Master thesis for M.Phil in Environmental and Development Economics degree

Vulnerability and Poverty Dynamics in Rural Ethiopia

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Preface

The issue of poverty analysis has been at the heart of development economics, economics of the poor. Two vital reasons lead me to work on the topic of this thesis. The first reason, which is most important, is that I am from a country where poverty is rampant and I often wondered on the nature and causes of the poverty of the nation, so I believed that this thesis will be a good starting point for research. Besides, as a prospective graduate in development economics I felt that I should start contributing my own share in the field by writing my thesis in one of the core areas of development economics.

I have benefited from the comments of many individuals who have given kindly their time to make substantive suggestions, whom I can hardly list. I take the first opportunity exhaustively to express my deepest gratitude to my supervisor, Henrik Wiig for his critical and invaluable comments through the stages of preparing the thesis.

My heartfelt thanks goes to Fitsum Hagos for his comments in the inception of the thesis and for providing me the Tigray panel data used in this thesis. I am indebted to Daniel Muluwork for his comments at the early stage of the thesis. I am also very grateful for the comments and encouragement forwarded by Sosina Bezu. High level of fraternity and friendship from Endeshaw and Muctar were invaluable during the whole period of my study, thank you guys! My colleagues from Mekelle University who contributed in one way or the other also deserve appreciation.

I must acknowledge the financial support of the Norwegian quota program, which turned my dream of studying in UiO real. Knut Sydsæter of the department Economics at UiO deserves special gratitude for his marvelous effort in supporting my home institution in particular and all African universities in general.

The panel data used in this thesis was collected by grants from the Norwegian Research Council, IFPRI, ILRI, Norwegian University of Life Sciences and Mekelle University (Ethiopia). I am grateful to all the institutions.

To all my friends I thank you for being friends indeed. Last but not the least, deepest and warm thanks to Mekdy and my family, who have been a source of rejoice in my life.

Needless to say, all errors remaining are my own responsibility.

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Contents

List of Tables

Summary

Most of studies in poverty analysis focused on analyzing poverty at a point in time or the trend over time based on cross sectional data. The drawback of such approach is that it measures poverty on a given date without distinguishing between those that are chronically poor due to low asset base and those that are transiently poor due to shocks, i.e., a household may be poor because it is not able to generate sufficient income to meet the basic needs due to lack of assets (physical as well as human) under normal circumstances or a household may be poor due to negative shocks like temporary layoff of the major income earner of the household due to illness from the labour market, bad agricultural weather condition, which pulls down the mean income or consumption of the household below poverty line for that particular period or vice versa. This might lead to the wrong policy direction, since the policy required for addressing the needs of transient poor is different from the chronic ones.

Indeed there is little research based on panel data that tries to investigate the poverty dynamics in Ethiopia in the 1990s. Exceptions are series of papers by Dercon and Krishnan (1998, 2000, and 2001), Hagos and Holden (2003), Bigsten and Shimeles (2003), Swanepoel (2005) used panel data in poverty analysis.

The analysis of poverty dynamics distinguish between the transient and chronic poverty or the exit, entry and re-entry into poverty. This means that there is a chance that a household that is not poor becomes poor, one that is poor remains poor. This leads to vulnerability assessment in terms of 'vulnerability to poverty'. 'Vulnerability to poverty' is the probability that a household will be poor next period. So it is an important concept to deepen the understanding of poverty, since it reveals information on what measures should be taken to prevent poverty while poverty dynamics largely imply the past and contemporary poverty situation and is helpful on how to alleviate the existing situation.

Using three round rural household Tigray panel data for 1997, 2000 and 2003, this thesis examined poverty dynamics, vulnerability to poverty of households. It also analyzed the determinants of poverty dynamics and correlates of vulnerability to poverty.

Methodologically, the thesis used the Foster-Greer-Thorbecke (FGT) poverty measures in order to measure poverty and both component and spells approach to decompose poverty into chronic and transient. Three econometric models were used in this thesis. One, a fixed effects regression used to analyze the determinants of the poverty dynamics. In the fixed effects regression, the poverty dynamics captured using the entity demeaned value of log per adult equivalent consumption expenditure and set of household characteristics used as explanatory variables. Two, to identify the factors that affect the likelihood of being chronic and transient to non-poor, I estimated a multinomial logit model. Three, to estimate the vulnerability to poverty of a household I adopted the vulnerability measure in Chaudhuri (2003). In order to estimate this measure I followed a three step Feasible Generalized Least Squares (3FGLS) to estimate the expected log per adult equivalent consumption expenditure and variance log per adult equivalent consumption expenditure. Using these estimates and assuming that per adult equivalent consumption expenditure is log normally distributed I

estimated the vulnerability measure as the probability that the standard normal variate will fall below standardized poverty line.

The main findings of this thesis are as follows: Firstly, poverty in rural Tigray is chronic, however, there is some evidence of dynamics in the rural poverty as one can infer from the transient component of poverty. Secondly, the fixed effects regression identifies that household's farm size improve significantly welfare of the household while the number of children, juniors and adults in the household found to adversely affect household's welfare. Thirdly, the explanatory variables for chronic and transient poverty are the same, where the household's head age and the numbers of children in the household increase the probability of being chronic and transient poor compared to non-poor. Farm size and off farm participation of the head of the household reduce the likelihood of becoming chronic and transient poor. Lastly, there is high vulnerability to poverty, i.e. high probability of becoming poor in a period ahead, in the region and it is significantly correlated with household head age and education, household size, asset ownership and number of seniors (or elderly) in the household.

The thesis suggests two different policy interventions. One, since poverty is chronic in rural Tigray the policy interventions in the region should focus on assisting poor households to accumulate assets through increased investment and employment generation that enhances their mean consumption level. Two, the evidence that there are more vulnerable households' calls for policy intervention that reduce consumption variability through reducing exposure to risk or improving the *ex post* coping mechanisms of the vulnerable

1. Introduction

Any yardstick of poverty ranks Ethiopia at the bottom list of nations, with an estimated GDP per capita of $110 in 2004 (World Bank, 2005); life expectancy at birth 48 years in 2005 and 50% of the population below poverty line in 2004 (CIA, 2005). The country was in long political instability during the military rule*, Derg*, where the countries economic performance deteriorated. By 1991 the country moved from central planning communist to reformist market led economy. Besides, the government adopted a long term development strategy called Agricultural Development Led Industrialization (ADLI) for economic transformation with prime objective of poverty reduction. And in 2002 the government produced the Sustainable Development and Poverty Reduction Program (SDPRP) targeting in poverty reduction.

In view of this several researchers studied how and whether the reforms reduced poverty, to understand the factors behind the poverty situation and its link with economic growth. Much of this research focused on analyzing poverty at a point in time or the trend over time based on cross sectional data, e.g. Woldehanna and Alemu (2002) and for the review in ('Ethiopia: Sustainable Development and Poverty reduction Program', 2002). The drawback of such approach is that it measures poverty on a given date with out distinguishing between those that are chronically poor due to low asset base and those that are transiently poor due to shocks, i.e. a household may be poor because it is not able to generate sufficient income to meet the basic needs due to lack of assets (physical as well as human) under normal circumstances or a household may be poor due to negative shocks like temporary layoff of the major income earner of the household due to illness from the labour market, bad agricultural weather condition, which pulls down the mean income or consumption of the household below poverty line for that particular period or vice versa. This might lead to the wrong policy direction, since the policy required for addressing the needs of transient poor is different from the chronic ones.

Indeed there is little research based on panel data that tries to investigate the poverty dynamics in Ethiopia in the 1990s. Exceptions are series of papers by Dercon and Krishnan

(1998, 2000), Hagos and Holden (2003), Bigsten and Shimeles (2003), Swanepoel (2005) used panel data in poverty analysis.

Moreover, the review work on ten developing countries by Baulch and Hodinott (2000) reveal that the percentage of households transiently poor exceeds the chronically poor implying that 'poverty problem' involves large turnover of vulnerable people rather than chronically poor, which has an implication on the policy mix required to address the issue of poverty at large.

The analysis of poverty dynamics distinguish between the transient and chronic poverty or the exit, entry and re-entry in to poverty. This means that there is a chance that a household that is not poor becomes poor, one that is poor remains poor. This leads to vulnerability assessment in terms of 'vulnerability to poverty'. 'Vulnerability to poverty' refers to the likelihood that a household becomes poor in next period. It is an important concept to deepen the understanding of poverty since it reveals information on what measures should be taken to prevent poverty while poverty dynamics largely imply the past and contemporary poverty situation and is helpful on how to alleviate the existing situation. Thus, it will be important to explore the vulnerability to poverty aspect of the rural households as well.

Based on these facts, the main theme of this paper is three fold. *First*, it seeks to analyze the dynamics of poverty in rural Ethiopia by making use of panel data of rural households for Tigray (a Northern region in Ethiopia) with observations in 1997, 2000 and 2003. Meanwhile attention will be given to the decomposition of the poor in to transient and chronic poor. *Second,* it attempts to measure the vulnerability of households to poverty. *Third*, it tries to investigate the determinants of poverty dynamics and correlates of households' vulnerability to poverty.

The dynamics of poverty revealed using the Foster, Greer and Thorbecke (FGT) poverty indices for the three waves. The paper decomposed the intertemporal poverty into chronic and transient components using both component and spells approach. The component approach of decomposing poverty is based on expected poverty overtime. According to this approach a household is chronically poor if its time-mean consumption is below poverty line and transiently poor if its time-mean consumption is above poverty line but one of its consumption levels is below the poverty line. The spells approach is based on poverty spells experienced by an individual over a given period of time. According to this approach a

household is chronically poor if its consumption is below the poverty line all the time and transiently poor if its consumption level is below poverty line only sometimes.

Econometrically, to analyse the factors behind the change in the welfare of the household I estimated a fixed effects model using the panel data. To identify the determinants of the chronic, transient or non-poor, the paper uses limited dependent variable model, namely, multinomial logit model. The paper measures the vulnerability to poverty of the households adopting the measure in Chaudhuri (2003), which is commonly referred as the Vulnerability to Expected Poverty (VEP). The correlates of the vulnerability of the household identified using ordinary least square (OLS) regression.

