Impacts of Rainfall Shock on Smallholders Food Security and Vulnerability in Rural Ethiopia: Learning from Household Panel Data

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Abstract Ethiopia's agriculture is predominantly rainfed and hence any irregularity in weather conditions has adverse welfare implications. Using panel data, this paper analyzes the effect of rainfall shocks on Ethiopian rural households' food security and vulnerability over time while controlling for a range of other factors. To this end, we generate a time-variant household food security index which is developed by principal components analysis. Based on this index, households are classified into relative food security groups, and their socioeconomic differences are assessed. The exploratory results show that compared to the less secured households, the more secured ones have male and literate household heads, tend to have a greater number of economically active household members, own more livestock, experience better rainfall outcome, and participate in local savings groups. Using the food security index as the dependent variable, we estimate a fixed effects instrumental variable regression model to identify determinants of households' food security over time and find that rainfall variability is an important factor. Moreover, household sizes, participation in local savings groups and livestock ownership positively affect food security. Results from multinomial logistic regression model complement the fixed effects instrumental variable regression results by showing that the level and variability of rainfall are important determinants of persistent food insecurity and vulnerability. The results highlight the need for efficient risk reducing and mitigation programs to improve risk exposure and coping ability of rural households. Careful promotion of investment in infrastructure to support irrigation and water resources development is one aspect worth considering.

Keywords: *food security, rainfall variability, principal component analysis, panel data, Ethiopia*

1. Introduction

It is widely recognized that climate variability and the occurrence of extreme weather conditions are among the major risk factors affecting agricultural production and food security in Sub-Saharan Africa (SSA). In the region, the rainfall pattern is influenced by large-scale inter-seasonal and inter-annual variability resulting in frequent extreme weather events such as droughts (Haile 2005). According to projection by IPCC in the coming decades with climate change, rainfall variability and extreme climatic events are expected to adversely affect agricultural production and food security (Christensen et al. 2007). By 2020 yields from Africa's rainfed farm production could decrease by 50% as a result of changes in climatic conditions (Boko et al. 2007).

As in other SSA countries, Ethiopia's economy is mainly based on rainfed agriculture; as a result food production is highly vulnerable to the influence of adverse weather conditions such as drought. According to Von Braun (1991) a 10% decline in the amount of rainfall below the long run average leads to a 4.4 % reduction in the country's national food production. In the future too, studies show that rainfall is expected to decline (Funk, et al. 2009) and also becoming more irregular. Drought has been an increasing occurrence over the last decades in Ethiopia as has the proportion of the population adversely affected by it. For example, Adnew (2003) indicates that the proportion of drought affected people doubled from 8% of the total population in 1975 to 16% in 2003. Consequently, the country has been dependent on food aid to bridge its huge food gap. Even in a year where rainfall is favourable it is estimated that around 4-5 million Ethiopians depend on food aid (Devereux 2006) reflecting how deep-rooted food insecurity is in the country. Thus, increasing food production and ensuring its steady access to the fast growing population on one hand and designing effective drought mitigation strategies on the other remains to be a major challenge for Ethiopia's development endeavour.

Previous studies have shown that weather variability emanated from changes in climatic condition affect food security (Rosenzweig et al. 1995) and the effect is more pronounced particularly in rural households in developing countries (Downing 1992; Benson and Clay 1998) such as Ethiopia where the capacity to cope in the event of shock is low. The impact of climatic variability on agricultural production and productivity in different parts of Africa has been widely studied (Downing 1992; Schulze et al. 1993; Mohamed et al. 2002a, b; Chipanshi et al. 2003; Deressa 2007; Yesuf et al. 2008). However, as Gregory et al. (2005) state, while several studies delve into assessing the link between changes in weather conditions and crop production and productivity, assessments of the effect of climate change on food security remain scarce. Particularly, in Ethiopia in spite of the fact that food insecurity mainly arising from extreme weather conditions is pervasive, there is little empirical work that documents the influence of weather variability on food security. Hence, the objective of the present study is to empirically assess the impact of rainfall shock on changes in households' food security over time thereby contribute to the scarce empirical literature that investigate the link between climate variability and household food security.

The present paper differs from earlier studies in two important aspects. Firstly, earlier works on food security and vulnerability commonly concentrate on employing a single measure of food security such as calorie availability, per capita food expenditure, self- reported food security status, and daily meal intake frequency. Yet, food security is a broad concept and it is difficult to capture by simply applying a single indicator (Von Braun et al. 1992). Therefore, in the present study, a time-variant food security and vulnerability index is constructed from a combination of factors which capture its different dimensions as well as its validity and evolution over time is assessed. Secondly, previous research on food security and vulnerability mainly used cross-sectional data and assessed the problem of food security at one point in time while the present study, using panel data, addresses the dynamics of food security and specifically examines the relationship between rainfall variability and household food security. The results of the study can be used to fine-tune and adjust policies aimed at reducing food insecurity and vulnerability. The remainder of the paper is organized as follows. The next section gives brief description of climatic features of Ethiopia and section 3 presents an overview of the data. Section 4 provides the conceptual framework and methods of analysis employed in the study. The results are presented and discussed in section 5, and conclusions are drawn in section 6.

2. Description of climatic features and rainfall trends in Ethiopia

Ethiopia is characterized by diverse climatic conditions. The country's climatic system is largely determined by the seasonal migration of the Intertropical Convergence Zone (ITCZ) and the complex topography (Bekele, 1993; NMSA, 2001). Ethiopia's climatic conditions range from warm and humid in southeastern region to semi-arid in the low lying regions. Average temperature, mean annual rainfall and length of growing period substantially vary across the different climatic zones. For example, in our study villages mean annual rainfall varies from about 1417 mm in Adado (Southern region) to less than 600 mm in Geblen and Haresaw (Tigray region)..

