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Makoka, Donald

University of Bonn, Centre for Development Research (ZEF)

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The Impact of Drought on Household Vulnerability: The Case of Rural Malawi

Donald Makoka

Centre for Development Research

University of Bonn

Walter-Flex-Str. 3

53113 Bonn, GERMANY

dmakoka@uni-bonn.de

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Abstract

Vulnerability to poverty in Malawi is highly associated with risk. Households face multiple shocks, most of which threaten their livelihoods and impact negatively on their welfare. Among the important risks that rural households face is drought, which is exacerbated by environmental change. This study analyzes the impact of drought on household's vulnerability using a two-period panel dataset of 259 rural households in Malawi. In the framework of vulnerability as expected poverty, the study employs the methodology proposed by Christiaensen and Subbarao (2004). The results show that recurrent drought makes households more vulnerable to the extent that households that were affected by drought in both periods were twice as vulnerable as those who experienced drought in only one period. Policies that are aimed at building poor households' resilience to recurrent drought hold more promise of enabling the households cope with this livelihood-threatening hazard.

1.0 Introduction

Malawi, like many countries in sub-Saharan Africa, continues to experience high levels of poverty despite decades of implementing poverty alleviation and prevention programmes. The depth and severity of poverty in Malawi are an indication that the static anti-poverty programmes are not sufficiently effective in moving the majority of the population out of the trap of poverty. For example, a comparison between the Malawi first Integrated Household Survey (IHS1) of 1998 and the IHS2 of 2004 shows that there is no significant decline in the headcount poverty rate in Malawi. While poverty rate was estimated at 54.1 percent in 1994, the figure only declined to 52.4 percent in 2005 (Malawi Government and World Bank, 2006).

The majority of the poor in Malawi are severely affected by drought when it occurs. In the past ten years, Malawi has been hit by severe drought for about four times. These persistent droughts, combined with the devastating impact of HIV/AIDS continue to threaten the livelihoods of thousands of men, women and children, who depend on

agriculture for their livelihoods. It is estimated that due to the drought in the 2004-2005 crop production season, more than five million people (out of a total population of about 11 million) were dependent on food aid. The 2004/5 drought reduced the food staple harvest to only 37% of the total food requirement (Malawi Government and World Bank, 2006). The impact of the recurrent droughts is of great concern in Malawi because the economy is heavily dependent on rain-fed agriculture. The agricultural sector contributes over 38.6 percent of the country's gross domestic product (GDP), accounting for over 82 percent of its foreign exchange earnings and supports over 90 percent of the population (Malawi Government, 2004; World Bank, 2006b). Almost 85% of the population in Malawi are employed in the agricultural sector, most of whom are subsistence farmers. As such, the occurrence of a drought makes the majority of these households who derive their livelihoods from farming vulnerable to poverty. The situation is worsened by the fact that the majority of these farmers are so poor that they have no assets at their disposal. Some of the few households who hold assets (such as livestock and bicycles) end up selling them to supplement their consumption in the face of the drought.

Most of the developing countries' economies, particularly those in the Sub-Saharan Africa, are agricultural-based. As such agricultural shocks are an important source of vulnerability for the majority of the populations. In the case of Malawi, climate and environmental risks play an important role in household vulnerability to poverty. In particular, the heavy dependency on rain-fed agriculture renders the majority of the Malawians vulnerable in the face of erratic and unpredictable rainfall. The rural households depend on rainfall for their livelihoods, both directly in the form of crop production and indirectly through on-farm sale of labour. According to Malawi Government and World Bank (2006), the volatility in the rainfall pattern in Malawi can reach as much as 50 percent below or above the historical average. This erratic rainfall gives rise to droughts and flooding, both of which can have significant negative welfare impacts on farmers, due to loss in crop production and livestock. The impact of these shocks is also felt by non-farm households through increased price of food commodities, such as maize (Malawi Government and World Bank, 2006). For instance, Tiba (2005) was able to show the variability in maize production in Malawi between 1991 and 2001

that was attributed to erratic rainfall. Two studies (Hoddinott and Kinsey, 2001; and Alderman *et al.*, 2004) have shown that rainfall shocks are causally related to reduced human capital formation and that the magnitudes of these effects are meaningful.