The main findings of this paper are as follows: Firstly, poverty in rural Tigray is chronic, however, there is some evidence of dynamics in the rural poverty as one can infer from the transient component of poverty. Secondly, the fixed effects regression identifies that household's farm size improve significantly welfare of the household while the number of children, juniors and adults in the household found to adversely affect household's welfare. Thirdly, the explanatory variables for chronic and transient poverty are the same, where the household's head age and the numbers of children in the household increase the probability of being chronic and transient poor compared to non-poor. Farm size and off farm participation of the head of the household reduce the likelihood of being chronic and transient poor. Thirdly, there is high vulnerability to poverty, i.e. high probability of becoming poor a period ahead, in the region and it is significantly correlated with household head age and education, household size, asset ownership and number of seniors (or elderly) in the household.

The contribution of this paper to the literature is two folds. One, to compute the poverty components for the region using component approach as in Jalan and Ravalllion (1998) and estimate the vulnerability and identify the correlates of vulnerability. Two, this study also updates the previous study on poverty dynamics in rural Tigray by Hagos and Holden (2003) by extending the panel data further by a wave.

Broadly the paper aims to uncover the important issues in poverty analysis for enhanced understanding of the dynamics in poverty and vulnerability, which will prove useful for the proper adjustment of the series of economic reforms aiming at poverty reduction.
Specifically, the paper attempts to:

- Investigate the welfare movement of a set of households over time by using standard poverty measures and decompose the poor in to transient and chronic
- Measure the extent of vulnerability to poverty of the households
- Identify the determinants of poverty dynamics and correlates of vulnerability to poverty

The paper is structured as follows. Section 2 reviews both theoretical and empirical literature on poverty dynamics and vulnerability, section 3 presents simple conceptual frame work and testable hypothesis of the study , section 4 discusses the methodology and data used in this study, section 5 reveal results and section 6 concludes the study. I used Stata software (version 9) in estimating the econometric models specified in section 4.3, and Microsoft Excel program for doing some computations on poverty measures.

2. Review of Literature

2.1 Theory on why poverty persists

Poverty dynamics refers to processes which either increase or decrease the poverty. This implies that the analysis of poverty dynamics focuses on the flow than mere stock of poverty. The conception of poverty dynamics can be broadened by including a range of social change factors including different forms of capital like social, political, environmental, cultural and coercive on top of economic and human capital (Shaffer, 2000). Changes on one of the forms of capital interact in a complex way with other forms of capital and result in change in poverty relevant policy. The changes may have either complementing or conflicting effects on each other and different aspects of well being.

Studies that try to investigate on the causes of poverty and its persistence base their theoretical frame work on either aggregate or micro levels.

Piachaud (2002) describes theoretically different forms of capital that are important in avoiding poverty drawing views from economics and other social sciences. Adam Smith a couple of centuries ago acknowledged the wealth of nations depended on their level of physical capital, on the skills of the labor force, on the technological processes used, and on the prevailing moral values. In 1940s, the Harrod-Domar model emphasized on accumulation of physical capital beyond the amount required to replace depreciation (Todaro, 2003) while Solow (1956) expanded the Harrod-Domar model giving attention to another factor labor and technology .In mid 1960s, the Chicago economists, Schultz and Becker realized that alike to physical capital, human capital can also be accumulated in the form of education and skill, which could result in rise in output hence earning. Kalador (1957) hypothesized that technical progress depend on level of investments and Romer (1986) argued that capital accumulation results in learning which cannot be internalized and imitation then raises efficiency in the economy as a whole.

In 1990's a shift of view occurred that institutions really matter for economic growth. A society that lacks good institutions will be characterized by low investments and low incomes. Besides, other social science disciplines initially identified that social capital (the norms, networks, rules and social values) is important for prosperity and avoiding poverty, which economic literature recently has recognized its importance.

Based on the above reviews Piachaud (2002) identified the following forms of capital: financial, physical, human, public infrastructure and social as important varieties of capital that can be accumulated and affect prosperity and poverty at individual, community and national levels.

Similarly, Shaffer (2000) reviews the changes in conception and analysis of poverty dynamics and identifies two major changes. One, the causal factors broadened to include a range of social factors. Two, the causal structure deepened focusing on flows than stock of poverty. Based on the causal factors different poverty intervention approaches are in practice. A few among others are the human capital approach based on presumption that there is a link between investment in education, health and nutrition and the primary income of the individual (or poor), and the production function approach presupposing that the primary income of an individual (or poor) is related to the output she or he produces and output is a function of factors of production (land, labor and capital).

The conventional micro perspective of proximate causes of poverty is based on individual's behavior. The neoclassical economics argues that an individual is poor because of his/her decisions. The assertion is individuals seek to maximize their own well being by making choices and investments. When some people choose short term and low-payoff returns, economic theory holds the individual largely responsible for their individual choices, for instance to forego education or other training that will lead to better paying employment or adoption of production process in the future.

2.2 Previous Empirical studies on Poverty Dynamics

In this section I review some of earlier empirical studies on poverty dynamics and by no means an exhaustive.

Several studies of poverty in Ethiopia are due to Dercon and Krishnan (1998, 2000) and Dercon (2002, 2004). Dercon and Krishnan (1998) using panel data of Ethiopian rural households (ERHS) collected for 1989,1994 and 1995 found that poverty declined between 1989 and 1994 and remained same between 1994 and 1995. They also found households with substantial human and physical capital, and better access to roads and towns have both lower poverty levels and are more likely to get better off over time. Human capital and access to roads and towns also reduce the fluctuations in poverty across the seasons.

Similarly, Dercon (2002) reconfirms the fall in poverty between 1984 and 1994. Using decomposition of changes in poverty he demonstrated that the main factors behind the change in consumption attributed to change in the prices as a result of the economic reform, resulting to change in return of land, labor, human capital and locations. A group of poor in 1989 with good land and location outperformed all the households, while a group of poor with poor endowments remain unchanged and persistently poor. Dercon (2004) found that rainfall shocks have substantial impact on consumption growth.

Bigsten and Shiemeles (2003), Swanepoel (2005) analyzed the dynamics of poverty using spells and component approach for ERHS 1994-1997, found a decline in poverty for the rural sector and transient poverty dominating the rural sector. In rural areas factors as age of the head of the household, dependency ratio within the household greatly affect the odds of moving into poverty, whereas factors such as size of cultivated land, education of the head of the household, education of the wives, value of crop sales, type of crops planted, access to local markets, reduce significantly vulnerability to poverty (Bigsten and Shimeles, 2003).

Devaruex and Sharp (2003) question claim of declining poverty arguing that the initial sampling frame is not representative of the rural Ethiopia. Besides, in Ethiopian rural context, consumption alone can not be considered as a very good indicator of welfare given seasonality, weather patterns and food-aid distort the distribution. Hagos and Holden (2003) using Tigray panel data also found poverty in rural Tigray at best remaining same. In

analyzing the rural Tigray poverty dynamics, they found that the proportions of people falling in to poverty are greater than those escaping. Investigating the determinants of poverty they showed that physical and human capitals are welfare enhancing and the village level variables (whether the village is affected by war, weather calamity) are found to have significant impact on the welfare of the household.

In fact, empirical works on poverty dynamics dates back to Bane and Ellwood (1983) using panel study of income dynamics (PSID) for United States (US), where they review previous approaches used in studying poverty dynamics classifying them as statistical approach that model some variables like income allowing for complex lags or some error structure to capture dynamics, tabulation of frequency of the event over some fixed time frame and spells approach. And they argue that the dynamics is appropriately understood if it is defined in terms of spells of poverty that allows for estimating the extent to which the poor slips in and out due to changes in income and family structure. They found majority of poor amidst longer spells of poverty. Besides, less than 40 % of the poverty spells begun due to decline in the household's head earnings while 60% of the spells end due to rise in household head's earnings. Similarly using PSID for 1968-1988, Steven (1995) investigated the persistence of poverty in US. In contrast to Bane and Ellwood (1983) he used multiple periods spell approach.

Considering some developing economies, Jalan and Ravallion (1998) using panel data set for China decomposed the poor in to chronic and transient poor. The overall expected poor are one with the inter-temporal consumption below poverty line. The chronic poor is one with "time-mean consumption" below poverty line over a given time period. While the transient is the difference between overall expected poor and chronic one. They proposed and used a 'component' approach of decomposing the poverty in to chronic and transient. They also investigated the process behind the chronic and transient poverty using censored conditional quintile regression method.

They found that physical assets are important in determining the transient poverty, i.e., household's stage of life cycle which falls up to age 45 years and rises afterward, household's wealth holdings found to decrease the transient poverty, while the standard deviation of the household's wealth holding likely increases transient poverty. Education level and other demographic characteristics of the household are less likely to influence the transient poverty.

The chronic poverty is highly influenced by demographic characteristics of the household, cultivated land holding and high variance of wealth holding. Generally they found that the determinants of chronic and transient poverty are different but for physical asset holding and life cycle effects. They suggested that poverty reduction intervention require policy instruments like seasonal public works, credit schemes, buffer stocks, and insurance options for the poor that can reduce the consumption variability.

Gaiha (1989) used the National Council of Applied Economic Research (NCAER) data for 1968-71 and found 47% of the households as chronically poor that are identified as landless or near landless and more dependent on wage. He defined chronic poor those whose welfare is below the poverty line over the three years.

Based on International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) panel survey for 240 households from six semi-arid villages in India ranging between 1975/76 to 1984/85, Gaiha and Deolalikar (1993) found 87.8% of the sample households at least once poor over the 9 periods. And more than one-fifth of the sample households were poor all the 9 periods. On the contrary the review work by Baulach and Hoddinott (2000) on ten developing countries reveals that chronic poverty accounts only from 3% in Pakistan to 33% in India. They conclude that poverty in developing countries is more of transient than chronic.

In case of Africa there are few studies of poverty dynamics despite the rampant poverty in the region. This may be due to the demanding nature of the data to analyze the dynamics. To my knowledge only few countries Coted'Ivoire, Ethiopia, Egypt, South Africa, Uganda and Zimbabwe have household-level panel data.