In Ethiopia one can identify three distinct rainfall regimes classified taking into consideration the annual distributional pattern. The southwest and western areas of the country are characterized by a unimodal rainfall pattern. Whereas the central, eastern and north eastern parts exhibit a quasi bi-modal and the south and south eastern areas a distinct bimodal rainfall pattern (World Bank 2006). The rainy seasons are known as *belg* and *kiremt* in local language. *Belg* is a short rainy season extending from February to May and the main season (*kiremt*) falling between June and September. Many of our study villages have a single harvest following the main rainy season.

Large interannual variability which is clearly reflected in the prevalence of recurrent drought is the characteristic feature of the country's climatic system (Gissila, et al. 2004). According to the National Meteorological Services Agency (NMSA) (2001), the country's rainfall is characterized by a high degree of spatial and temporal variability. If seasonal rainfall fails or its amount or timing deviates from the norm, agricultural production will be negatively affected (World Bank 2006) with a damaging consequences for the country's overall economy[1] and food security. Studies indicate that the mean temperature and precipitation have been changing in the country. The annual average minimum temperature has been increasing by about 0.25 ^{o}C every 10 years and the maximum by 0.1 ^{o}C every decade. Over time, amount of rainfall is also exhibiting a declining trend with increasing variability (NMSA, 2001).

1 A study by World Bank (2006) has shown the high correlation between Ethiopia's economy measured by its GDP and rainfall fluctuation. Irrigation is very minimal in the country, despite its huge potential it accounts only less than 1% of the country's total cultivated land (Yesuf, et al., 2008).

Drought events with differing scales of devastation are a notable feature of the Ethiopian climate and existed throughout the country's human history. Web, et al. (1992) indicates that the history of famine crises traces back to 250 BC. During the 1900-2009 period, 12 extreme droughts2 have been recorded (EM-DAT, 2009) which resulted in a huge humanitarian crises. Evidence suggests that over the past few decades the frequency of drought as well as the share of affected population has increased significantly (Adenew, 2003).

3. Data and study areas

The study used a dataset commonly called the Ethiopian Rural Household Survey (ERHS) - a longitudinal dataset collected from randomly selected farm households in rural Ethiopia. Data collection and supervision was conducted by the Department of Economics at Addis Ababa University, Centre for the Study of African Economies (CSAE)-University of Oxford, UK and International Food Policy Research Institute (IFPRI) in collaboration. Data collection started in 1989 on seven study sites mainly those which suffered from the 1984-85 drought and others that occurred between 1987 and 1989. The sample size was 450 households. The primary intention of the survey was to study smallholders' responses to food crisis (Dercon and Hoddinott 2004).

The 1989 survey was expanded in 1994 by incorporating other survey sites in different regions of the country. From 1994 onwards data collection has been conducted in a panel framework. Six of the study areas covered in 1989 have been included and one site was excluded due to security reasons. The number of study areas was increased to fifteen with the resulting sample size totalling 1477 households. The newly included study villages were selected in order to represent the country's diverse farming systems.

Before a household was chosen, a numbered list of all households (sampling frame) was developed with the help of local Peasant Association (PA) authorities. Once the list had been constructed, stratified random sampling was used to select sample households in each village (Kebede, 2002), whereby in each study site the sample size is proportionate to the population, resulting in a self-weighing sample (Dercon and Hoddinott 2004).

A total of six rounds (from 1994 till 2004) of data collection have been undertaken with an emphasis on emerging current issues in each wave although the main module of the questionnaire was kept as it was. The data is an unbalanced panel and the spacing between the survey rounds was inconsistent. It has been indicated that these data are not nationally representative, however they give a good picture

2 Drought is one of the top natural disasters in Ethiopia and for the period between 1900 to 2010 major drought events have been registered in 1965, 1969, 1973, 1983, 1987, 1989, 1999, 2003, 2005, and 2008 (EM-DAT, 2009).

of the major farming systems of the Ethiopian highlands (Dercon and Hoddinott 2004).. The main parts of the questionnaire include demography, asset ownership, farm input use, outputs, livestock production, and health. The present study utilized three rounds of the dataset (1994a, 1999 and 2004). The three rounds are selected to allow for even time spacing and have greater variability in food security and other socioeconomic conditions.

4. Conceptual framework and methodology

4.1 Conceptual framework

Food security can be defined as a situation "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996). There are three important, interlinked components imbedded in this definition. The first component is the availability of food in a given country/household through any means (production, imports or food aid, for example). The second aspect concerns the access to food by people/households as reflected by their ability to get food through purchases from market, from own stock/home production, gift or borrowing. The third component relates to the actual processing and absorption capacity of the body of the supplied nutrients. The latter is not considered in the present study.

Maxwell et al. (2008) describe the frequently available and utilized indicators which potentially measure food security as the following: nutritional status, actual food consumption at the household level by a 24-hr recall, coping strategies index, as well as proxy indicators such as calorie intake, household income, productive assets, food shortage, under 5 nutritional status, dietary diversity, and household food insecurity access scale. Although these indicators reasonably capture and designate a small portion of the problem, they do not provide a comprehensive picture. Maxwell et al. (2008: 534) further note that "although some progress has been made, the search for more broadly applicable measures of food security continues". Hence, in the present study we develop a relatively simple measure of food security in the context of rural Ethiopian households and thereby make a contribution to the improvement of food security measurement.

Food security is a complex concept, and it is not directly observable. Hence, using the approach outlined here we try to predict it using selected indicators which represent its multiple dimensions. However, due to data limitations we are not able to take into account the utilization aspect. The selection of indicators was driven by food security literature drawing mainly from Haddad, et al. (1994), Hoddinot and Yisehac (2002), Hoddinott (1999), Smith and Subandoro (2007), Alene and Manyong (2006), Qureshi (2007) as well as data availability. Accordingly, the following indicator variables3 which reflect its different dimensions are selected: size of land cultivated, the availability of food stocks, variety of food groups consumed, the variety of crops planted, and oxen ownership. A brief justification of their inclusion is provided below.

