knowledge dissemination (extension services) are associated with a 0.12% increase in food security. These results confirm the study's prediction of signs and further uphold the now much touted role of formal and informal education and information in general, in ensuring food security in educated farmers will have good access to price, nutrition, rainfall as well as farming information through newspapers and other sources unavailable to less educated ones. Education is expected to positively impact food security

Market proximity (Distance to markets/trading centre from the household): Interestingly, although not unexpectedly, market proximity as measured by locational distances from market centres or roads is highly significant with a very higher elasticity. The results show that a 1% increase in distance from the household to markets is associated with a 0.4% reduction in food security of the household. This is possibly so because the longer the distance to the market, the less frequently the farmer visits the market and, hence, the less likely they are to get market information (Staal *et al.*, 2002; Fekele *et al.*, 2005). Lack of adequate information about prices, farmers may sell their produce at times when prices are low and buy when prices are high, decisions which compromise the household's food security status.

Asset ownership (a good versus poor house versus an average house): The reference category in this case is households whose main houses are average households which may have bricks but without cement or corrugated iron sheets but better than muddy thatched houses. Owning a good house as the main house is associated with an increase in food security situation of 0.12% whereas having a very poor house as a main house for the household is associated with a food security reduction of -0.05%. Ownership of a good house is indicative of asset and wealth holding of the household. A household's level of resources can be expected to affect its ability to survive sudden changes in production, prices, income, or unforeseeable events that create the need for additional expenditures (see Guo, 2010). The results presented above, which are obtained using the dichotomous choice logistic model and the OLS model are informative and the results presented make intuitive sense. Most of the general conclusions that emerge from the preceding analysis are similar to those that are widely available in literature. The uniqueness of the present approach is that despite using different measures of food security and using different analytical frameworks the conclusions about the possible determinants of food security are similar.

The above work as well as work from previous researchers has helped shape the current understanding of how to empirically test factors that may affect food security, however, perhaps die to the paucity of data for proxying the food security variable, most previous work has concentrated too much on using logistic models and in some cases simple OLS frameworks without worrying paying attention to two potentially policy relevant issues namely; 1) It is important that the differences in conclusions about potential determinants of food security that are evident in literature may be due to the fact that analytical models restrict estimation to certain functional forms. For instance in the event that neither an OLS nor a logistic model are the correct models underlying the generation of food security or lack thereof, estimated parameters may be misleading. 2) Secondly, even everything aside, the previous estimation methods do not pay cognizance to the possibility that regressors may have different effects on food security depending on the level of food security in question. OLS and binary choice model frameworks only estimate one coefficient per regressor, which is at best an average susceptible to influences from outliers and other forms of noise. What would be useful is to estimate the effects of explanatory across the entire distribution of the dependent of the variable.

Such analysis is important not only from the perspective of econometric correctness but for purposes of policy. If coefficients for a particular policy variable differ in different quantiles of the food security variable, it implies that a blanket policy change seeking to address issues of food security will have different effects on different households conditional on their position on the distribution of the food security variable.

Table 4: Simultaneous Quantile-regression results with bootsrap standard errors (log of food end time in months)