Using panel data from Egypt for 1997-1999, Haddad and Ahmed (2002) analyzed chronic and transient poverty using both transition matrix and components approach. The evidence shows that those who climb into poverty were over twice those who climb out and two-third of the overall poverty was chronic. Investigating the determinants of chronic and transient poverty, they documented that average years of schooling of household members inversely affect both types of poverty but stronger effect on chronic one. The value of land and livestock found negatively correlated with chronic poverty. While number of children under 15 and household size increase the chronic poverty. The location of residence of the household, being in urban

is correlated with transient poverty. In the Egyptian context the policy for reducing poverty should focus on improving the asset accumulation process since majorities are chronic poor.

A study by Woolard and Klasen (2004) analyzes the dynamics in income and poverty for South Africa. Based on Kwa Zulu-Natal Income Dynamics Study (KIDS) panel data they found higher income mobility. Investigating the welfare changes using both univariate and multivariate frame work, the univariate framework revealed that a change in economic event (especially a change in household's head status of losing or getting employment and change in the remittances) largely determine the climbing in and out of poverty than the demographic events. In the multivariate analysis they developed a model of change in real adult equivalent income as function of initial income, physical and human assets, adult equivalent of the household and change in human assets, demographic compositions and employment status. Their study shows that the welfare change is negatively correlated to initial income level, household size, female headship, change in headship (from male to female) and number of children. The initial physical and human assets and their change and change in employment status (from unemployment to employment) found positively influencing the welfare change. They also document four types of poverty traps, associated with large initial household size, poor initial education, poor initial asset endowment and poor initial employment access.

Two papers by Okidi and Mckay (2003) and Lawson *et al* (2006) deal with the dynamics of poverty and factors affecting the dynamics in Uganda over the1990s. Lawson *et al* (2006) using different econometric approaches investigated the correlates of the never poor, those moving in and moving out. They found lack of education and assets are important factors making people remain poor. For other studies on the dynamics of poverty in Africa see Bokosi (2006) in case of Malawi and Grootart and Kanbur(1995) in case of Coted'Ivoire

Methodologically the above articles used the class of decomposable poverty measures of FGT in measuring poverty. The decomposition of poverty was done using either the spells or component approach. To study the factors associated with total poverty, chronic and transient poverty; different authors used different econometric models such as multinomial logistic, probit, bivariate probit, tobit, quantile regression and variant of micro-growth regressions.

2.3 Vulnerability: Concept and Quantification

Conceptually, vulnerability may mean different thing to different individuals. It may mean a situation where an individual feel insecure that something harmful happens in the future. In daily language, 'vulnerable' mean something likely to be harmed or wound. The term 'vulnerable' is originally derived from Latin '*vulnerare*' that mean 'to wound' (Calvo and Dercon, 2005).

Non-technically, vulnerability is defined as "defenselessness, insecurity, and exposure to risk, shocks, and stress" (Chambers, 1989). Technically, vulnerability is an *ex ante* measure of well being (Chaudhuri, 2003), i.e., an *ex ante* expectation of the welfare level of a unit of analysis. He notes that poverty and vulnerability are two side of same coins, Poverty is an *ex post* realization of a state (where the welfare of an individual is below some cutoff point-poverty line) something observed, while vulnerability is an *ex ante* probability of that state. Kurosaki (2002) defines vulnerability to consumption risk if the household's consumption level drastically reduced when hit by a negative income shock. Vulnerability, according Calvo and Dercon (2005), is the existence of *threat* of poverty, measured *ex-ante*, before the veil of uncertainty has been lifted. In contrast, poverty is an observed outcome of low welfare level with certainty. Morduch (1994) regarded a household as vulnerable when its expected welfare level is above poverty line but stochastically below poverty line or vulnerability as synonymous to transient poverty.

In regard to empirical quantifications, several authors attempted to develop measure of vulnerability ranging from the vulnerability to expected poverty (VEP) proposed and implemented by Christiaensen and Subbarao (2001, 2005), Chaudhuri *et al* (2002) and Chaudhuri (2003) to the recent axiomatic based measure of vulnerability by Calvo and Dercon (2005). See Hoddinott and Quisumbing(2003), Kamanou and Mordouch(2002) and Calvo and Dercon (2005) for comprehensive review .

Christiaensen and Subbarao (2001), Chaudhuri *et al* (2002) and Chaudhuri (2003) defined vulnerability as the probability the household falls in to poverty in the future.

$$V_{it} = \Pr(c_{it+1} < z) \qquad (1)$$

Where V_{it} is the vulnerability of the i^{th} household at time *t*, Pr (.) is probability, c_{it+1} is one period ahead per adult equivalent consumption level (measure of household welfare) and *z* is the poverty line. This paper adopts this approach and details are discussed in section 4.2 and 4.3.3.

With uncertainty in the future, the degree of vulnerability rises with time horizon, in view of this, Pritchett *et al* (2000) extended the time horizon for computing vulnerability of a household in *n* periods.

Equation (1) does not take in to account the depth and severity of poverty, according Hoddinott and Quisumbing (2003) one can overcome this limitation by rewriting them as below:

$$V_{it} = \sum_s^S p_s \Pr(c_{it+1} < z) = \sum_s^S p_s I\left[c_{it+1} = z\right]\left[\frac{z - c_{it+1}}{z}\right]^{\alpha} \quad (2)$$

Where $\sum_s^S p_s$ is the sum of the probability of all possible 'states of the world', *s* in period *t* + *1* and □ is the FGT weight. One can also aggregate this measure over *N* households as:

$$VEP_t = \frac{1}{N}\sum_{i=1}^N \left(\sum_s^S p_s I\left[c_{it+1} = z\right]\left[\frac{z - c_{it+1}}{z}\right]^{\alpha} \right) \quad (3)$$

Another vulnerability measure is one based on welfarist ground, vulnerability as low expected utility (VEU) due to Ligon and Schechter (2002). They point out that VEP has the perverse implication that increases in risk would reduce the vulnerability level of those with mean consumption levels below the poverty line since the FGT measure is not well suited in representing household risk attitude. To remedy this weakness, they propose VEU, where vulnerability is defined as the difference between the utility derived at some certainty - equivalent consumption ($U_i(z_{ce})$), which the household is considered not vulnerable, and the expected utility of consumption, $E(U_i(c_i))$

The merit of this measure, besides redressing the weakness of VEP, is to allow decomposition of vulnerability to the factors that resulted them, that is vulnerability due to poverty reflecting low asset or low asset return, vulnerability due to aggregate or idiosyncratic risk reflecting the aggregate or idiosyncratic shock and inability to cope with them. However, two demerits of this measure are: results depend on the functional form assumed and the unit of measurement is in terms of *util* not easily understandable to non-economists.

Another approach is an *ex post* assessment of welfare to measure vulnerability. Noting that aggregate and idiosyncratic shock may result in welfare loss several authors attempted to measure vulnerability as a consequence of uninsured exposure to risk, VER. Usually it is based on the regression of a dependent variable, consumption growth, on set of explanatory variables, i.e. aggregate shocks, idiosyncratic shocks and household characteristics.

The merit of this approach is that it allows seeing whether aggregate or idiosyncratic shocks are dominant cause of welfare loss. Moreover, it shows whether the existing risk management is doing poorly in protecting households from income shocks. The downside of the approach is it requires panel data, it doesn't provide a "headline" estimate of vulnerability and it is backward looking. Indeed, looking in retrospect is important, nevertheless forward looking poverty interventions require measures that can identify who will loss than those actually lost in retrospect. Besides, under this approach what matters is the change in outcome not the levels for there is no critical threshold (like poverty line) and probabilities of shock occurring doesn't matter rather it is the reaction to shock, given the shock occurs (Calvo and Dercon, 2005).

Kamounuo and Mordouch (2002) define vulnerability in a population as the difference between the expected value of a poverty measure in the future and its current value.

Recent attempt of developing vulnerability measure is by Dercon and Calvo (2005). They define vulnerability as the magnitude of threat of poverty, measured *ex ante*, prior removing the veil of uncertainty. They propose two classes of vulnerability measure fulfilling their axiomatic approach based on welfare-economic foundation. To my knowledge, this approach has never been in operational ground unlike the aforementioned measures.

In regard to vulnerability assessment in Ethiopia, Dercon and Krishnan (2000) measure 'vulnerability' in rural Ethiopia by estimating determinants of consumption levels and then

predicting the degree to which households would suffer severe consumption shortfalls given particularly poor rainfall (less than half the long-term mean). Their estimates suggest that the 'vulnerable' population those that have a risk of falling below the poverty line) is 40 to 70 per cent higher than the observed poverty rate.

Adopting the vulnerability measure used by McCulloch and Callandrino (2002), Bigsten and Shimeles (2003) found factors such as size of cultivated land, education of the head of the household, education of the wives, value of crop sales, type of crops planted, access to local markets, reduce significantly vulnerability to poverty.

Dercon (2004) using micro growth model demonstrates that in Ethiopia rainfall shocks have substantial persisting effect on consumption growth; further, he shows that covariates capturing the severity of the 1980s famine are causally related to slower growth in household consumption in the 1990s. Dercon *et al* (2005) found drought and illness shocks as an important factors reducing consumption of the household. They reported that drought and illness shock reduce consumption by 20% and 9% respectively. Besides, different types of shocks found to affect households differently. The drought shock affects more households headed by females or with no schooling and households with small land holding in their village. Illness shock affects largely households with large land holding and households headed with no schooling household head.

Other similar studies in economic literature are Ligon and Schechter (2003), Chaudhuri *et al* (2002). Ligon and Schechter (2003) using their measure to a panel dataset from Bulgaria, found that poverty and risk play roughly equal roles in reducing welfare. Aggregate shocks are more important than idiosyncratic sources of risk, but households headed by an employed, educated male are less vulnerable to aggregate shocks than are other households.

Using Indonesian household panel data from mini-SUSENAS, Chaudhuari *et al* (2002), found household's vulnerability is greatly affected by educational attainment and dependency ratio. Female headed households have the same likelihood of being vulnerable to male headed ones.

3. Conceptual Framework and Testable Hypothesis

In this section I layout a simple conceptual framework to motivate the variables I include in the econometric models, which will be tested. From micro perspective, a household maximizes utility that comes from consumption of commodities and home production activities. I assume that a household makes decision on the level of consumption of commodities to consume and how much home production activities to undertake so that it maximizes the household's welfare.