Indicators such as size of land under cultivation and number of oxen4 owned were used as a proxy for agricultural output and thereby access to food. A household's access to food among other things depends on availability of sufficient land and other productive resources to grow its own food. Households in rural communities commonly store crops for future use in case shortage prevails. Hence, availability of stored crops can show the capability of a household to cope with unexpected food crisis situation. It can also serve as an indicator of food security at the household level (Haddad, et al., 1994). A large amount of evidence suggests that dietary diversity is an important indicator of food security which reflects the nutritional quality of the food consumed (Smith and Subandoro, 2007). Studies have also shown the positive association between dietary diversity and high food consumption (Hoddinot and Yisehac, 2002). In view of this, it is logical to include the number of food groups5 consumed as a proxy for dietary diversity. According to Hoddinott (1999: 7) "a diverse diet is a valid welfare outcome in its own right". The types of crops grown could indicate households risk aversion behaviour and also indirectly shows how varied the household's enterprise and food consumption is.

Once the indicator variables are identified we construct the food security index through aggregating the indicator variables outlined above via a multivariate statistical procedure known as Principal Component Analysis (PCA), which is described in section 4.2. The next analytical step involves identifying factors which influence household food security using regression analysis. Food security is hypothesized to be mainly influenced by a resource endowment of the household which we broadly summarize them into five categories based on DFID's (1999) Sustainable Livelihood Framework (SLF). The SLF indicates that the livelihood of a given household/state is dependent on its asset endowments mainly human capital, social capital, physical capital, financial capital and natural capital which together enable households to pursue a sustainable livelihood. Summarizing the above propositions, we formulate the following estimable model of determinants of household food security.

$$\text{FSI} = f\left(HC, SC, PC, FC, NC\right) \qquad (1)$$

3 With regard to measurement of the variables, size of land cultivated was measured in hectare. For the availability of stored crops, household were asked if they had stored any crops for future use and a value of one was assigned if the household had stored crops and zero if not. The types of crops grown, food groups consumed, and oxen owned were measured in numbers.

4 Oxen are the primary draft power source in rural Ethiopia which guarantee the timely execution of agricultural activities thereby improving household food availability.

5 The food types consumed are grouped into seven categories namely cereals, pulses, fruits, vegetables, meat, milk and milk products, oils, and eggs. We created a separate dummy for each food types so that a household assigned a value one if it has consumed at least one food item from the group and zero otherwise.

Where, FSI is food security index whereas HC, SC, PC, FC, and NC stand for human, social, physical, financial and natural capital respectively. The explanatory variables are discussed in detail in section 4.3.

4.2 Generating an index of household food security using principal component analysis

PCA linearly transforms the indicator variables of food security identified above into smaller components which account for most of the information contained in the original indicators (Dunteman 1994). Stated mathematically, from an initial set of n correlated variables $\left(X_1, X_2, X_3, \ldots X_n\right)$, PCA creates uncorrelated indices or components whereby each component is a linear weighted combination of the initial variables as follows:

$$PC_m = a_{m1}X_1 + a_{m2}X_2 + a_{m3}X_3 + \ldots + a_{mn}X_n \qquad (2)$$

Where a_{mn} represents the weight for the m^{th} principal component and the n^{th} variable. The components are ordered so that the first component explains the largest amount of variance in the data subject to the constraint that the sum of the squared weights $(a^2{}_{m1} + a^2{}_{m2} + a^2{}_{m3} + \ldots + a^2{}_{mn})$ is equal to one. Each subsequent component explains additional but less proportion of variation of the variables. The higher the degree of correlation among the original variables, the fewer components required to capture common information. Once the first component is identified, we can derive the food security index for each household as follows:

$$FSI_j = \sum F_i\left[\left(X_{ji} - X_i\right)/S_i\right] \qquad (3)$$

Where FSI_j is the Food Security Index, which follows a normal distribution with a mean of 0 and a standard deviation of 1, F_i is the weight for the i^{th} variable in the PCA model, X_{ji} is the j^{th} household's value for the i^{th} variable, and X_i and S_i are the mean and standard deviations of the i^{th} variable for overall households. Since we are using three rounds of household panel dataset, we need to generate the index that is comparable over time. To this end, following the innovative approach of Cavatassi et al. (2004) we pooled the data for the three rounds and estimated the principal components over the combined data. The resulting weight is then applied to the variable values for each rounds of the data using equation (3) above. According to Cavatassi et al. (2004) this approach helps to facilitate the index's comparability over time. Since the variables used to construct the index and their respective weights remained the same in all the three rounds, we can use it to compare changes over time (Vyas and Kumaranayake 2006). World Food Program routinely applies PCA in generating food security index in household profiling. A study by Qureshi (2007) also employed PCA generated food security measurement index for rural households in the Bolivian Amazon.

4.3 The econometric models applied

Determinants of food security over time

The present analysis is performed on three rounds of household panel data sets which are spaced five years apart. The panel nature of the data calls for the use of models which are appropriate for it. Accordingly, econometric estimations are done applying the two prominent panel data models: fixed effects and random effects models. These models, by virtue of their capacity to account for intertemporal as well as individual differences, provide a better control for the influence of missing or unobserved variables (Chan and Gemayel 2004). Let us consider the following simple panel data model:

$$Y_{it} = \beta X_{it} + \alpha_i + u_{it} \qquad (4)$$

Where:

Y_{it} is the dependent variable observed for household i at time t, in our case it is the food security index derived from PCA procedure.

X_{it} is a vector of explanatory variables for household i at time t

β is a vector of coefficients.