	q20	q30	q40	q50	q60	q70	q80
constant	1.423	1.225	1.052	0.938	0.901	0.938	0.896
t	4.22	4.82	4.85	6.24	7.9	9.95	10.65
Log Age	-0.006	-0.006	-0.005	-0.005	-0.005	-0.006	-0.005
t	-4.64	-4.3	-4.03	-4.69	-6.11	-7.98	-7.23
Log Cw-ratio	-0.799	-0.694	-0.524	-0.481	-0.415	-0.416	-0.388
t	-2.96	-3.05	-2.81	-3.39	-3.8	-4.24	-5.17
Tobacco	0.039	0.095	0.132	0.110	0.123	0.079	0.082
t	0.27	1.06	1.94	2.21	3.07	2.06	3.02
Education	0.319	0.263	0.281	0.256	0.250	0.250	0.234
t	5.02	5.33	8.68	10.14	11.05	12.3	12.91
Extension	0.138	0.147	0.128	0.141	0.147	0.153	0.148
t	3.05	4.43	5.39	7.22	8.83	14.13	12.74
Good house	-0.006	0.001	-0.011	0.016	0.001	0.006	0.020
t	-0.22	0.05	-0.44	0.77	0.05	0.37	1.41
Log Land pc	0.015	0.009	0.003	0.008	0.005	0.003	0.003
t	1.13	0.88	0.32	1.1	0.81	0.63	0.91
Log Credit pc	0.067	0.069	0.067	0.066	0.061	0.063	0.065
t	5.52	6.57	7.97	9.09	11.27	12.5	14.98
Log Distance	-0.627	-0.531	-0.508	-0.458	-0.447	-0.447	-0.426
t	-9.98	-8.74	-10.29	-13.09	-14.65	-15.68	-15.19
Log Farm income pc	0.282	0.239	0.213	0.210	0.202	0.229	0.207
t	5.15	5.25	5.63	7.1	7.86	10.46	10.48
Log Off farm income pc	0.005	0.003	0.004	0.005	0.004	0.004	0.002
t	1.03	0.74	1.09	1.88	1.7	2.14	1.32
Bicycle	-0.016	-0.015	0.018	0.010	0.004	0.002	0.001
t	-0.44	-0.55	0.96	0.65	0.39	0.16	0.06
Radios	0.266	0.251	0.256	0.239	0.257	0.266	0.263
t	5.91	7.32	8.17	8.11	9.67	11.76	12.35
Gender	0.092	0.092	0.080	0.093	0.087	0.106	0.078
t	1.57	2.06	2.2	2.65	2.72	3.85	3.9
Thatched house	-0.047	-0.047	-0.044	-0.041	-0.043	-0.046	-0.048
t	-4.35	-5.8	-6.36	-7.06	-9.09	-10.17	-12.18

*Note: the first row against each quantile (Qi) are coefficients, the second column in italics presents t-statistics calculated with (bootsrap), and the last and bold columns present p-value;Adj R-Squareds range from 0.67 to 0.72 as opposed to zero that appear in quantile regressions with constants only. Number of replications=100; pc means per capita

Quantile regressions are best suited for this purpose and the results below are based on simultaneous quantiles regression models. The Adjusted R-squared statistics are again used to test the dependence of food security (measured as length of time that own produced food lasts) on the selected variables in the model. Under the null hypothesis ($H0$) where there is only one parameter, which is the intercept ($\beta 0$), the values of the restricted Adjusted R-squared functions are 0.0, in all the 8 quantiles simultaneously estimated while under the alternative hypothesis ($H1$) where the model has all the parameters, the value of the unrestricted *R*-squared functions range between 0.67 to 0.72 (Table 4). The number of replications involved in the estimation of the simultaneous

quantiles is 100.The parameter estimates show that apart from land per capita, housing, off farm income and bicycle ownership, which were insignificant in most of the quantiles computed, the remaining variables had statistically significant coefficients and largely with expected signs. Below the significant coefficients are discussed.

Household farm level income: The elasticity values associated with a 1% change in farm income on food security range from 0.28% to 0.20% with a median value of 0.21%. This again shows that food security is farm income inelastic however the results further reveal that in fact the impact of farm income on food security varies across the distribution of household food security. The effect of household farm income (a measure of both market access and aggregate farm production) is higher for food insecure households and tapers among food secure households. A policy that sought to increase aggregate production or that which sought to increase household incomes would greatly positively impact the food insecure more than those who may already be food secure.

Household access to credit: The household's access to credit boosts its food security status and the median quantile regression (quantile =0.5) shows that a 1% increase in income from the credit market is associated with a 0.066% increase in the household's food security status. There is variation in the impact of credit across the different quantiles of food security so that a policy that sought to increase credit access to rural households would probably benefit those very food insecure households slightly more than those whose food security situation may be better. This upholds the postulate that social supports influence food security by providing access to food or production and consumption resources (Bernell *et al.,* 2005).