The household's decision is constrained by its budget. The consumption of commodities is any goods and services purchased and/or self produced and consumed. Home production activities refer to both leisure and any home activities like caring children and the elderly.

The household's income consists of both earned (Y^e) and unearned income (Y^u). Where the earned income is derived from business activities that includes both farm and non-farm activities. The unearned income is comprised of government transfers (like food aid) and private transfers (like remittances). This further depends on the household characteristics, the household's physical and human capital ownership. i.e., whether the household is with high dependency ratio or the household have small land ownership, few livestock and other physical assts that entitles for government transfer. Besides, a household may send some of the members to participate in the non-farm sector in expectation of receiving remittances.

The earned income, Y^e, can be regarded as overall returns from all factors of production. Alternatively, it is the earnings from sale of crop output, which depends on the production function of the household, price of the outputs and inputs, land or ox renting out, sales of livestock and traditional drinks (home made beer 'Tella' or 'Sewa'), wage earning as labourer. Formally:

$$Y^u = Aid + \mathrm{Re}mit\tan ces = f(P,H,D) \quad (4)$$

$$Y^e = f(p,Y,m) \quad (5)$$

Here *Aid* refers to aid from government and/or private individuals either in kind or cash. *Remittances* is the transfer of money from relatives living outside the village, *P* is vector of physical capital, *H* is vector of human capital, *D* is vector of demographic composition and characteristics of the household, *Y* is the total output, *p* is price of input and output, *m* is the wage earning. However, I suppress price for simplicity and is considered incidental factor for analysis in this paper.

Further, the total output depends on factors of production and assuming a Cobb-Douglas technology can be written as below:

$$Y = AP^{\alpha}H^{\beta} \tag{6}$$

Where *P* is the physical capital, *H* is human capital, α and β are parameters. Besides, the wage earnings of the household take the Mincerian type earning function based on human capital model developed by Becker (1967, 1993) and Mincer (1974) as below:

$$m = \alpha_1 H + \alpha_2 Exp + \alpha_3 Exp^2 \tag{7}$$

Here *H* is the human capital, *Exp* and Exp^2 are the experience and its squared value, $\alpha_1, \alpha_2, \alpha_3$ are parameters. In using (7) as model for off-farm earnings, *H* measures the educational attainment of the household head and household members and *Exp* (and its squared value) can be replaced by proxy variables age and (its squared value) of the household head and its members. In sum the total income of the household, Y^T is obtained after simple manipulations as

$$Y^T = Y^e + Y^u = f(P, H, D) \tag{8}$$

The household's problem is to choose the level of consumption, *C* and home production activity level, *x* subject to the budget constraint given her/his welfare function $U(C, x)$

$$\begin{aligned} &\text{Max } U(C, x) \\ &\quad \text{Subject to } C + x = Y^T \end{aligned} \tag{9}$$

Substituting (8) in to the budget constraint and the budget constraint in to the welfare function the household's optimization problem becomes

$$\text{Max } U(f(P,H,D),x) \tag{10}$$

The first order condition implies that marginal utility from both consumption and home production activities should be zero. Given the above framework, we see that the household's welfare depends on several factors identified above. Choosing the household's welfare[1] at any period to be measured using per adult equivalent consumption expenditure one gets the equation below.

$$c_{it} = f(P,H,D,x) \tag{11}$$

Testable Hypothesis

Based on the conceptual frame work set above the household's welfare is affected by the assets the household owns and their returns, and demographic composition of the household. So this paper hypothesizes that both physical and human assets enhance household welfare. In regard to the nature of poverty status of the household the factors hypothesized to influence both chronic and transient poor are same but the degree of their effect.

[1] See Deaton (1997) for discussion on the choice of household welfare measure.

4. Methodological Issues and Data

4.1 Poverty Measure and Decomposition

There are several methods of measuring poverty and identifying the chronic from the transient. I use the widely used class of decomposable poverty measures by Foster, Greer and Thorbecke (FGT) for they are consistent and additively decomposable (see Foster *et al*, 1984). The formula for FGT class of poverty measure is given as:

$$P_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right)^\alpha \qquad (12)$$

Where z is the poverty line, y_i is the value of poverty indicator, household's consumption expenditure per adult equivalent; q is the number of poor people in the population of size n, and α is the poverty aversion parameter that takes values of zero, one or two. By setting the value of α to zero, one, two respectively, the FGT poverty measure formula delivers a set of poverty indices. Setting α equal to zero, P_0, is the head count index measuring the incidence of poverty, i.e., proportion of poor people from the total population. Setting α equal to one, P_1, is the poverty gap measuring the depth of poverty, i.e., on average how far the poor is from the poverty line. Setting α equal to two, P_2, is the squared poverty gap measuring the severity of poverty among households, i.e. the depth of poverty and inequality among the poor.

There are two approaches in measuring inter-temporal poverty and decomposing them in to the long run (chronic) and short run (transient) part of the poverty, namely, the *spells* and *component* approach (Gleww and Gibson, 2005).

The spells approach is based on poverty spells experienced by an individual over a given period of time. According to this approach an individual is identified chronically poor if its welfare is below the poverty line all the time over the given period of time, i.e., *always poor*.

A transient poor is an individual whose welfare is below the poverty line some times over the given period, i.e., *some times poor.* The demerit of this approach is that it focuses on head count measure of poverty, which is not sensitive to depth and severity of poverty. Furthermore, it is sensitive to the frequency of survey waves available (Gleww and Gibson 2005). It is less likely to identify a household as always poor in 15 survey waves than 2 or 3 of them, since it is more likely for several reasons that a positive windfall may visit a household in 15 waves than in 2 or 3 waves.

The component approach is developed by Jalan and Ravallion (1998). According to them, transient poverty is the portion of expected poverty over time due to consumption variability while the chronic part is portion of expected poverty overtime due to consumption when inter-temporal variability of the consumption has been smoothed out.

Following Jalan and Ravallion (1998), let $y_{i1}, y_{i2}, ..., y_{it}$ be streams of consumption of a household, which is agreed measure of household welfare that is adjusted for economies of scale and prices. The intertemporal poverty index is given as:

$$P(y_{it}) = \frac{1}{T}\sum_{t=1}^{T} P_{\alpha} = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{1}{n}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right)^{\alpha}\right) \qquad i = 1, 2...q \text{ and } t = 1, 2, ..., T \qquad (13)$$

The chronic component is measured as

$$P^{C} = P(Ey_{it}) = \frac{1}{n}\sum_{i=1}^{k}\left(\frac{z - Ey_{it}}{z}\right)^{\alpha} \qquad (14)$$

Where, Ey_{it} is the expected value of consumption for i^{th} household and k is the number of chronic poor. Here the time mean consumption, $\overline{y_i}$, is assumed to be equivalent to the expected value of consumption, Ey_{it}. The transient component is obtained by taking the difference between the intertemporal poverty and chronic poverty.

$$P^{T} = P(y_{it}) - P(Ey_{it}) \qquad (15)$$

4.2 Vulnerability Measure

As discussed in section 2.3 above, there are several approaches of quantifying vulnerability to poverty. I adopt the measure in Chaudhuri (2003)[2], since in this paper the aim is to show the magnitude of vulnerability and the correlates of vulnerability of the households with out dealing, the contribution of risk to vulnerability and which type of risk dominates. Vulnerability to poverty (VEP) is an *ex ante* measure of well being of a household indicating what the future prospects of the household is than cataloging the well being currently. That is the probability a household falls in to poverty in the future.

$$V_{it} = \Pr(c_{it+1} < z) = \int_{\tilde{c}}^{z} f(c_{it+1})dc \qquad (16)$$

Where V_{it} is the i^{th} household's vulnerability, c_{it+1} is consumption level of household at time *t+1, Pr* is the probability indicator, $\tilde{c}$ is the lowest consumption level in the distribution and $f(c_{it+1})$ is the probability density function for a period ahead consumption distribution. V_{it} is the probability that i^{th} household consumption at time *t+1* is below the poverty line, *z*.

Assuming that the consumption of household's is normally distributed and estimating the mean and variance of consumption, V_{it} can be rewritten as

$$V_{it} = \Pr\left(\frac{c_{it+1} - E(c_i)}{\sqrt{\text{var}(c_i)}} < \frac{z - E(c_i)}{\sqrt{\text{var}(c_i)}}\right) = \Phi\left(\frac{z - E(c_i)}{\sqrt{\text{var}(c_i)}}\right) \qquad (17)$$

$E(c_i)$ and $\text{var}(c_i)$ are intertemporal mean consumption and variance respectively. Equation (17) is the probability that the standard normal variate will fall below standardized poverty line. In order to estimate the mean and variance of consumption following Chaudhuri (2003) I use a three step feasible GLS regression.

In order to investigate what factors are responsible for the changes in the household's welfare or poverty dynamics, I estimate a fixed effects model. A multinomial logistic model is used to

[2] Similar measures to this are those of Christiansen and Bosiverti (2000), Christiaensen and Subbarao (2001, 2005) and Chauduhari *et al* (2002)

identify the factors behind chronic and transient poverty. And I run a simple OLS on the VEP and some variables that are supposed to be correlates of vulnerability. The specification and estimation issues are discussed in the following section.

4.3 Econometric Specifications

4.3.1 The Consumption Model

The main objective in this sub section is to specify an estimable model to identify the determinants of poverty dynamics (change in the households' welfare measured using entity demeaned value of log per adult equivalent consumption expenditure).