α_i denotes unobserved household specific effects which are assumed to be fixed over time and vary across household i.

u_{it} is the error term

The assumption behind the relationship between X_{it} and α_i makes the fixed effects and random effects models different. The fixed effects approach assumes that α_i is treated as non-random and hence makes the correlation between the observed explanatory variables (X_{it}) and α_i possible. On the other hand, the random effects approach is applicable under the assumption that α_i is random and not correlated with X_{it} and puts it into the error term (Wooldridge 2002: 257). We used a Hausman test to check whether there is such a correlation between the observed explanatory variables and α_i so that the suitable model specification is decided. According to Hill et al. (2008) if there is no correlation, in large samples the results obtained in applying the two estimators should be alike. Yet if there is correlation, the estimated results of the two estimators are different. Specifically, in the presence of such a correlation the random effects estimator is inconsistent whereas that of the fixed effects remains consistent. However, in our case the endogenous nature of some of the regressors (see section 4.4) might pose a problem (i.e. they might be related to the error term (u_{it})). Even though the fixed effects model reduces the problem, it cannot completely remove it. Hence to address the concern of endogeneity, we opt for applying fixed effects instrumental variable regression procedure. In the analysis the predicted values[6] of each of the endogenous variables together with their lagged values are used as instruments.

Determinants of staying in prolonged food insecurity and vulnerability

In addition to the model specified above, we also estimate a multinomial logit model. Based on the evolution of their index values over the three periods, households were classified into three states of food security: Households that were food insecure all the time were given a value of zero (those whose index value is persistently negative across the three survey periods), those who change their status at least once were given a value of one (vulnerable households whose index value is sometimes positive and sometimes negative), and those who are always food secure (whose index value is persistently positive) were assigned a value of two. These values were regressed on the initial (1994) socioeconomic characteristics of the households. Similar approach is applied by Bigsten et al. (2003). The purpose of the multinomial logistic model is to identify the factors that are associated with the likelihood of the household becoming always-less-secure, vulnerable, and always-more-secure. The model compares the probability of two states of food security to the probability of the third (the reference category). Both models use the same set of explanatory variables.

4.4 Description of explanatory variables

Based on the sustainable livelihoods framework (see section 4.1) we relate the explanatory variables in our regression models to households' endowment with different forms of capital. In the following, we describe the variables and our prior expectations about their relationship with food security.
With respect to natural capital, the crucial role of rainfall in the life of agricultural households in Ethiopia is widely recognized; any irregularity in its timing and/or fluctuation in amount results in adverse welfare consequences. The present study examines how household food security is associated with rainfall variation over time. It should be recognized that in developing countries like Ethiopia meteorological stations are sparse and hence reliable rainfall data at micro-level is scarce. So, given this difficulty, the present study uses both a subjective index and objective measures of rainfall.

The subjective rainfall index is calculated to represent households' perceived rainfall adequacy in the preceding agricultural season. Table 1 shows the questions with their original coding and their conversion into binary items in the right side.

6 We predict the endogenous variables by regerssing them on all the variables in the system. For the use of predicted values as instruments in past studies see Pender et al. (2004).

Table 1: Rainfall satisfaction index construction

During the growing season preceding the last main harvest:	Codes	Recoded into:
Did the rainfall come on time?	On time 1 Too early 3 Too late 2	On time 1 Others (2-3) 0
Was there enough rain on your fields at the beginning of the rainy season?	Enough 1 Too little 3 Too much 2	Enough 1 Others (2-3) 0
Was there enough rain on your fields during the growing season?	Enough 1 Too little 3 Too much 2	Enough 1 Others (2-3) 0
Did the rains stop on time on your fields?	On time 1 Too late 2 Too early 3	On time 1 Others (2-3) 0
Did it rain near the harvest time?	Yes 1 No 2	No 1 Yes 0

As the Table shows households were asked whether rain came and stopped on time, whether there was enough rain at the beginning and during the growing season and whether it rained at harvest time. The responses for these questions were dichotomized in such a way that those who respond "on time" coded into one and others (early /late) into zero. We summed them up and divided them by the number of rain related questions (5). So the most favorable rainfall outcome is one and the least is zero. Quisumbing (2003) in the study of food aid and child nutrition in Ethiopia followed a similar approach in generating a rainfall satisfaction index. Nevertheless, findings by Meze-Hausken (2004) in northern Ethiopia show a discrepancy between observed climate data and farmers climate perception. Whereas Deressa et al. (2008) found farmers perception of climatic situation is in line with actual data from weather stations.

In addition to the subjective index we also include observed rainfall data from nearby meteorological stations in our analysis. We considered previous year mean rainfall level as well as its deviation from the long-run mean (30 year) which shows the riskiness of the rainfall regime. We hypothesize a positive relationship between food security index and prevalence of favorable rainfall measured by the rainfall satisfaction index derived and the mean village level main season rainfall. The deviation of previous season's rainfall from its long-run mean is hypothesized to associate with food security negatively.

Financial capital is represented by access to credit and off-farm employment. Access to credit is anticipated to have a positive influence because it enables farmers apply more inputs by easing short term liquidity constraints thereby influencing food production. Credit can also be used as a consumption smoothing mechanism in the event of food shortage in the household (Zeller and Sharma 2000). Involvement in off-farm activities is also hypothesized to affect household food security but its effect cannot be determined beforehand. This is because engagement in these activities might bring about more money thereby corroborating the food security situation of the household. If, however, farmers spend more of their time on off-farm activities, there is less time for farm operation and particularly if the wage they earn is not commensurate with the forgone farm income, their food security situation will be in jeopardy.

Livestock[7] ownership being an important physical capital is expected to have positive effects on food security since livestock are an important source of household capital and a means to cope with difficult times. Membership in traditional revolving saving and credit associations (*equb*[8]) indicates both social and financial capital endowment and is expected to influence food security positively since it reduces potential household liquidity problems. Also, more savings encourage more investment in farm and household affairs.