In other countries, vulnerability in agriculture is mainly attributed to rainfall shocks. For example, Dercon and Krishnan (2000) reported that rainfall shocks, crop damage and livestock diseases are among the leading shocks that make households vulnerable to poverty in rural Ethiopia. Further, in their study of 15 Ethiopian villages between 1999 and 2004, Dercon *et al.* (2005) found that more than 50 percent of their surveyed households reported drought as the most important shock. The authors were able to show that experiencing a drought at least once during the five-year study period lowered per capita consumption by about 20 percent. In their study on shocks and poverty in Guatemala, Tesliuc and Lindert (2004) reported that 7 percent of all sampled households were affected by drought in 2000. In Bangladesh, on the other hand, floods were reported as an important shock that has a negative impact on the agricultural sector (Quisumbing, 2007).

Although drought is among the shocks that farming households have to deal with in Malawi, the effect of recurrent drought on household vulnerability in Malawi has not been documented. Since there have not been studies to estimate the degree of vulnerability to poverty in Malawi using panel data on household consumption[1], it has not been possible to analyze the impact of different shocks on household vulnerability. This study, therefore, aims at filling this gap in knowledge. In particular, the paper analyzes not only the incidence of drought and other shocks facing rural households, but also explores the coping mechanisms that households employ to deal with the shocks, as well as determining the extent to which households facing recurrent drought are vulnerable to poverty.

[1] Among the few studies that have tempted to estimate household vulnerability in Malawi include Devereux *et al*. (2007) who analyzed vulnerability using an asset index as a proxy for household welfare. A study by Malawi Government and World Bank (2006) investigated the likelihood of being ultra-poor where being ultra-poor is associated with being vulnerable.

The paper proceeds as follows: section 2 outlines the objectives of the study. This is followed by a section on the methodology. Section 4, which discusses the data that are used in the study, is followed by a section on the results. Section 6 concludes the discussion and offers some policy implications.

2.0 Objectives

The general objective of the study is to understand the impact of drought on household vulnerability in rural Malawi. Specifically, the study has the following objectives:

1. To analyze incidences of drought and other shocks among rural households ;
2. To analyze households' coping mechanisms for drought and other shocks;
3. To examine whether experiencing recurrent droughts is associated with higher levels of vulnerability.

3.0 Methodology

The paper adopts an econometric methodology for analyzing household vulnerability proposed by Christiaensen and Subbarao (2004). The model follows vulnerability as expected poverty (VEP) approach and uses consumption as a measure of household welfare. This study defines vulnerability as the probability that a household would find itself consumption poor in the future, regardless of whether it is currently poor or not. This definition underscores the fact that vulnerability is a forward-looking (*ex-ante*) measure of household welfare while poverty is an *ex-post* measure of household well-being.

While the derivation of the model is presented in the appendix, it is important to note that determining the probability that a household finds itself consumption poor in the future period involves a number of steps. First, there is need to determine the time horizon over which potential future consumption shortfalls are assessed. In this study it is done for two years (2004 -2006) because of the data limitations. Second, household consumption expenditure per capita is used as the indicator of well-being. Third, consumption poverty line is used to define a threshold for well-being. In this study, the official poverty line for Malawi in 2006 is used. Fourth, a probability threshold $\theta = 0.5$ is used, such that a

household is considered vulnerable if that household's probability of shortfall exceeds θ[2]. Fifth, an *ex-ante* probability distribution ($f_{t=0}(C_t)$) of *ex-post* consumption is then estimated.

Using this method, each household's probability of having its level of consumption to fall below the consumption poverty line, which is pegged at (Malawi Kwacha) MK 16,165[3], is estimated. All the households whose probability of falling below the poverty line is greater than the vulnerability threshold θ value of 0.5 are classified as vulnerable.

4.0 Data Considerations

Estimating household vulnerability requires panel data of sufficient length and richness. Since such data are not available in Malawi, a sample of 300 households was obtained from the Second Malawi Integrated Household Survey (IHS2) dataset, with the aim of following them up and applying a similar questionnaire to obtain a two-period panel data.

The sampling procedure for the 300 households involved the identification from the IHS2[4] dataset of one district in the northern region, three districts in the central region, and four districts in the southern region. The districts were purposively sampled based on rainfall distribution in 2004-2005 cropping season. The districts with the highest and the lowest annual rainfall were included. This is important in our estimation of the vulnerability model since drought (which is the major shock included in the study) is highly correlated with rainfall distribution. In each district, at most two traditional

[2] θ is the threshold for vulnerability such that households whose probability of consumption shortfall exceeds the threshold are classified as vulnerable. Although the choice of θ is quite arbitrary, two threshold points are reported in the literature. The most common vulnerability threshold is 0.5, implying that a household whose probability shortfall is greater than 0.5 is more likely than not to end up poor. Most authors including Christiaensen and Subbarao (2004), Dercon (2001), Harrower and Hoddinott (2004) use this vulnerability threshold. The second threshold is setting θ equal to the observed current poverty rate in the population. The reasoning is that because the observed poverty rate represents the mean vulnerability level in the population, any household whose vulnerability level lies above this threshold faces a risk of poverty that is greater than the average risk in the population and can therefore be classified as vulnerable (Chaudhuri *et al.* 2002). In their study on vulnerability in Indonesia, Chaudhuri *et al*. (2002) use both thresholds and they referred to the θ=0.5 threshold as high vulnerability threshold while the observed incidence of poverty threshold was referred to as relative vulnerability threshold.