Age of the respondent: The fact that a farmer is young appears equally important in determining food security at the household level. In all the quantiles the impact of a 1% increase in age of a farmer brings about a -0.005% reduction in food security levels. Although the first two lower quantiles (quantile 0.2 and 0.3) are associated with a slightly different age elasticity of food security, the differences are essentially not economically significant. In general, it appears that young farmers are good for food security.

Sex of the respondent: Gender (male =1, female=0) of the respondent positively affects food security implying that male respondents on average have more opportunities to guarantee food security. This makes intuitive sense since it is well documented that many women households face poor labour, land, input and output market opportunities. Gender of the household head has a median impact of about 0.09 which is statistically significant at 1% level. The effect of gender changes from one quantile to another implying that OLS based estimation would fail to reveal the changing impact of gender across the quantiles of the food security distribution.

Education of the respondent: Education appears to have positive and significantly impact on food security status of the household (impact from median regression is 0**.**256) implying that educated farmers may indeed have good access to price, nutrition, rainfall as well as farming information through newspapers and other sources unavailable to less educated ones. The impact of education on food security however is also different across different quantiles of the food security distribution implying that a policy that sought to educate farmers would have different effects on household level food security conditional on the existing food security status. In fact education would benefit food insecure households more.

Asset ownership (radio), Extension services, Market proximity: Food security is defined in terms of food availability, access and utilization (Barrett, 2010). A radio is

important in dissemination of information about availability, access and utilization. The coefficient from the median regression is 0.239 implying owning a radio increases food security by 0.24%. So owning a radio is associated with increased food security but the effect varies across the distribution of food security. This is the same with other sources of information. For instance extension services have a median coefficient of 0.14 but the impact varies across quantiles. Extension visits provide farmers an opportunity to get useful information on input and output prices, farming techniques, health consumption and other forms of farm and nutritional advice.

Market proximity (Distance to markets/trading centre from the household): For households that are on the lower quantiles of food security, bringing markets close to them either by way of rural road construction of stimulating the development of physical markets would greatly improve their food security outcomes. The median market distance elasticity of food security is -0.46% at the elasticity, which is statistically significant at the 1% level. For those in the 20% category of the food security distribution (quantile =0.8) a reduction in distances to markets could increase their food security by about 0.43%. Conversely, for those who are already in food insecure categories, an increase in distances to market of 1% would yield to a further deterioration of food security by 0.63%. In other words, they would face even more daunting market opportunities such that their food end time decreases. From the evidence provided, it appears to reasonable to uphold the hypothesis that the longer the distance to the market, the less frequently the farmer visits the market and, hence, the less likely they are to get market information (Staal *et al.,* 2002; Fekele *et al.,* 2005). It is important however to note that the impact of market proximity on household level food security varies across the distribution of food security.

Asset ownership (main house is thatched): A poor main house is an indicator of limited resources. If the main house for the household is poor, such a household may be said to have lower levels of wealth and hence are likely to be food insecure. The data show that households whose only main house is poor are associated with lower food security and the decrease is of the order of -0.041 to -0.048. Again, the impact is different across quantiles of food security distribution.

Dependency (consumer worker ratio at the household): The ratio of consumers to workers, proxies labour resource position of the household. The impact of consumer-worker's ratio is significantly at the 1% level. The impact is different across quantiles of the food security distribution. Households with poor food security positions are more negatively impacted in the advent of an increase in consumer worker ratio. In fact a 1 % increase in consumer worker ratio leads to a -0.48% reduction in food security as evidenced from the median regression. The impact also varies from one quantile to another and the impact is more for households on the lower quantiles of the food security distribution. To put it in context, the elasticity of consumer worker ration for the 20^{th} and 80^{th} quantile are -0.8% and 0.4% implying that methodologies that concentrating on estimating only one coefficient as if assuming all quantiles would be impacted similarly would be misleading. It would appear that policies that sought to reduce dependency ratios through either child spacing or an increase in life expectancy, households' food security may increase.