Family and household characteristics such as labor availability and educational status reflect the household's human capital and play a role in determining households' food security. Male-headed households are expected to have higher food security status than their female-headed counterparts since most female-headed households in the Ethiopian rural system are formed as a result of death of husband or divorce, a situation which leaves the female with insufficient resources such as land, livestock and other productive assets. The head's age might affect food security of the household he/she manages through asset accumulation, technology adoption or risk aversion but cannot be determined *a priori* since household heads become more experienced with age and acquire more knowledge and physical assets thereby affecting food security positively. Yet it could be negatively correlated with food security indicating that as the head ages he/she might be less efficient to carry out demanding farm operations resulting in low farm production and productivity. Likewise, the size of a household definitely has an effect on food security though its direction cannot be known beforehand. In many prior empirical works, the effect of household size on food security is mixed. Some studies identify household size negatively associated with food security since larger sized households need more resources to fulfil household food needs whereas others read this positively as it means that there is a larger available labour force. Availability of economically active manpower helps to carry out farm operations timely and effectively. The subjects might also be involved in other farm or non-farm activities thereby diversifying and increasing the income source of the household which in turn affects food security in a positive way. In any development endeavour the role of education is well-acknowledged. In the present study we hypothesize a household with literate head will have a better food security status. Moreover, time dummies are also added for the survey rounds to control for any

7 Livestock represents cows, sheeps and goats only.

8 Equb is a traditional source of fund both in rural and urban Ethiopia. Usually people form small groups to improve their own economic conditions through savings that may be used for consumption and new investments (Mamo 1999). A fixed amount of money is collected from members (usually monthly) and paid out for members turn by turn in a lottery system. For a more extensive description of equb see Dejene (1993).

time specific changes. Table 2 presents the definitions and summary statistics of the variables used in the regression models.

Table 2 Description of the variables in the regression models

Variable	Description	Mean	SD
Dependent variables			
FSI	Food security index	0.05[a]	1.00
Food security status	Relative food security status over time, =0 if a household persistently food insecured, =1 if changed its status at least once, =2 if persistently food secured	0.96	0.77
Natural capital			
Rainfall index	Index constructed from responses of a set of questions related rainfall timeliness, amount and distribution	0.51	0.37
Mean rainfall	Average village level rainfall obtained from near by weather station (mm)	933.70	321.16
Rainfall deviation	Deviation of the previous season rainfall from its long-term (30 year) mean (mm)	-45.38	211.96
Human capital			
Age	Age of the household head in years	48.73	15.01
Household size	Number of household members	5.70	2.73
Gender	Dummy, = 1 if the household head is male, 0 otherwise	0.76	0.42
Literacy	Dummy, =1 if the household head is literate, 0 otherwise	0.35	0.48
Adult labor	The number of household members who are economically active)' i.e., aged between 15 and 65	0.30	0.17
Social/financial/physical capital			
Savings group	Dummy, = 1 if a household member participates in a local savings group (equb), 0 otherwise	0.17	0.38
Credit	Dummy, = 1 if a household member has taken out a loan in the past 12 months, 0 otherwise	0.42	0.49
Off-farm	Dummy, =1 if the household earns off-farm income, 0 otherwise	0.37	0.48
Livestock	The number of cows, sheep and goats owned by the household	0.79	1.01

[a] This value is not zero due to cases with missing values on some of the explanatory variables,

5. Results and discussion

5.1 The Food Security Index

The results of the PCA indicate that the first factor explained 32.5% of the total variation in the data. The second factor explains only 12% of the variance. The component loadings, which are the most important output for determining the first principal component, are presented in Table 3.

Table 3 Summary statistics and component loadings of the food security indicators

Variables	Mean	SD	Component loading
Number of oxen owned	0.76	1.00	.715
Number of crops grown	2.04	1.17	.698
Whether the household stored crops	0.60	0.49	.536
Size of land under cultivation	1.51	3.13	.448
Number of food groups consumed	3.65	1.56	.370

As the table shows, the loadings in the first component all exhibit positive signs as expected. For example, ownership of more oxen, which are the primary draft power source in rural Ethiopia, guarantees the timely execution of agricultural activities thereby improving household food availability. This variable is hypothesized to correlate positively with the index and is confirmed as anticipated.

More oxen is also associated with having larger cultivated land size, consumption of more diverse food, growing of varied types of crops, and higher probability of crops stored by the household. So, the first component is considered to be the index of food security and vulnerability for our purpose. The value of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.66, indicating relatively compact patterns of correlations between the variables and hence justifying the use of PCA for our purpose (Dunteman 1994).

A correlation analysis was done for each year to examine to what extent our index is associated with some of the factors commonly known to indicate food security such as per capita consumption expenditures, value of food consumption per month, number of meals per day, value of household asset owned, among others. The results[9] show that our index is highly significantly correlated with the variables in the expected directions. For example, the Pearson correlation with per capita consumption expenditures is 0.37, 0.40, and 0.42 for the years 1994, 1999, and 2004, respectively ($P < 0.001$), indicating the validity of our index in measuring the relative food security status of farm households.

5.2 Descriptive analysis

Sample households are classified into relative food security groups using the mean of the index as a decision point: Those households with a positive index values are categorized as relatively higher-level of food security (factor score ≥ 0) whereas those with negative index values as low level of food security status (factor score < 0). In the following we examine differences between these groups and thereby evaluate the ability of the index to separate the households into the two groups of different characteristics in a way that conforms to our hypotheses. Results of the investigation of the differences

[9] Detailed results of the correlation analysis are not reported in the interest of saving space but are available on request.

between the more and the less food secure groups in several demographic, economic and institutional variables are provided in Table 4.