Given the conceptual frame work in section 3 and equation (24) an estimable consumption model is formulated as below:

$$\ln c_{it} = \alpha_i + \beta H_{it} + \gamma P_{it} + \delta D_{it} + \varepsilon_{it} \tag{18}$$

The model specified as nonlinear regression function to capture any non-linear effects of covariates on the dependent variable. Here $\ln c_{it}$ is natural logarithm of i^{th} household per adult equivalent consumption expenditure in period *t*, *H* is vector of human capital variables, *P* is the vector of physical capital variables, *D* is vector of demographic composition (household size or adult equivalent, number of children (under 5 years of old), number of juniors (5-15), number of adults (15-65) and number of seniors (65+)), α_i is the household fixed effect that captures unobserved household heterogeneity β, γ and δ are vector of parameters and ε_{it} is the disturbance term accounting for unexplained part of the model. The disturbance term is assumed to satisfy the following to estimate unbiased and consistent coefficients.

$$\begin{aligned}
&E(\varepsilon_{it} / X) = 0 \\
&E(\varepsilon_{it}\varepsilon_{jt} / X) = \begin{cases} \sigma_e^2 & i = j \\ 0 & i \neq j \end{cases} \\
&E(\varepsilon_{it}\varepsilon_{is} / X) = 0 \quad t \neq s \\
&E(\varepsilon_{it} X) = 0 \\
&\varepsilon_{it} \sim N(0, \sigma_e^2)
\end{aligned} \tag{19}$$

An alternative specification in economics literature is to directly employ measure of poverty (the FGT class) on the left hand side replacing consumption expenditure, which is referred as the direct approach. My approach of modeling the household welfare using consumption has plus points over the direct approach as in Datt and Jollife (1999). One, given the household consumption, c_{it} the household's poverty level is completely determined. Two, using the direct approach leads to loss of information since households above the poverty line are treated alike as in censored data. Three, the parameters estimated using the direct approach varies with the poverty line. Four, estimating the direct approach requires strong assumption about the distribution of the disturbance term of the non-linear limited dependent variable models.

Using the three round Tigray panel data and assuming α_i may be correlated with the explanatory variables; equation (31) is a fixed effects model. This model can be estimated in two ways, either using the "least squares dummy variable" (LSDV) regression or using "within" regression. Both methods theoretically produce identical estimates of parameters and standard errors.

In LSDV regression case, the unobserved heterogeneity can be considered as *n* dummy variables[3] and then it can be estimated using OLS. The problem with this method is that the dummy variables increase with increase in the number of observations, which leads in violating an OLS assumption of no incidental parameters (i.e. the number of explanatory variables does not increase with the number of observation). In the case of "within" regression (or equivalently the Entity demeaned OLS regression) the estimation requires the following: First, considering the fixed effect model

$$\ln c_{i03} = \alpha_i + \beta H_{i03} + \gamma P_{i03} + \delta D_{i03} + \varepsilon_{i03} \qquad (20)$$

[3] $\ln c_{it} = \alpha_1 d_{i1} + \alpha_2 d_{i2} + ... + \alpha_n d_{in} + \beta H_{it} + \gamma P_{it} + \delta D_{it} + \varepsilon_{it}$ where

$$d_{i1} = \begin{cases} 1 \; if \;\; i = 1 \\ 0 \; otherwise \end{cases} \quad ... d_{in} = \begin{cases} 1 \; if \;\; i = n \\ 0 \; otherwise \end{cases}$$

Where $\ln c_{i03}$ is household i^{th} log per adult equivalent consumption expenditure for year 2003, H_{i03}, P_{i03} and D_{i03} are vectors of human capital, physical capital and demographic composition of i^{th} household in period 2003.

Second, averaging over *T* observations (1997, 2000 and 2003) for each individual

$$\frac{1}{T}\sum_{t=1}^{T}\ln c_{it} = \frac{1}{T}\sum_{t=1}^{T}\alpha_i + \beta\frac{1}{T}\sum_{t=1}^{T}H_{it} + \gamma\frac{1}{T}\sum_{t=1}^{T}P_{it} + \delta\frac{1}{T}\sum_{t=1}^{T}D_{it} + \frac{1}{T}\sum_{t=1}^{T}\varepsilon_{it} \qquad (21)$$

Third, taking the deviation between equation (20) and (21) as below

$$\ln c_{i03} - \frac{1}{T}\sum_{t=1}^{T}\ln c_{it} = \alpha_i - \frac{1}{T}\sum_{t=1}^{T}\alpha_i + \beta\left(H_{i03} - \frac{1}{T}\sum_{t=1}^{T}H_{it}\right) + \gamma\left(P_{i03} - \frac{1}{T}\sum_{t=1}^{T}P_{it}\right) + \delta\left(D_{i03} - \frac{1}{T}\sum_{t=1}^{T}D_{it}\right) + \left(\varepsilon_{i03} - \frac{1}{T}\sum_{t=1}^{T}\varepsilon_{it}\right) \qquad (22)$$

Then running OLS regression on equation (22) yields the within estimates[4]. Equation (22) removes the problem of incidental parameters and the usual assumptions of the disturbance term are also satisfied. This yields a consistent parameter estimates.

In specifying and estimating the above model one assumption set is the correlation between the household fixed effect and some of the explanatory variables. This is not a stringent assumption compared to counter part assumption of no correlation between the household fixed effect and the explanatory variables, which leads to random effects model. For instance, it is convincingly reasonable to assume that unmeasured attitude of a household head towards work is correlated to the sex of the household head (male and female household heads may not have same attitude towards work). Even if the assumption that there exist a correlation between the household fixed effect and some of the explanatory variables does not hold, the within estimates are consistent. Given this I estimate the within parameters in section (5.2.1).

The Fixed effect within estimator may have two problems arising from measurement errors in the explanatory variables or endogeneity of the explanatory variables. In estimation part,

[4] In Stata this is done using *xtreg* command and the option *"within"*

attempt is made to select arguably exogenous explanatory variables but no attempt is made to minimize the measurement errors.

4.3.2 The Chronic-Transient-Non poor Model

In this section I specify a limited dependent variable model, namely, multinomial logit model to identify the factors behind different poverty status of households. From the conceptual framework the household's welfare is given as in equation (11). Let the household's poverty status P_i is discrete variable taking values zero, one or two for non-poor, chronic poor and transient poor respectively and depends on the covariates as in (23)

$$P_i = \Gamma_i X + \upsilon_i \tag{23}$$

Here X is vector of covariates including the physical and human capital endowment, demographic composition of the household. Γ_i is vector of parameters and υ_i is the disturbance term.

In equation above, P_i is defined as below

$$P_i = \begin{cases} 0 \text{ if } c_{it} > z \ \forall t \\ 1 \text{ if } \overline{c_{it}} < z \\ 2 \text{ if } \mathrm{c}_{it} < z < \overline{c_{it}} \end{cases} \tag{24}$$

Letting P_{np} to represent $P_i = 0, P_{cp}$ to represent $P_i = 1$ and P_{tp} to represent $P_i = 2$ where the subscripts: *np, cp* and *tp* are non-poor, chronic poor and transient poor respectively. c_{it} and $\overline{c_{it}}$ are consumption expenditure per adult equivalent and time mean consumption expenditure per adult equivalent respectively. Under the assumption that the disturbance terms υ_{np}, υ_{cp} and υ_{tp} are each distributed independently and extreme value, the probability a household is non-poor $Pr(P_{np})$ is:

$$\Pr(P_{np} \mid X) = \frac{e^{\Gamma_{np} X}}{e^{\Gamma_{np} X} + e^{\Gamma_{cp} X} + e^{\Gamma_{tp} X}} \tag{25}$$

While the probability a household is chronic poor and transient poor respectively are:

$$\Pr(P_{cp} \mid X) = \frac{e^{\Gamma_{cp} X}}{e^{\Gamma_{np} X} + e^{\Gamma_{cp} X} + e^{\Gamma_{tp} X}} \tag{26}$$

$$\Pr(P_{tp} \mid X) = \frac{e^{\Gamma_{tp} X}}{e^{\Gamma_{np} X} + e^{\Gamma_{cp} X} + e^{\Gamma_{tp} X}} \tag{27}$$

Since only differences in the deterministic part of the model matters alternative specific parameters can not enter meaningfully hence need arise for normalization. Normalizing the coefficients for the non-poor (that is setting the coefficients to zero) the probability of non-poor, chronic poor and transient poor respectively can be reformulated as:

$$\Pr(P_{np} \mid X) = \frac{1}{1 + e^{\Gamma^*_{cp} X} + e^{\Gamma^*_{tp} X}} \tag{28}$$

$$\Pr(P_{cp} \mid X) = \frac{e^{\Gamma^*_{cp} X}}{1 + e^{\Gamma^*_{cp} X} + e^{\Gamma^*_{tp} X}} \tag{29}$$

$$\Pr(P_{tp} \mid X) = \frac{e^{\Gamma^*_{tp} X}}{1 + e^{\Gamma^*_{cp} X} + e^{\Gamma^*_{tp} X}} \tag{30}$$

Where $\Gamma^*_{cp} = \Gamma_{cp} - \Gamma_{np}$ and $\Gamma^*_{tp} = \Gamma_{tp} - \Gamma_{np}$ reflect the difference in the impact of X on becoming chronic poor or transient poor compared to becoming non-poor. That is, if Γ^*_{cp} is positive it means the increase in X increases the probability of becoming chronic poor to non-poor. In order to compare the impact of X on whether it largely increases the probability of chronic to transient poverty, one should compare Γ^*_{cp} and Γ^*_{tp}. If $\Gamma^*_{cp} > \Gamma^*_{tp}$ then increasing X increases the probability of chronic to transient.

One more issue in specifying and estimating the multinomial model in this paper was the inclusion of alternative specific constant. This was done in order to serve two purposes as in Train (1986). One, it assures that the disturbance term has zero mean. Two, it can mitigate and in some cases remove the inaccuracies due to the independence from irrelevant alternatives (IIA) property of the logit model. The above formulation is estimated using maximum likelihood estimation procedure.

4.3.3 The Vulnerability model

In this section I discuss the econometric issues behind computing vulnerability to poverty and the model for correlates of vulnerability. I adopt the methodology in Chaudhuri (2003). According to Chaudhuri (2003) the empirical approach to vulnerability requires the following steps. One, specify the data generating process for consumption. Two, using survey data on household consumption expenditures and characteristics, estimate the relevant parameters. Three, make necessary distributional assumptions needed to draw inferences about future consumption prospects, i.e. to go from estimates of consumption process to estimates of vulnerability. Four, using vulnerability estimates and decompositions, answer various policy-relevant questions. The following econometric specification is an ideal specification of consumption process (Chaudhuri, 2003)

$$\ln c_{ijt} = \alpha_j X_i + \beta_j X_i P_t + \gamma_j X_i R_{jt} + \delta_j X_i M_{ijt} + v_{jt} + \eta_i + \varepsilon_{ijt} \quad (31)$$

Where $\ln c_{ijt}$ is log per capita consumption expenditure, X_i is a vector of observable characteristics of household i, P_t, a vector of observable macro shocks in year *t*, for instance, commodity price shocks, R_{jt} captures observable locally covariate shocks in area *j* in year *t*, for instance weather shocks, M_{ijt} denotes an observable idiosyncratic shock experienced by household *i* in area *j* in year *t*, e.g., illness of the main income earner, v_{jt} represents unobserved area-specific shocks, η_i ,an unobserved time-invariant household effect, and ε_{ijt} an idiosyncratic time-varying disturbance term.