[3] US$1=MK140 (at June 2008 exchange rate).

[4] The IHS2 was conducted between March 2004 and March 2005, covering a sample of 11,280 households spread across 564 communities in all the 26 districts of Malawi.

authorities (TA) were randomly sampled, and then at most three enumeration areas (EA) in each TA were randomly sampled. Finally, at least thirty households in each EA were randomly selected to form the sample.

Due to attrition, data were only collected from 259 households during the second round of data collection which was conducted between June and October 2006. This study therefore uses a two-period panel data of 259 households spread across 20 communities in rural Malawi.

5.0 Results

5.1 Incidence of Shocks

Shocks are classified into a number of broad categories in this study: climatic, economic, health, crime and agricultural production shocks. Similar classifications are made in similar studies such as in Ethiopia (Dercon *et al.*, 2005), Malawi (Malawi Government and World Bank, 2006) and in Tanzania (Christiaensen and Sarris, 2007). Table 1 provides the incidence of various shocks among the sampled households between 1999 and 2006. The incidence of shocks is defined as the proportion of households affected by various shocks which gives an indication of the riskiness of the environment in which the studied households reside (Christiaensen and Sarris, 2007). As table 1 shows, drought is the most common shock affecting households to such an extent that in both 2004 and 2006, over 45 percent of the surveyed households reported experiencing it at least once. The second most common reported shock in both survey rounds was large rises in food prices, although the percentage of households that reported this shock was less in the second round (9.7 percent) than in the first round (15.8 percent). In 2004, around 9 percent of the households reported an illness or accident at least seven days prior to the survey date, while in 2006 the figure was around 6 percent. Falling sale prices for crops was another important economic shock reported in both rounds, with over 8 percent of

households experiencing it at least once between 1999 and 2004 and close to 7 percent encountering it at least once between 2004 and 2006[5].

Table 1: Percentage of Households Affected by each Shock between 1999 and 2006

Shock	Percentage (2004)	Percentage (2006)
Climatic		
Drought	45.9	49.4
Economic		
Large rise in food prices	15.8	9.7
Large fall in sale prices for crops	8.1	6.6
Rise in farm input prices	1.9	6.9
Household business failure	5.0	5.4
Loss of salaried employment	2.7	0
Health		
Illness or accident	9.3	6.2
Death of household head	0.4	0
Death of household working member	1.5	2.7
Death of other family member	1.5	2.3
Birth in the household	0.8	2.7
Agricultural Production		
Crop diseases or crop pests	0.8	2.7
Loss of livestock	6.2	1.9
Crime		
Theft	0	1.9
N = 259		

Source: Own compilation

Notes: 1. 2004 covers shock that households experienced between 1999 and the survey date in 2004
2. 2006 covers the shocks between the first survey date (2004) and the second survey date (2006)

[5] Using the whole IHS2 dataset, Malawi Government and World Bank (2006) reported that the major shocks that affected households between 1999 and 2004 include large rise in price of food (reported by 77 percent of all households), drought (reported by 62.5 percent),and illness (reported by 45.7 percent)

Among the significant shocks reported in 2006 which had a very low incidence rate in 2004 include rising prices for farm inputs. Around 7 percent of the sample reported experiencing this shock in the second round while only 2 percent reported it in the first survey round. On the other hand, loss of livestock affected more households in the first round than in the second round. The major health shocks reported include deaths and births in the households and these were reported in both rounds with low frequency. However, the type of shocks that poor households experience are often different from those experienced by wealthier households, as shown in table 2 where only the major shocks reported in 2004 are considered. It should be pointed out that in this particular analysis, the studied households were divided into expenditure quintiles based on their 2006 annual household expenditure per capita.