Human capital

One can identify from the table that in all the three rounds of the data the more food secure households tend to consistently have more family members than the less secured ones. Moreover, the number of household members who are economically active is relatively higher in more secured households indicating that these households are better endowed with economically active labor resource which is vital for agricultural production. Similarly, in all the three rounds the less secured households tend to have larger number of dependents than the relatively more secured ones. In each of the cases the analysis reveals that the difference is statistically significant at 1% level of probability. With regard to household head attributes such as gender and education, the results show that the index score is significantly higher for households whose head is male and literate signifying that secured households are in a better position in human capital. Concerning the head’s age, in 1994 data, more secured households tend to have relatively older heads than the less secured ones and the difference is statistically significant at 1%. However, in 1999 and 2004, there is no statistically significant age difference between the two groups.

Ownership of livestock and rainfall perception

Livestock is an integral part of smallholders’ production system in Ethiopia. It can serve as a critical input in farm operations as it enhances production and is also an important source of capital through which considerable income is generated. In our analysis of all of survey periods the two groups noticeably differ in the number of livestock (cows, sheep and goat) owned, i.e. more livestock was kept by households that were more food secured. The difference is statistically significant at 1%. This implies that if households’ livestock possession were increased, their food security status would also respond positively. In the study villages, agricultural production is mainly dependent on the availability of sufficient rain. Over the three survey periods the two groups significantly differ in their experience of rainfall quality in that the more secured ones persistently experiencing relatively better rainfall outcome than the less secured counterparts. These results confirm the importance of livestock and rainfall in household food production system in Ethiopia and in line with the common knowledge that prevalence of adverse weather conditions as the underlying causes of food insecurity.

Off-farm employment, input use, and credit

In all survey rounds under consideration, we found a clear and consistent pattern of association of participation in local savings groups with higher level of food security index score. The results indicate that those households who are members of savings groups consistently registered a significantly higher score of the food security index. This observation might justify the role traditional savings associations play in strengthening household food security in sample households. The pattern in households’ credit access and participation in off-farm activities is rather mixed. In 1994 and 2004 those households who had access to credit exhibit a significantly higher index value whereas in 1999 survey period the trend is reversed. Likewise, participation in off-farm activities shows an inconsistent picture. In 2004 those who participated in these activities were found to have a significantly higher index score but the reverse holds true for 1999.

The foregoing descriptive analyses confirm the validity of the food security index for measuring household relative food security. The index performed well in categorizing households into more food secured and less secured groups. It is demonstrated that there are clear significant differences between the two groups in their various socioeconomic characteristics. Overall, the more secured households experience better rainfall outcome, have male and literate head, tend to have more number of economically active household members and less dependents, own more livestock, and participate in local savings groups.

Table 4 Differences in household characteristics by food security groups

Characteristic	1994			1999			2004		
	More secure	Less secure	Stat. sig.[/a]	More secure	Less secure	Stat. Sig.	More secure	Less secure	Stat. Sig.
Gender of the head is male, %	40.1	37.7	***	34.0	40.8	***	35.45	39.70	***
Mean age of the household head, years	47.01	45.88	n.s.	50.24	49.01	n.s.	51.14	50.07	n.s.
Mean household size	5.88	4.78	***	5.27	4.44	***	5.63	4.88	***
Mean number of economically active members (aged 15 to 64)	3.14	2.73	***	3.06	2.46	***	3.19	2.52	***
Mean dependency ratio	0.52	0.62	n.s.	0.47	0.50	n.s.	0.26	0.24	n.s.
Mean value of food consumption per month, Birr	341.7	206.1	***	558.1	336.1	***	566.5	296.4	***
Mean value consumption expenditure per capita, Birr	85.2	62.1	***	99.3	82.8	***	113.4	73.8	***
The household head can read and write, %	39.9	28.1	***	36.2	26.0	***	47.9	32.5	***
Mean value of consumer durable assets owned, Birr	247.5	88.4	***				325.6	115.9	***
Mean number of meals per day during recent drought							2.33	1.98	***
Household faced shortage of food during the last rainy season, %							52.6	74.3	***
Mean number of months in the last 13 months[/b] with food shortage							2.11	3.08	***
Mean rainfall index	0.28	0.24	*	0.68	0.63	**	0.68	0.61	***
At least one household member has taken a loan last year, %	20.0	17.2	**	47.3	56.2	***	56.3	51.2	n.s.
At least one household member participates in *equb*, %	23.9	12.4	***	16.0	12.3	n.s.	22.1	12.8	***
At least one household member involved in off-farm activities, %	31.8	37.0	n.s.	20.2	32.7	***	53.3	42.3	***
Mean number of cows owned	0.48	0.16	***	1.00	0.47	***	0.91	0.50	***
Mean number of sheep and goats owned	1.24	0.46	***	2.47	1.11	***	2.56	1.25	***
Used purchased fertilizer for use on own fields, %	53.6	20.0	***	76.3	27.5	***	69.5	29.5	***

[/a] Statistical significance of the difference is based on Chi-square test for categorical variables, Mann-Whitney test for cows and sheep and goats, and t test for the rest. * (**) [***] Statistically significant at the 10% (5%) [1%] level of error probability. Blank entries show no data available. Dependency ratio is the ratio of dependents (aged <15 and >64) to total household size.

[/b] The Ethiopian calendar consists of 13 months per year, 12 months with 30 days plus one month with 5 or 6 days.

Changes in relative state of food security

The movement of sample households in and out of a given state of food security between 1994 and 2004 is assessed using the transition matrix presented in Table 5 which is based on quintiles of the food security index. Bold figures indicate the share of households that stayed in the same food security quintile. A visual inspection of the matrix shows that a large share of those households that are either in the first (severely insecured) or the fifth (highly secured) quintile in 1994 are still found in the respective quintile in 2004.