Cash crop orientation (tobacco farming indicator): The results show that tobacco adoption has the potential to increase the household's food security position. The tobacco

adoption elasticity of food security is 0.11% at the median regression but varies from one quantile to another with values ranging from 0.04% to 0.13%. This is also evidence that treating all quantiles as one and hence estimating only one coefficient such as in OLS would be misleading both for policy and inference.

5. Conclusion

This paper has shown using logistic, OLS and Quantile regressions that food security in Malawi is a function of both supply and demand factors. Specifically, food security as proxied by dietary diversity, reported food security, and food end time is a function of farm level production as proxied by farm level incomes. It is also a function of credit accessed, age and sex of a household head, while access to the markets, extension information, radio ownership, assets such as housing and adoption of a cash crop (tobacco). Education and consumer worker ratio are also important signifying the role that knowledge and labour play in deciding household level food security.

The results also show that the impact of the regressors on food security depends on the level of food security in question such that in general factors with a positive effect on food security have a greater impact on food insecure households than on households that are better off. For instance, the impact of farm income on food security is as high as 0.28% for the lowest quantiles of food security whereas it is up to 0.21% for the highest quantiles of food security. Similarly, an increase in market distance from the market lowers food security greatly for food insecure households but the decline is less for those households whose food security situation is better. Precisely, and conversely, if market distance was reduced by 1% for every household, households in lowest quantiles of food security would improve food security by as high as 0.63% whereas those on the higher quantiles of food security would gain by about 0.43%. Thus the importance of the market proximity, access to road, technology and good management of land resources are crucial for food security. This evidence supports the common understanding that emerges from the comprehensive African agriculture development (the CAADP) framework that food security (Pillar III), efficient management of land resources, rural markets and technology (Pillars I, II, and IV respectively) are all interrelated (NEPAD, 2009). Given the preponderance of evidence in this paper it appears that policies that seek to enhance market access, improve market opportunities, enhance extension services, enhance informal education, encourage cash cropping, and support household level consolidation of assets would be useful in enhancing household level food security. Future research should focus on adopting the approach proposed herein, using other common welfare indicators (nutrition, weight for height, incidences of malnourishment, BMI etc.) to proxy food security.

References

Abdulai, A., and Aubert, D. (2004), A cross-section analysis of household demand for food and nutrients in Tanzania. *Agricultural Economics* Vol. 31, pp. 67-79.

Austin, P. C., Tu, J. V., Daly, P. A., and Alte, D. A. (2005), The use of quantile regression in health care research: a case study examining gender differences in the timeliness of thrombolytic therapy. *Statistics in Medicine,* Vol. 24 No. 5, pp. 791–816.

Barrett, C. B. (2002), Food Security and Food Assistance Programs In B. L. Gardner and G. C. Rausser (Eds.), *Handbook of Agricultural Economics.* Amsterdam: Elsevier Science.

Barrett, C. B. (2010), Measuring Food Insecurity. *Science* Vol. 327, 825-828.

Bernell, S., Edwards, M., and Weber, B. (2006), Restricted opportunities, unfortunate personal choices, ineffective policies? What explains food insecurity in Oregon. *Journal of Agricultural and Resource Economics*, Vol. 31 No. 2, pp. 193-211.

Bickel, G., Nord, M., Price, C., Hamilton, W., and Cook, J. (2000), *Guide to measuring household food security*. Washington, DC: USDA Food and Nutrition Service.

Broegaard, R. J. (2005), Land tenure insecurity and inequality in Nicaragua. *Development and Change*, Vol. 36 No. 5, pp. 845-864.

Buchinsky, M. (1998), Recent Advances in Quantile Regression Models: A Practical Guideline for Empirical Research. *Journal of Human Resources*, Vol. 33 No. 1, pp. 88–126.

Buchmann, C., and Hannum, E. (2001), Education and stratification in developing countries: a review of theories and research. *Annual Review of Sociology*, Vol. 27, pp. 77-102.

Buvinic, M., and Gupta, G. R. (1997), Female-headed households and female-maintained families: Are they worth targeting to reduce poverty in developing countries? *Economic Development and Cultural Change*, Vol. 45 No. 2, pp. 259-280.