This paper uses the reduced form of equation above as below:

$$\ln c_{it} = \alpha + \beta X_{it} + \gamma H_{it} + \delta P_{it} + \kappa E_{it} + e_{it}\sqrt{f(X_{it}, \tau)} \quad (32)$$

Here $\ln c_{it}$ is the log per adult equivalent consumption expenditure, X_i, H_i and P_i are vector of household characteristics, human capital and physical capital respectively. E_i is a binary variable whether the household participates in off-farm activities or not (participation is

denoted as 1, 0 otherwise). β, γ and δ are vector of parameters where as α and κ are scalar parameters.

As in the ideal specification there is no constant variance of the disturbance term and this allows for hetroscedasticity. This is appealing since the economic interpretation of the variance of the disturbance term is as intertemporal variance of log consumption in this setting[5]. Additional theoretical justifications are in Christiansen and Biosverit (2000).

$$\text{var}(\ln c_{it} / X) = \sigma^2_{e_{it}} = \tau X_{it} \tag{33}$$

Technically, hetroscedasticity biases only the disturbance term and standard error of the coefficients not the coefficients and may be thought to be corrected using standard error robust estimation. However, in computing vulnerability the standard deviation of the disturbance term enters directly hence bias the vulnerability estimate. This leads to employ another estimation approach, namely, GLS estimation.

The parameters in equations (32) and (33) are estimated using three step feasible GLS (3FGLS) (Amemyia, 1977). Using the FGLS estimates of the parameters, I estimate the expected log consumption conditional on *X* and variance of consumption conditioned on *X*, here *X* is all covariates in (32).

Assuming log normality of the consumption distribution, I estimate the probability that a household becomes poor next period given *X*, i.e., the vulnerability estimate, as below:

$$\begin{aligned} V_{it} = \Pr(\ln c_{it} < \ln z / X) &= \Phi\left(\frac{\ln z - E(\ln c_{it} / X)}{\sqrt{\text{var}\ln(c_{it} / X)}}\right) \\ &= \Phi\left(\frac{\ln z - \hat{\mathrm{B}}_{gls} X}{\sqrt{\hat{\tau}_{gls} X_i}}\right) \end{aligned} \tag{34}$$

[5] Assuming constant variance of the disturbance term means that the households have constant variance in log consumption. This is on contrary to empirical evidence since poor households have more variance in consumption than their counterpart non-poor (Chaudhuari,2003)

Where Φ is the operator for standard normal cumulative distribution, $\hat{B}_{gls}$ and $\hat{\tau}_{gls}$ are the GLS estimated vector of parameters. X and X_i are vectors of covariates in equations (32) and (33) respectively.

4.3 The Data

The primary data used in this paper is the Tigray rural households panel data based on three round surveys covering 16 villages from four zones of the Tigray region. For details about the study site and the survey see Hagos and Holden (2003). A multi purpose questionnaire designed and administered to 400 households using stratification based on altitude, market access, population density and presence of irrigation projects. 25 households selected from each community using simple random sampling from list of all households. Using the questionnaire information was gathered on household's income, expenditure, access to public services and safety nets, off-farm income, and household assets alongside a host of other information related to production and sale of agricultural products. In order to assure comparability and reliability of the survey standard sampling procedures and questionnaire was used. Besides, to minimize the seasonal variability the data collection was carried during same season.

I used 315 households, due to attrition of some households in the second and third round surveys and some households were dropped for lack of substantial information about the household in one of the surveys that might cause selection bias. However, about 12% of the attrition between 1997 and 2000 was due to redefinition of boundaries (Hagos and Holden, 2003), which implies no direct link with the household's living standard.

4.4 Household Welfare Measure

Through out this paper, real consumption expenditure per adult equivalent is used as the measure of household welfare. Compared to income, consumption is better measured, since in Ethiopia traditionally it is easier for households to give information on their consumption than their earnings besides the arguments in economic literature, for details see Deaton (1997) and Deaton

and Zaidi (1999). Obviously, this measure fails to incorporate some important aspects of individual welfare, such as consumption of public goods (for instance, schools, health services).

The measure of consumption used in this paper is sum total of food consumption and nonfood consumption. The food consumption includes food that the household purchased and produced (used for own consumption) for 19 food items. The nonfood consumption is based on sum total of expenditures on 24 non-food items. The welfare measure is computed in away that can take into account the price difference between different locality and any economies of scale. This was done by computing regional price index based on southern zone 2000 constant price and the household's real consumption divided by the adult equivalent of the household. The adult equivalent used is based on Dercon and Krishnan (1998) that was constructed based on World Health Organization (WHO) minimum calorie requirement.

4.3.6 The Poverty Threshold

This paper adopts the poverty line used by Dercon and Krishnan (1998). In fact, Hagos and Holden (2003) constructed poverty line for Tigray based on cost of basic needs (CBN) approach and it is not significantly different than the Dercon and Krishnan (1998). The regional poverty line by Hagos and Holden (2003) is Birr 1033.45 compared to Birr 909.44 based on the food poverty line. While the food and moderate poverty lines Birr 806.27 and Birr 1075 respectively are the ones used by Dercon and Krishnan (1998). In this paper Birr 806.27 is the poverty line.

5. Estimation and Results

5.1 Descriptive Results: Poverty Measures and Decomposition

This section discusses the level of poverty and its dynamics in the region based on the FGT poverty measure and the two approaches of poverty decomposition in to chronic and transient poverty.

Table 5.1 below shows the extent of poverty in Tigray for 1997-2003 using headcount, poverty gap and poverty gap squared. All the indices show that poverty fell down. About 22% decline in poverty based on headcount index. The decline is even more dramatic using poverty gap, which is 40%, and poverty gap squared, which is 48%. For detailed poverty profile discussion based on bivariate association that includes the socioeconomic characteristics of the households and regional distribution of poverty see Hagos and Holden (2003).

Table 5.1: Poverty in Rural Tigray 1997-2003 (*n=315*)

	Headcount P_0	*Poverty Gap* P_1	*Poverty Gap Squared* P_2
1997	0.82	0.42	0.25
2000	0.68	0.33	0.20
2003	0.64	0.25	0.13

Source: Author's calculation

In regard to the decomposition of the poor in to chronic and transient, table 5.2 evince figures of poverty decomposition using the Spells approach, 56% are transient poor while 42% are chronic poor.

Table 5.2: Poverty Decomposition (Spells Approach), *n=315*

Poverty Status	Percentage
Chronic	42
Transient	56
Non poor	2
Total	100

Source: Author's calculation

In contrast the component approach presents that only 26% are transient and 74% are chronic using poverty gap index.

As shown in table 5.3 below, the chronic nature of poverty declines as the poverty index becomes more sensitive to depth of poverty. This is reasonable because the more sensitive an index is to the depth of poverty, the more weight the transient component gives to a household that is poor in a year but not poor in the other year (relative to the chronic component, which considers just the average income over a given period) Gleww and Gibson (2005).

Table 5.3: Poverty Decomposition (Component approach)

Poverty type	Head count(P_0)	Poverty gap (P_1)	Squared Poverty gap (P_2)
Transient Poor	0.02	0.088	0.081
Chronic Poor	0.70	0.251	0.117
Total Poor	0.72	0.339	0.198
Chronic/Total	0.97	0.741	0.593

Source: Author's calculation

In general, taking in to account the limitation of spells approach poverty is chronic in rural Tigray. This implies the poverty alleviation policy of the region should focus on how to pull out the long run poor from their poverty trap. While giving due attention to the transient poor.

Though the nature of poverty is chronic there is significant amount of mobility from a state to another. This usually may be due to significant measurement error on consumption expenditure that limit the results presented above. In this regard, one should attempt to correct the measurement errors in further works using either simulation as in Gleww and Gibson

(2005) or instrument variable (IV) methods, for instance as in Luttmer (2001), which is left for further work.

5.2 Econometric Results

Before discussing the results of the estimation of the models specified in section 4.3 I discuss the set of explanatory variables used in the estimation. The selection of the explanatory model was guided by the conceptual framework in section 3, poverty profiles for Tigray in Hagos and Holden (2003) and other previous empirical works in Ethiopia and developing countries. A key consideration was given in selecting arguably exogenous explanatory variables. The explanatory variables include demographic characteristics of the household, capital base of the household and the employment sector of the household.

The demographic characteristics of the household include age of the household head (its squared value) in order to capture any possibilities of lifecycle effects, headship sex (Female headed=1, 0 otherwise) , household size, dependency ratio, the number of children (under age 5), the number of juniors (between 5 and 15), and number of elderly (age above 65).

The capital base include both physical and human capital base of the household. Farm size owned[6], total livestock unit and ox ownership[7] measure the physical capital of the household while the number of adults (age 15-65), members of the household with primary and secondary education and the household's head education capture the human capital. Moreover, a binary variable for the household's head participation in off farm activities also included.

5.2.1 The Consumption Model

Based on the specification in 4.3.1 a fixed effects regression of the dependent variable, change in household welfare (measured as entity demeaned value of the log consumption expenditure per adult equivalent) on set of explanatory variables discussed above that change overtime.

[6] One may suspect the exogenity o f land ownership. However, due to the land policy of the country there is missing land market hence it is not easy to buy, sell and rent

[7] This may also be considered as endogenous; nevertheless, in rural Tigray setting ox is an important fixed asset that the household's are adamant to sell their oxen in order to smooth consumption, hence exogenous.