Table 5 Transition matrix for quintiles of the food security factor score between 1994 and 2004

		2004 food security quintile (1 = lowest to 5 = highest; values are % of households; total N = 1260)					
		1	2	3	4	5	Total
1994 food security quintile	1	**47**	25	17	7	4	100
	2	24	**29**	22	19	5	100
	3	20	21	**25**	20	13	100
	4	7	15	23	**28**	26	100
	5	2	9	12	26	**51**	100
	Total	100	100	100	100	100	

However, overall, households' food security status is not stable over time. For example, of 250 households classified as being in the third quintile in 1994, only 25% remained in their same position in 2004; 42% of the households moved back to less secured state and 32% moved forward.

Looking at the movement of households in all the three rounds of the data, it can be indicated that 32% of households were less food secured in all the three survey rounds whereas the always-more-secured category constitutes 28%. The remaining households have experienced movements into a less secured status (21%) and a more secured status (19%) over the three survey periods.

The indices computed for the three rounds were also compared to each other to determine whether there were changes in the overall food security situation of sample households. A paired t-test analysis shows that between 1994 and 1999 there is no statistically significant difference in relative food security status measured by our index. However, the same analysis reveals that between 1994and 2004 and between 1999 and 2004, there is a statistical difference at 10% and 1% level of significance respectively. These results were compared against the results of prior studies which report poverty is declining over the period from 1994 and 2004 in the same households (Dercon et al. 2007) and in line with these findings. This suggests the strong link between poverty and food security in the sample households.

4.2 Econometric analysis

Determinants of food security over time

Initially, models employing both fixed effects and random effects were estimated. The appropriateness of the specifications was tested using the Hausman test under the null hypothesis that the unobserved household effects are uncorrelated with the explanatory variables included in the model, which was rejected at $P < 0.001$. We thus concluded that the random effect model produces inconsistent estimates and used the fixed effects specification (Wooldridge 2002:288). In our case, due to the endogenous nature of some of the explanatory variables, we apply a fixed effects instrumental variable regression procedure. With regard to specification tests of the instrumental variable model, we note that the F-test of the joint significance of the instruments in the first stage regression shows large and highly statistically significant F-statistic, indicating the relevance of the instruments. The Hansen J test fails to reject the null-hypothesis that the instrumental variables are uncorrelated with the error term, thus indicating the validity of the instruments. In the estimation, we used robust standard errors correcting for heteroskedasticity (White 1980). The results are presented in Table 6.

Since the dependent variable is a relative measure of food security the absolute magnitude of the coefficients is not informative. We therefore focus our interpretation on the sign of the coefficients and their relative magnitude. The effect of rainfall shock represented by three variables is as anticipated. Rainfall satisfaction index and mean rainfall at main rainy season are found to be positively and significantly associated with food security over time. The result suggests that if rainfall is favourable (in terms of timeliness, amount and distribution), then households experience a relatively better food security condition. As expected, the parameter estimate for rainfall variability measured by the deviation of previous season rainfall from its long-run mean, though small, is found to be negatively associated with food security implying that the higher deviation the less food security. These findings confirm the notion that climate variability is one of the critical "drivers of food security" in many African agrarian households (Gregory et al. 2005; World Bank 2006).

The parameter estimates for household size is significant and positive reflecting that a household with more family members is in a more advantageous position to enhance its food security. The positive sign is consistent with the findings of Alene and Manyong (2006) in Nigeria. A study by Toulmin (1986) in rural Mali also suggests that larger sized households tend to have diverse income sources and have the advantages of economies of scale that can be realized by higher family assets such as oxen and labour income sources. However, this result is contradicted by other studies done in Ethiopia (Ramakrishna and Demeke 2002) and elsewhere (Nyariki et al. 2002) which report a negative association between household size and food security. The differences in these results may be partly attributable to differences in household composition. As the ratio of dependent and adult household members (only consuming versus producing and consuming individuals) increases, household food security will decline since the implication on food consumption is higher than labor contribution.

Table 6 Results of the fixed effects instrumental variable (IV) regression and multinomial logit model

	Fixed effects IV model	**Multinomial logit model**	
		Always insecured	**Vulnerable**
	Coef.	**Coef.**	**Coef.**
Rainfall index	0.0871 (1.83)*	-0.547 (-0.73)	-0.267 (-0.42)
Mean rainfall[a]	0.8348 (2.52)**	-7.989 (-8.17)***	-7.222 (-17.00)***
Rainfall variability	-0.0007 (-2.08)**	0.503 (5.05)***	0.466 (5.03)***
Gender	0.1668 (1.17)	-1.216 (-2.71)***	-0.534 (-1.43)
Literacy	0.0426 (0.91)	-0.438 (-1.27)	-0.286 (-1.00)
Age	0.0110 (1.34)	0.061 (1.34)	0.006 (0.17)
Age squared	-0.0001 (-1.26)	-0.001 (-1.14)	-0.000 (-0.16)
Household size	0.0474 (4.78)***	-0.247 (-3.09)***	-0.157 (-2.36)**
Adult labor	0.0629 (0.61)	-0.056 (-0.69)	0.048 (0.76)
Livestock	0.0857 (3.63)***	-1.229 (-3.64)***	-0.594 (-2.46)**
Credit	-0.0719 (-0.88)	6.815 (1.01)	6.445 (1.13)
Savings groups	0.3317 (2.33)**	1.131 (0.30)	-0.214 (-0.07)
Offarm	-0.0063 (-0.12)	-6.961 (-1.44)	-3.701 (-0.94)
Year 1994	0.0117 (0.24)		
Year 1999	-0.0113 (-0.36)		
F(15, 1946)	7.31	LR chi2(48)	686.24
Prob > F	0.0000	Prob > chi2	0.0000
N	3080	N	1144

Note: *, **, *** indicate significance levels at 10, 5, and 1% respectively. Numbers in parenthesis are Z-values based on heteroskedasticity-consistent standard errors (1980). a/ logged. Dependent variable for the fixed effects IV model is food security index and for the multinomial model food security status with 3 categories (always-secured, always-insecured, and vulnerable). Village dummies are included for the multinomial logit model but not reported.