Cade, B. S., and Noon, B. R. (2003), A gentle introduction to quantile regression for ecologists. *Frontiers in Ecology and the Environment*, Vol. 1 No. 8, pp. 412-420.

Chavas, J. P., Petrie, R., and Roth, M. (2005), Farm household production efficiency: Evidence from the Gambia. *American Journal of Agricultural Economics*, Vol. 87 No. 1, pp. 160-179.

Ecker, O. (2009), *Economics of Micronutrient Malnutrition: The Demand for Nutrients in Sub-Saharan Africa*. Frankfurt: Peter Lang Verlag.

Ellis, F., Kutengule, M., and Nyasulu, A. (2003), Livelihoods and rural poverty reduction in Malawi. *World Development*, Vol. 31 No. 9, pp. 1495-1510.

Faridi, R., and Wadood, S. N. (2010), An Econometric Assessment of Household Food Security in Bangladesh. *The Bangladesh Development Studies*, Vol. XXXIII No. 3, pp. 97-111.

Fedorov, V., and Wu, Y. (2007), Generalized probit model in design of dose finding experiments In J. Lopez-Fidalgo, J. M. Rodriguez-Diaz and B. Torsney (Eds.), *mODa8-Advances in Model-Oriented Design and Analysis* (pp. 67-74): Physica-Verlag HD.

Feleke, S. T., Kilmer, R. L., and Gladwin, C. H. (2004), Determinants of food security in Southern Ethiopia at the household level. *Agricultural Economics*, Vol. 33, pp. 351–363.

Garrett, J. L., and Ruel, M. T. (1999), Are Determinants of Rural and Urban Food Security and Nutritional Status Different? Some Insights from Mozambique. *World Development*, Vol. 27 No. 11, pp. 1955-1975.

Government of Malawi (GoM), (2002), *Malawi Poverty Reduction Strategy Paper*. Lilongwe.

Guo, B. (2010), Household Assets and Food Security: Evidence from the Survey of Program Dynamics. *Journal of Family and Economic Issue*, Vol. 32 No.1, pp. 98-110

Harvard Institute for International Development (HIID), (1994), *Fertilizer policy study: Market structure, prices, and fertilizer use by smallholder maize farmers*. Lilongwe: Ministry of Economic Planning and Development.

Hendriks, S. L., and Msaki, M. M. (2009), The impact of smallholder commercialisation of organic crops on food consumption patterns, dietary diversity and consumption elasticities. *Agrekon*, Vol. 48 No. 2, pp. 184-199.

Kherallah, M., and Govindan, K. (1999), The sequencing of agricultural market reforms in Malawi. *Journal of African Economies*,Vol. 8 No. 2, pp. 125-151.

Koenker,R., and Bassett, G. (1978), Regression Quantiles. *Econometrica*, Vol.46 No. 1, pp. 33–50.

Koenker, R. W., and d'Orey. (1987), Computing Regression Quantiles. *Applied Statistics*, Vol. 36, pp. 383-393.

Lau, L. J., Jamison, D. T., and Loua, F. F. (1991), *Education and Productivity in Developing Countries: An Aggregate Production Function Approach*. Washington DC: Policy Research and External Affairs, World Bank.

Lewin, P. A. (2011), *Three Essays on Food Security, Food Assistance, and Migration*. Unpublished PhD Dissertation, Oregon State University, Oregon.

Maxwell, D. G., and Wiebe, K. D. (1999), Land tenure and food security: exploring dynamic linkages. *Development and Change* 30 No. 4, pp. 825-849.

Mosteller, F., and Tukey, J. W. (1977), *Data analysis and regression*. NY: Addison-Wesley.

Mukherjee, S., and Benson, T. (2003), The determinants of poverty in Malawi, 1998. *World Development*, Vol. 31 No. 2, pp. 339-358.

Mutangadura, G. (2007), The incidence of land tenure insecurity in Southern Africa: Policy implications for sustainable development. *Natural Resources Forum*, Vol. 31, pp. 176–187.