Table 5.4 below presents the regression result. The results in general are plausible. The household's welfare, *ceterius paribus*, is influenced by household's composition, headship of the household and physical capital. Change of the household sex from male to female due to several reasons improve the household's welfare, this seems counter intuitive, nevertheless, this may be picking up the effect of remittances from the male head of the household, who is away from the village and doing casual labour in near by towns.

Table 5.4 Fixed Effects Regression: Determinants of Poverty dynamics

Dependent Variable*: log per adult equivalent consumption Expenditure*		
Explanatory variables	Coefficient	Standard errors
Household head Sex	.9071637***	.1357619
Household head Age	-.0164801	.0204815
Household head Squared Age	.0002195	.0001972
Household head Education	.0601606	.0986232
Household size	-.0006055	.0013134
Ox per adult equivalent	.2584293	.19741
TLU per adult equivalent	-.104387	.0995467
Farm size per adult equivalent	1.101353***	.1382627
Number of children	-.3636779***	.0356684
Number of Juniors	-.4337864***	.0547927
Number of Adults	-.4312141***	.0438846
Number of Seniors	-.159204	.1187025
Members with Primary Education	.0178197	.0405862
Members with Secondary Education	-.1464747	.0941809
Constant	4.047859***	.4970234
Number of observation = 940	R-sq: within = 0.56	F(14,611) = 56.65
	between = 0.59	Prob. > F = 0.0000
Number of groups = 315	overall = 0.57	

*** Significant at 1%.
Source: Author's Calculation

The household's welfare enhanced significantly due to change in the per adult equivalent farm size ownership. Household's composed of many numbers of children and elderly negatively affect the change in the household's welfare. Counter intuitively, more adult per household reduces the household's welfare. This may be due to overall resource scarcity at a household

level in the region that complement labour, hence the labour available is underemployed and contributes less in household welfare enhancement. Besides, this may be a sign of the failure of the government strategy that claims to focus on intensive labour utilization.

5.2.2 The Chronic-Transient-Non poor Model

A multinomial logistic model, as specified in section 4.3.2, estimated to identify the factors that affect the likelihood of the household becoming chronic, transient or non poor.

As mentioned in the specification part, the advantage of using this model is ease of specification and estimation. This is not at no cost rather it is at cost of assuming the disturbance terms are uncorrelated among alternatives, which results in to an independence from irrelevant alternative (IIA) assumption. A more problematic issue may be the heterogeneity of the factors and the cumulative dynamic nature of the factors behind some of the conditions. The transient group may be different than the chronic or non poor and the factors that influence household's moving out of poverty is due to the dynamic cumulative effect of the factors that lead them to be poor initially and the factors that help them move out. In general, to capture such dynamic factors and to release the IIA assumption one can use a class of generalized extreme value (GEV) models due to Mcffaden (1978, 1981), for instance the Nested logit model based on nests of becoming poor non-poor, and if poor chronic or transient, should be employed .Though computationally extremely intensive due to the requirement of evaluating multiple integrals to obtain the probability (Maddala 1983, Dagsvik, 2006) multinomial probit models may also overcome the limitation of the multinomial logit. As mentioned in section 4.3.2 alternative specific constant is included in the model to mitigate the problem due to the IIA property of the logit model. Generally the model is regression of limited dependent variable (dummy variable) on the covariates for 1998 observations.

From table 5.5 below we can see that only household age, dependency ratio, number of children, farm size per adult equivalent and participation in off-farm activities significantly influence both chronic and transient nature of poverty.

The older the household and is poor, the more likely the household's poverty is chronic, this result is significant at 5% level of significance. The likelihood of chronic nature of poverty

increases with the more the number children in the household. As one would expect, farm size per adult equivalent and participation in off-farm activities negatively affect the likelihood of chronic poverty at 5% level of significance. Counter intuitively, dependency ratio found to be negatively correlated with probability of becoming chronic poor. This may also be picking up the effect of aid (food aid) which is highly correlated to dependency ratio.

Similarly, the factors behind the likelihood of becoming transient poor are identified as same as the chronic ones. Based on the multinomial logit estimates the factors behind the probability of becoming chronic and transient poor are congruent. Overall, the model is significant at 5% level of significance and the pseudoR^2 indicates that the model predicts both chronic and transient poor well.

The findings in this paper suggest that more work is required in regard to the impacts of demographic characteristics of households. Besides, several means should be designed to increase the physical capital of the households and policies that enhance the return of the off-farm activities are needed.

Table 5.5 Multinomial Logit Regression: Determinants of Chronic-Transient-Non poor

Dependent Variable*: Dummy variable=0 if non-poor, 1 if chronic poor and 2 if transient poor*		
	Chronic poor	**Transient poor**
Explanatory variables	Coefficient	Coefficient
Household head Sex 1998	.5148599 (3.679017)	1.067247 (3.683849)
Household head Age1998	.1386693** (.0651137)	.1366591** (.0654323)
Dependency ratio 1998	-4.789938* (2.556371)	-4.795402* (2.555328)
Ox per adult equivalent	-2.119669 (1.614348)	-1.501781 (1.605145)
TLU per adult equivalent	-.2139178 (.9967836)	.0708917 (1.001056)
Farm size per adult equivalent	-3.668193** (1.758926)	-3.575644** (1.767103)
Number of children	5.27453* (2.788063)	5.212118* (2.788437)
Number of Juniors	8.540026 (5.636399)	8.38325 (5.636085)
Number of Adults	-1.392492 (.8882601)	-1.352889 (.8903286)
Number of Seniors	-.6016466 (1.936056)	-.792626 (1.95307)
Members with Primary Education	.6563494 (1.549694)	1.002395 (1.551904)
Off-farm	-4.260276** (2.13336)	-3.873609* (2.136649)
Constant	4.809504 (3.158234)	3.538594 (3.167058)
Number of obs = 315 Log likelihood = -190.56446	Pseudo R^2 = 10 LR chi2(24) = 41.93 Prob > chi2 = 0.0131	

* Significant at 10% and ** significant at 5%. The values in parenthesis are standard errors.
Source: Author's Calculation

5.2.3 The Vulnerability Model

Using 2003 cross sectional data derived from the Tigray panel and the specifications in section 4.3.3 I estimated the models and results are in table 5.6 below

The GLS results indicates that expected log consumption per adult equivalent is negatively influenced by household size, and positively affected by ownership of physical capital like farm size and livestock. Besides, the life cycle effects also exist, that is household's expected log consumption per adult equivalent increases with household head age but weakens afterwards.

Table 5.6 GLS Regression: The expected value and variance of log per adult equivalent Consumption expenditure

Dependent Variable:	$E(\ln C / X)$	$Var(\ln C / X)$
Explanatory variables	Coefficient	Coefficient
Household head Sex 2003	.0315945	-.0244496
	(.1105398)	(.1944142)
Household head Age2003	.1480394 ***	-.0085391
	(.0130124)	(.018741)
Household head Squared Age2003	-.0013036 ***	.0000714
	(.0001334)	(.0001631)
Household head Education 2003	.1258411 ***	-.0106158
	(.0416896)	.0203242
Household size 2003	-.3310134 ***	.0482966
	(.0831445)	(.0525947)
Ox 2003	.0521612	
	(.0612852)	
TLU 2003	.1378918 ***	-.0193201 *
	(.0245969)	(.0100275)
Farm size 2003	.1731314 ***	
	(.0542089)	
Number of children 2003	-.0137685	
	(.0930244)	
Number of Juniors 2003	.0335383	
	(.0870823)	
Number of Adults 2003	.0037349	
	(.0751516)	
Number of Seniors 2003	.2237305	
	(.1464283)	
Members with Primary Education 2003	.2903019 ***	-.0569809
	(.0418264)	(.0398561)
Members with Secondary Education 2003	.3724835 ***	-.0158259
	(.0787055)	(.0358252)
Off-farm employment 2003	-.0495688	1.280298
	(.0813432)	(1.057727)
Constant	3.205237 ***	
	(.3588789)	
	Number of obs = 309	Number of obs = 310
	F(15, 293) = 101.73	F(8, 301) = 8.46
	Prob > F = 0.0000	Prob > F = 0.0000
	R-squared = 0.8389	R-squared = 0.1837
	Adj R-squared = 0.8307	Adj R-squared = 0.1620

*** Significant at 1%. The values in parenthesis are standard errors.
Source: Author's Calculation

Similarly though not very well the GLS model for the variance of log consumption per adult equivalent is jointly explained by some household characteristics. Provided the above results, I computed the Vulnerability to poverty of the households and found that on average 56 % are vulnerable. This result tells us, on average, there is a probability of .56 of falling in to poverty in a period ahead, which is the head count poverty next period.

In line with Chaudhuri (2003), choosing the focal point to be 0.5 where the household becomes vulnerable to poverty, 61% of the sampled households found vulnerable to poverty.

Estimating simple OLS of the vulnerability measure to identify the correlates with vulnerability as shown in table 5.7 below, I found that headship sex (female is 1), household size, dependency ratio, number of children in the household are significantly positively correlated. While, household's human as well as physical capital variables (household head education, number of members with primary as well as secondary level education; farm size, total livestock and ox ownership) are identified as significantly negatively correlated factors. Consistent, with lifecycle effects the age of the household head and its squared found as negatively and positively correlated respectively.

Table 5.7 OLS Regression: Correlates of Vulnerability to Poverty

Dependent Variable*:* Vulnerability to poverty

Explanatory variables	Coefficient	Standard Error
Household head Sex 2003	.0127159	.0183993
Household head Age2003	-.0439779***	.0033101
Household head Squared Age2003	.0003764***	.0000317
Household head Education 2003	-.028173***	.007226
Household size 2003	.1331034***	.0133928
Ox 2003	.0017537	.0113183
TLU 2003	-.0611655***	.0040752
Farm size 2003	-.041046***	.0091056
Number of children 2003	-.0149855	.0157725
Number of Juniors 2003	-.0194943	.0144346
Number of Adults 2003	-.0125074	.0126913
Number of Seniors 2003	-.0626074**	.0253457
Members with Primary Education 2003	-.1364994***	.0055987
Members with Secondary Education 2003	-.1277422***	.0152577
Off-farm employment 2003	.0190489	.0135936
Constant	1.464121***	.0867669
Number of obs = 309	R-squared = 0.8891	Adj R-squared = 0.8834
F(15, 293) = 156.63	Prob > F = 0.0000	

*** Significant at 1% and ** significant at 5%. The values in parenthesis are standard errors.
Source: Author's Calculation

5.2.4 Robustness

The econometric specifications used in this paper in general were robust. The fixed effect model explains the model well as one can see the R^2; the model is jointly significant as one can see the F-test and some covariates are also found significant based on t-test. Taking in to account the nature of the data collected through surveys, a usual suspect is heterogeneity resulting a non scalar variance covariance matrix. Heteroscedasticity is a rule not an exception in survey data (Deaton, 2000). I estimated the fixed effects regression using *robust standard errors* option in Stata, as recommended by Stock and Watson (2003) and the results does not change (regression results not reported in the paper).