Consistent with our expectation, livestock asset endowments are positively and significantly associated with food security implying that the more livestock a household has the better its food security position. This is similar to the finding of Ramakrishna and Demeke (2002) in Ethiopia.

Membership in local savings groups, significantly contributes to household food security. This result was anticipated because in rural Ethiopia, where the existence and operation of formal financial institutions is limited or nonexistent, one would expect the positive role played by such local savings and credit associations. Households who are members of these associations are in a better condition to access financial resources to make investments in their farm and to bridge the food gap in times of scarcity. In addition, membership in local associations offers households an opportunity to get more connected with other households resulting in formation of social capital on which households could count in times of food or financial shortages. Contrary to our expectation, access to credit and off-farm participation carried unexpected sign but not statistically significant. Overall, the empirical results presented here correspond to the results of foregoing descriptive analysis.

Determinants of staying in prolonged food insecurity and vulnerability

In order to identify influencing factors of prolonged food insecurity and vulnerability, multinomial logit model was applied using households who are always food secured as the base category. Results are shown in the last two columns of Table 6 and discussed in terms of the signs on the parameters and their statistical significance. Multinomial logit model is based on a strong assumption of Independence of Irrelevant Alternatives (IIA). We tested whether the assumption of IIA holds in our model using the Hausman and Small-Hsiao tests. The results consistently indicate that the assumption is not violated and hence application of multinomial logit model appropriate. The explanatory variables included in the model are jointly significant at $P < 0.001$, and the Pseudo R^2 value associated with the model is 0.2768 indicating that the specification fits the data well.

Turning to the results, the significance of mean rainfall level and its variability on prolonged food insecurity and vulnerability was consistent with the hypothesis that households who experience lower rainfall level and higher variability are more likely to remain in a state of persistent food insecurity and vulnerability. In Ethiopia, rural life revolves around rain-dependent agricultural production and characterized by uncertain rainfall pattern and prevalence of recurrent drought arising from extreme weather conditions. Many authors (Webb et al. 1992; Yesuf et al. 2008) acknowledge that drought is strongly associated with the problem of food insecurity in the country. Our findings are consistent with this line of earlier research.

The regression results reflect a negative association between household size and persistent food insecurity and vulnerability. The implication of this result is that the higher the number of members, the more likely the household will be in a relatively better status of food security. Of course this depends on the ratio of dependent members to that of productive adult members. The results indicate male-headed households tend to be relatively less trapped in prolonged food insecurity.

In line with our hypothesis, there is strong statistical evidence that amount of livestock owned has a substantial effect on the probability of staying in persistent food insecurity and vulnerability. As the number of livestock owned increases, the likelihood of food insecurity and vulnerability trap declines. Livestock are important capital assets in rural areas with multiple purposes. They serve as sources of food and income. Also serve as buffer stocks which at times of stressful periods such as production shortfalls can be easily converted to cash thereby reduce problems of food availability through generating income. This implies that availability of greater number of livestock permit households enhance their economic wellbeing in general and their food entitlement in particular.

In summary, the multinomial regression results reinforce the earlier fixed effects regression findings by showing the strong association of persistent food insecurity and vulnerability with adverse rainfall shock. Moreover, the results indicate that household size and livestock ownership significantly affect the likelihood that households are in a state of permanently low food security and vulnerability. The likelihood of staying in persistent food insecurity diminishes with male headed households, more livestock, and with adequate level of rainfall and lower variability.

5. Conclusions and recommendations

The main objective of this study was to investigate how household food security is associated with an important climatic variable, rainfall variation, over time. We developed a food security index using a combination of food security indicators and used this new index to examine the dynamics and determinants of food security and vulnerability among selected farm households using panel data in rural Ethiopia. Descriptive statistical analysis imply that the more food secured households tend to consistently endowed with more human capital, livestock, and experience favorable rainfall outcome compared to less secured households. Results from instrumental variable regression analyses are consistent with the descriptive analysis. In the regression analysis, both rainfall level and variability found to be significantly influence household food security over time. In addition, household size, *equb* membership, and livestock ownership variables are also positively and significantly associated with household food security. Similarly, multinomial logistic regression analysis reveals the profound impact of rainfall variability in putting households in food insecurity trap and state of vulnerability. It is also noted that gender of household head, livestock ownership and household size are associated with the likelihood of remaining in always-less-secured and being vulnerable.

Several important conclusions can be drawn from these analyses. The results highlight the critical role of rainfall variability in households' food security. Hence, an important intervention to reduce food insecurity in the study areas would be provision of efficient risk reducing and mitigation programs. In line with this, promoting measures that enhance the asset base of households thereby increasing their capacity to withstand the vagaries of the frequent rainfall risk is imperative. Correspondingly, strengthening the existing programs such as productive safety net, household asset building and the drought insurance program of World Food Program (2007) might be some of the potential ways to minimize the risk of rainfall shock ex ante and maximize households coping ability ex post. Moreover, given the large uncertainties about the country's future rainfall patterns, careful consideration should be given to major investments in infrastructure to support irrigation and water resources development so that the existing dependence on rainfed farm production is reduced. our results with respect to livestock suggests strong consideration of programs which are directed towards improving the diversity and productivity of the livestock asset such as provision of improved feed and fodder crops and improvement in animal health and market infrastructure. Policy makers may also need to embark on interventions that encourage the expansion of traditional savings associations as potential avenues for financial opportunities to help households smooth their food consumption in the wake of agroclimatic calamities.

However, our analysis is restricted to the non-pastoralist households and hence, although suggestive, the results cannot be generalized to all rural households in Ethiopia. Furthermore, due to inconsistency in the data available for constructing the index of food security, the set of indicators ultimately considered is limited and may therefore be incomplete. Apart from addressing these limitations, future research should apply the method presented here for measuring relative household food security in different socio-economic and agro-ecological settings to test its usefulness.

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