NEPAD. (2009), *The comprehensive African agriculture development programme (CAADP) Pillar III: framework for African food security (FAFS)*, Midrand, South Africa: New Partnership for African Development (NEPAD),

Place, F., and Otsuka, K. (2001), Tenure, agricultural investment and productivity in the customary tenure sector in Malawi. *Economic Development and Cultural Change*, Vol. 50 No. 1, pp. 79-99.

Psacharopoulos, G. (1981), Returns to education: An updated international comparison. *Comparative Education*, Vol. 17 No. 3, pp. 321-341.

Rose, D., Gundersen, C., and Oliveira, V. (1998), *Socio-economic determinants of food insecurity in the United States: Evidence from the SIPP and CSFII Datasets* Washington, DC: USDA Economic Research Service.

Sadoulet, E., and de Janvry, A. (1995), *Quantitative Development Policy Analysis*. Baltimore: The John Hopkins University Press.

Sen, A. K. (1981), *Poverty and Famines: An Essay on Entitlement and Deprivation* Oxford: Clarendon Press.

Sijm, J. (1997), *Food Security and Policy Interventions in Sub-Saharan Africa*. Amsterdam, The Netherlands.: Thela Publishers, Prinseneiland.

Singh, I., Squire, L., and Strauss, J. (Eds.), (1986), *Agricultural Household Models*. Baltimore. MD: The Johns Hopkins University Press.

Smith, R. E. (2004), Land tenure, fixed investment and land farm productivity: evidence from Zambia's southern province. *World Development*, Vol. 32 No. 10, pp. 1641-1661.

Staal,S.J., Baltenkweck, I., Waithaka, M.M., de Wolff,T., Njoroge, L.(2002), Location and uptake: Integrated household and GIS analysis of technology adoption and land use, with application to smallholder dairy farms in Kenya. *Agricultural Economics*, Vol. 27 No. 3, pp. 295-315.

Terrell, J., Cade, B., Carpenter, J., and Thompson, J. (1996), Modeling stream fish habitat limitations from wedged-shaped patterns of variation in standing stock. *Transactions of the American Fisheries Society*, Vol. 125, pp. 104–117.

Tschirley, D. L., and Weber, M. T. (1994), Food security strategies under extremely adverse conditions: The determinants of household income and consumption in rural Mozambique. *World Development*, Vol. 22 No. 2, pp. 159-173.

UNDP, (2011), *Sustainability and Equity: A Better Future for All*: Unnited Nations Dev. Program

Vakis, R., Sadoulet, E., A. DeJanvry, and C. Cafiero. (2004), *Testing for Separability in Household Models with Heterogeneous Behavior: A Mixture Model Approach*. California: Department of Agricultural and Resource Economics, University of California, Berkeley.

White, H. (1980), A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, Vol. 48 No. 4, pp. 817-838.

Wolday, A. (1995), *Ethiopia's market liberalization in agriculture: consequences and responses*. Paper presented at the Food Security, Nutrition and Poverty Alleviation in Ethiopia: Problems and Prospects. Proceedings of the Inaugural and First Annual Conference of the Agricultural Economics Society of Ethiopia, Addis Ababa, Ethiopia.

Wooldridge, M. J. (2002), *Econometric analysis of cross section and panel data*. Cambridge, MA: MIT Press.

Appendix on line at the journal Website: http://www.usc.es/economet/econometria.htm