The multinomial logit model also passes the minimum requirement for robustness where the likelihood ratio based on chi-square test for overall model and t-test for some covariates is significant. The model explains well given the pseudo R^2. However, as discussed earlier the limitations require due attention and one should employ more robust techniques than the logit for such analysis.

Finally, the model for vulnerability assessment estimated based on GLS yield efficient estimates as one can see the overall model and parameter significance.

6. Conclusion

Using the three round Tigray rural household panel data, this paper analyzed the dynamics in poverty and vulnerability to poverty of households. Taking in to account the robustness of the component approach over the spells, poverty is chronic in rural Tigray. There is also some dynamism in the poverty status as can be inferred from the spells approach.

This paper have examined the determinants of the household's welfare using fixed effects regression and found that larger farm size and female headed household significantly improve the welfare of the household, where as number of children, juniors and adults in the household found to negatively affect the household's welfare. In the analysis of determinants of chronic and transient poor, the likelihood of becoming both chronic and transient poverty is positively affected by factors such as the age of the household head and number of children in the household. Factors such as dependency ratio, farm size owned and participation in the off farm activities reduce significantly the likelihood of becoming both chronic as well as transient poor.

This paper have estimated the vulnerability to poverty of households using 2003 cross sectional data drawn from the panel and found that on average there is .56 probability of entering into poverty a period ahead. The vulnerability of a household is positively significantly correlated with household head age squared and household size. Factors like household age, household head education, total livestock unit, owned farm size, the number of seniors in the household and member of the household's educational attainment found negatively correlated with the household's vulnerability to poverty.

The results of the paper suggest two different policies. One, since poverty is chronic in rural Tigray the policy interventions in the region should focus on assisting poor households to accumulate assets through increased investment and employment generation that enhances their mean consumption level. Two, the evidence that there are more vulnerable households' calls for policy intervention that reduce consumption variability through reducing exposure to risk or improving the ex post coping mechanisms of the vulnerable.

Finally, a word of caution in using the results: The results depend on the methodologies employed and their limitation. For instance, it was argued as convincingly reasonable to estimate a fixed effect model but quantitative test of choosing the random versus the fixed effects model was not employed. So the parameter estimates though consistent may be inefficient if the random effects model is true. Similarly, the multinomial logit model estimated in section 5.3.2 assumes enough observation of the dependent variable (chronic poor, transient poor or non poor) while in my case there were rare events of non poor. Besides, the IIA assumption was not tested. In the vulnerability model, after estimating the expected and variance of log per adult equivalent consumption expenditure I assumed a parametric distribution about consumption distribution, i.e. a log normal distribution of consumption. This might limit the vulnerability estimates so a non-parametric approach of estimating future consumption distribution as in Kamanou and Morduch (2002) may be more robust. Besides the methodologies, measurement errors in the data biase the estimates

So further works of the study should check the limitation of the methodologies and employ more robust econometric approaches. Moreover, the information in the panel data should be enriched using some qualitative data at the household level and aggregate level data of the study area for each round of survey. Attempts should also be made to minimize measurement errors.

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Appendices

Appendix I: Three Step Feasible GLS

Consider a model

$$y_i = X_i \mathrm{B} + \mathrm{E}_i \sqrt{f(X_i, \Theta)} \qquad \text{(A1)}$$

Where y_i is a dependent variable, X_i is the vector of covariates and E_i is vector of disturbance terms, which is a function of X_i. B and Θ are vector of parameters . In this case the OLS estimate for B is not efficient since a classical assumption of scalar variance covariance matrix or homoscedasticity does not hold. To correct this inefficiency the usual way is to estimate a GLS model and obtain consistent and efficient parameters.

To estimate the 3 step FGLS: *Firstly*, estimate equation A1 using OLS and obtain the residual from A1. *Secondly*, estimate an OLS of the squared residual on X_i as below in A2 and transform A2 by its predicted value as in A3 and run OLS of the transformed value to get asymptotically efficient FGLS estimate of Θ (Θ_{FGLS}).

$$E_i^2 = X_i \Theta + \omega_i \qquad \text{(A2)}$$

$$\frac{E_i^2}{\widehat{X_i \Theta}} = \frac{X_i \Theta}{\widehat{X_i \Theta}} + \frac{\omega_i}{\widehat{X_i \Theta}} = X_i \Theta_{FGLS} + \upsilon_i \qquad \text{(A3)}$$

Θ_{FGLS} X_i is consistent estimate of the squared residual. *Thirdly,* transform A1 as in A4 and run OLS on the transformed equation to get a consistent and asymptotically efficient FGLS estimate of B (B_{FGLS}).

$$\frac{y_i}{X_i \widehat{\Theta_{FGLS}}} = \frac{X_i \mathrm{B}}{X_i \widehat{\Theta_{FGLS}}} + \frac{\mathrm{E}_i \sqrt{f(X_i, \Theta)}}{X_i \widehat{\Theta_{FGLS}}} \qquad \text{(A4)}$$

Appendix II: Summary statistics of variables used in econometric estimation

Table 1A: Summary statistics of variables used in econometric estimation

Variables	1997		2000		2003	
	Mean	St.dev	Mean	St.dev	Mean	St.dev
Log cons.exp.per a.e†	6.040254	.7121595	6.331272	.8945094	6.486256	.6411134
Household head Sex	.1333333	.3404755	.1460317	.3536999	.2603175	.439506
Household head Age	49.78413	15.34853	52.10159	15.17633	54.50159	14.57539
Household head Squared Age	2713.289	1642.634	2944.165	1649.363	3182.19	1626.852
Household head Education	.1047619	.3067337	.3873016	.4879086	.5980707	.9915105
Household size	4.88254	2.216509	5.636943†	2.345965	5.346032	2.258235
Dependency ratio	1.210854	1.039914	1.271822	1.00416		
Number of Ox	.9746032	.9025739	.7936508	1.099489	.8857143	.9474836
Ox per adult equivalent	.2548066	.2971831	.1970347	.3448729	.204534	.2412792
TLU	1.471746	1.875571	1.884762	2.719315	2.590794	2.678877
TLU per adult equivalent	.378014	.5131835	.4348459	.576769	.5927988	.6671259
Farm size	1.169737	1.342521	1.323013	.8935654	1.09976	.751323
Farm size per adult equivalent	.3323239	.3858464	.3570963	.3788196	.2958652	.249464
Number of children	1.793651	1.507505	2.196825	1.567786	1.307937	1.116081
Number of Juniors	.5047619	.6403195	.5047619	.5830484	1.139683	1.088232
Number of Adults	2.355556	1.277161	2.546032	1.354495	2.365079	1.275711
Number of Seniors	.2380952	.4624184	.2031746	.5383296	.2634921	.4623746
Members with Primary Education	.2253968	.6207578	1.104762	1.233222	1.076433‡	1.188558
Members with Secondary Education	.0285714	.2309138	.2126984	.6599296	.1460317	.4417775
Off farm activities participation	.3619048	.4813161	.5428571	.4989525	.3746032	.4847904

† Log cons.exp.per a.e refers to log per adult equivalent consumption expenditure
‡ For 314 households
Source: Author's calculation

Appendix III: Some Village characteristics

Table 2A: List of *Tabias* (Villages) and their location with few key village level variables

Location			**Population density (persons/km^2)**	**Distance to Wereda market (in km)** †	**Mean Rainfall****	**Affected by conflict (Yes =1)**	**Irrigation project (Yes =1)**
Tabia	Wereda	Zone					
Hintalo	Hintalo Wajerat	Southern	80.2	14	503.7 (183.5)	0	1
Samre	Seharti Samre	Southern	248.9	1.25	557.5 (175.7)	0	0
Mahbere Genet	Enderta	Southern	441.5	8*	552.1 (93.83)	0	1
Mai Alem	Enderta	Southern	429.6	6*	552.1 (93.83)	0	0
Kihen	Wukro	Eastern	160.6	23	420.4 (205)	0	0
Genfel	Wukro	Eastern	166.5	4	420.4 (205)	0	1
Emba Asmena	Tsada Emba	Eastern	631.10	7	596.8 (123.9)	0	0
Hagere Selam	Gulo Mekada	Eastern	749.4	39	419.05 (190.2)	1	0
Seret	Dagua Tembien	central	707	12.5	761.4 (178.9)	0	0
Debdebo	Ahferom	Central	161	6	668.52 (232.9)	1	0
Mai Keyahti	Ahferom	Central	636.6	16	736.6 (109.53)	0	0
Adi Selam	Merab Leke	central	206.8	29	579.32 (109.99)	1	0
Hadgti	Laelay Adiabo	Western	130.8	9	832 (156.7)	1	0
Tsaesha Ambera	Tahtay Koraro	Western	41.8	20	596.55 (152.63)	1	0
Mai Adrasha	Tahtay Koraro	Western	440	5.2	893.55 (152.63)	0	1
Adi Menabir	Tahtay Koraro	western	236	21	783.4 (158.2)	0	0

* Even though the wereda market is about 20 km away, the Mekelle market is close (5-10 km).
** It is calculated based on rainfall data gathered in 1991 to 2001 at the wereda level by the regional Bureau of Agriculture. Standard deviations are given in brackets.
† Tabias categorized into distant from market for those greater than or equal to 10 kms away from a major market and population density on a benchmark of greater than or equal to 200 persons/km^2.
Source: Hagos and Holden (2003)