Appendix: Description of variables

Food Security (y_i): To operationalize the construct of food security, researchers use different measures mostly dependent on data availability. For instance Fekele *et al.* (2005) uses the timing and volume of maize harvest as an indicator that can capture the vulnerability and unsustainability elements of food insecurity, and subsequently coding this as a bivariate variable taking the value 1 when the household is food secure and 0 when it is insecure. Other authors have used expenditure on food is an important indicator of food security which also captures the concept of vulnerability to food insecurity (see Farid and Wadood, 2010; Hendriks and Msaki, 2009), whereas Guo (2010) as well as Bickel et al (2000) consider that questions on malnutrition incidences, food deficit incidences, future availability worries, eating of balanced diets, diversity of foods eaten per week, and weekly expenditure on foods can be informative indicators of household level food security. In this paper food security indicators chosen are threefold: 1) Food security is constructed as a measure of dietary diversity whereby households were asked to recall and report the kind of foods they had eaten over the past week and the past two weeks. It was explicitly required of them to report on whether they ate roughly balanced diets in terms of whether they their consumptions included meat, beans, fish, vegetables, *Nsima* (thick porridge made from maize, Malawi's main dish), and fruits. They were also asked to report quantities of the foods in terms of number per individual for the case of fruits, number of fish and sizes, rough weight of fish, and quantity of nsima or rice or cassava and beans consumed. Data on consumption of pumpkins, groundnuts, sugarcane were also collected. These data were then aggregated into a monotone index spanning 0 to 2 where higher values implied a higher level of food security and lower values implied food insecurity. 2) Secondly, food security is indicated by the household's reported duration of own food. The rationale is that households whose food lasts early after harvesting will likely be food insecure in the months to come all factors being equal. This is constructed as a continuous variable in months and again, higher values are indicative of food security whereas lower ones are indicative of food insecurity. 3) Lastly, food security is proxied by household level own reported perception of food security. Households were asked whether they felt that they would face days without consuming food in the near or distant future, or whether they had already done so in the recent past. Those households that reported that they would or had spent a day without food or with too little food were coded as 0 (insecure) and the rest as 1 (secure). These three measures are then used to estimate food security using ordinary least squares (OLS), Logit models, and Qauntile regressions.

Household farm level income per capita: The farm level income is measured in terms of the household level income for the previous sales season. This quantity could proxy the capabilities that the household has in dealing with any abrupt changes in its food stocks for the future. It could also indicate the household's ability to access market food stuffs such as fish, some meats and some fruits. It is also an aggregate measure of household level production as households sell only what they produce. It is expected that household farm level incomes are positively related to food security.

Household access to credit per capita: The household's access to credit could boost its production levels and its survivability in times of disaster. Credit access is measured by the reported amount of credit the household gets formally or informally. Credit access is

also a measure of social support. Social supports influence food security by providing access to food or production resources (Bernell *et al.,* 2005).It is expected that the amount of credit a farmer gets would be positively associated with food security.

Household level off-farm income per capita: Off-farm work is measured based upon the household's reported amount of money they get from an off farm job, typically a small business (such as paraffin sales, sugar sales, soap sales, firewood sale). Such income would be very useful in cases of crop failure. The expected effect on food security (*yi*) is positive.

Age of the respondent: Young farmers may be more dynamic and energetic that they can easily access markets and information, whereas at the same time they have low experience about certain agricultural operations. Although young families may be associated with low dependency ratios, the dynamic nature of the youth considered with the fact that they are less experienced suggest that the effect of age of the respondent on household level food security is an empirical question

Sex of the respondent: Gender (male =1, female=0) of the respondent may be related to food security through access resources, as well as through knowledge. It is generally believed that women in Africa have poor access to resources, but studies have also shown that women do more to help their household meet basic food needs. They may be allocating a good share of resources to basic necessities at the household level and hence ensuring a health life. Women may have superior managerial skills (Chavas *et al.,* 2005), but are also burdened by child care, household maintenance, and economic production. Malawian women suffer from gender inequities in the labour market (Buvinic and Gupta, 1997), and males have better employment opportunities than women (Mukherjee and Benson, 2003). It is hence expected that the relationship between gender and food security is an empirical question.

Education of the respondent: Educated (measured as 1 for schooling up to standard 8 and 0 for schooling up to standard 5) farmers will have good access to price, nutrition, rainfall as well as farming information through newspapers and other sources unavailable to less educated ones. Education is expected to positively impact food security. Householder education is expected to have a positive effect on food security. Education imparts greater knowledge regarding food choices, cooking methods, and nutrition (Rose *et al.*, 1998; Abdulai and Aubert, 2004; Bernell *et al.*, 2006), and influences both present and future income (Psacharopoulos,1981;Lau *et al.*,1991; Buchmann and Hannum, 2001).

Asset ownership (bicycle): In rural areas transportation to distant places is difficult and bicycle ownership would ease travel to markets and other destinations of agricultural or nutritional importance. Some studies have measured market access as a combination of distance to markets, capacity of the agent to travel to markets (Staal *et al.,* 2002). Bicycle ownership is hence expected to positively affect food security.

Asset ownership (radio): A radio is important in information dissemination and owning it would make the farmer more aware of issues in farming and marketing. It is hence expected that radio ownership is positively related to food security.

Asset ownership (main house is a good house with iron sheets): It is expected that ownership of a good house (bricks, cemented, corrugated iron sheets without any major leaking, as opposed to muddy houses with leaking iron sheets, and those without bricks and without iron sheets) is indicative of asset and wealth holding of the household. A household's level of resources can be expected to affect its ability to survive sudden changes in production, prices, income, or unforeseeable events that create the need for

additional expenditures. When crop failure occurs because of rainfall shortage, the level of a household's resources is very important to deal with food shortages. Wealth would be expected to positively impact on food security (see Guo, 2010).

Asset ownership (main house is thatched): If the main house for the household is only thatched without other features as discussed previously, such a household may be said to have lower levels of wealth and hence are likely to be food insecure.

Security of land tenure (in terms of size and expropriation potential): Security of land holding is a composite measure of an index of farm size held by the household and whether it is held uncontestably. The rationale is that land that is large and held uncontestably would act as a reliable input in farm production, and would also act as an asset (which may be used to borrow for example money informally from societal members). So it is expected that households that score high on the composite index of farm size and farm security will be more secure and will put their land to more productive use. It is expected that this variable will provide an indication of a household's agricultural capacity and degree of food security (Ellis *et al.,* 2003). Households with secure and larger farms should have a higher probability of being food secure, since farm size is positively associated with cash crop income (Tschirley and Weber, 1994). Security of land tenure is hence expected to be associated with food security, positively.

Extension services available to the household: Extension services are proxied by the number of visits that an extension worker has visited the household. It is expected that extension visits provide farmers an opportunity to get useful information on input and output prices, farming techniques, health consumption and other forms of farm and nutritional advice. It is expected that extension services would be positively related to food security.

Market proximity (Distance to markets/trading centre from the household): Some of the households surveyed lived in remote areas. Distance from the household to the nearest urban centre/trading centre, or some market/ or in case of absence of all these, distance to the nearest good road (all measured in kilometres), can proxy information access. The longer the distance to the market, the less frequently the farmer visits the market and, hence, the less likely they are to get market information (Staal *et al.,* 2002; Fekele *et al.*, 2005). Lack of adequate information about prices, farmers may sell their produce at times when prices are low and buy when prices are high. It is expected that food security (*yi*) is negatively related to distance to the market.

Dependency (consumer worker ratio at the household): The household consumes what it produces using resources that it has. If the number of people who contribute to production is very small than the number of consumers at the household level, the dependency (consumer-worker) ratio for such a household is high. This is calculated as household size divided by number of people who contribute to the household's labour supply. The international dependency ratio formulation of dependants per worker can be derived from this definition by subtracting unity. The dependency ratio herein is defined as:

$$DR_c = \frac{w+d}{w} = 1 + \frac{d}{w}$$

where *DRc* is the dependency ratio and *w* and *d* are workers and dependants (children who are less than 10 years and older people who are over 65 years) respectively. The

international definition is equivalent to DR_c *-1*. A higher dependency ratio implies that there is less production per individual in the household and consequently it is expected that dependency should be negatively related to food security.

Cash crop orientation (tobacco farming indicator): The effect of tobacco farming on household level food security is an empirical question because while tobacco farming has the potential to increase household incomes and boost household potential to purchase food, it also has the negative effect on food production. Depending on expectations on tobacco prices at the markets it is not uncommon in Malawi to hear of farmers allocating too much land to tobacco at the expense of maize production, which in turn harms the household in case tobacco prices turn out low.

Figure A: Coefficient impact over quantiles