Table 2: Number of Households Reporting a Particular Shock in 2006 (Percentage)

	Expenditure Quintiles					
Shock	**Poorest 20%**	**2**	**3**	**4**	**Richest 20%**	**All**
Drought	60.8	50.0	42.3	53.8	40.4	49.4
Rise in food prices	7.8	7.7	9.6	7.7	15.4	9.7
Illness	5.9	5.8	7.7	7.7	3.8	6.2
Falling crop sale prices	3.9	3.8	5.8	9.6	9.6	6.6
Rise in farm input prices	3.9	9.6	5.8	5.8	9.6	6.9

Source: Own compilation

As table 2 shows, the prevalence of drought becomes less frequent as one moves from the poorest expenditure quintile to the richest quintile. This finding is not surprising as wealthier households tend to have different means of protecting their consumption from such shocks, as will be discussed later. As a result, the consequences of such shocks on household welfare are less severe among the non-poor. A surprising finding, however, is that the richest quintile reported rising food prices more than any other quintile in table 2. The *a priori* expectations were that rising food prices would affect the poor households more than the non-poor. A plausible explanation is that between 2004 and 2006, many poor households received free maize from the Government and non-governmental

organization, as a response to drought. Since such a safety net programme is targeted at poor households only, their participation in the local food market where prices were rising was very low.

Falling crop sale prices and rising farm input prices are the few shocks that are highly correlated with wealth. Falling crop sale prices were more often reported by wealthier households because they were usually the ones who were engaged in cash crop production. In most of the sampled areas, the major cash crop is tobacco, although cotton is also grown in two of the districts under investigation. The majority of the poor, on the other hand, are mainly involved in food crop production at subsistence level. As such, falling sale prices for crops would not have a direct significant impact on their welfare. Similarly, rising farm input prices appears to be more prevalent among wealthier households due to their involvement in cash crop production which requires a lot of inputs. Additionally, most of the poor households have benefited from the government's agricultural input subsidy programme that has been running since 2005. Through the programme, most of the poor and vulnerable households are issued with vouchers that enable them to buy seeds and fertilizer[6] at subsidized prices. This could be one explanation for the poorer households to be less likely to report rising input price shock in the second round.

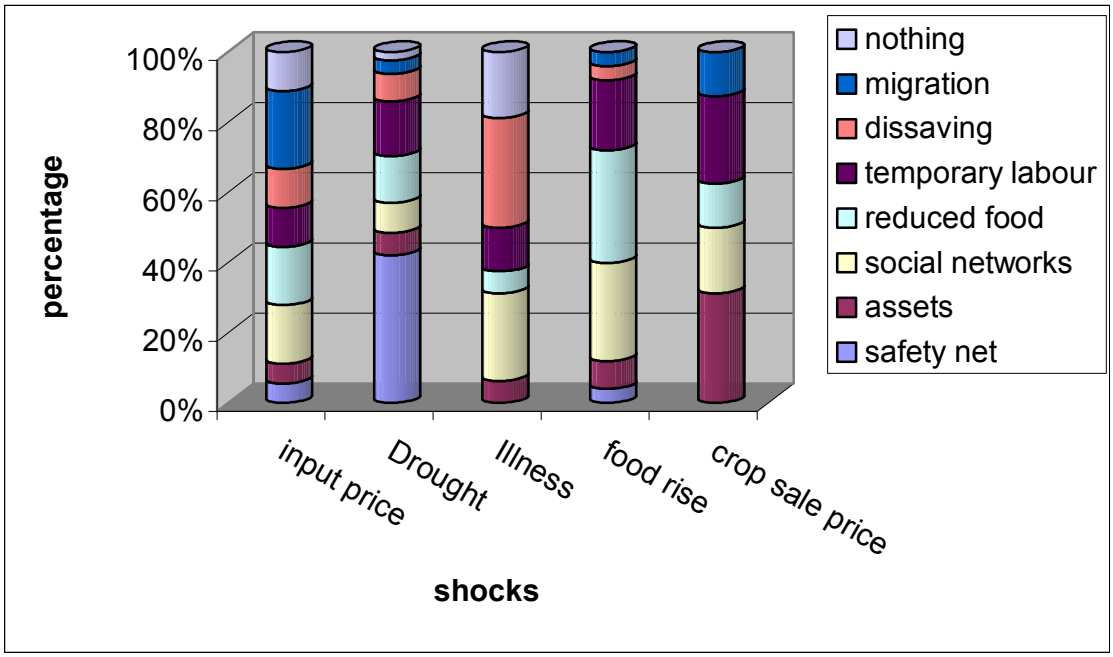
5.2. Household Coping Mechanisms

Since the sampled households face multiple shocks, it is important to identify the particular strategies that households employ when faced with a specific shock. This information is presented graphically in figure 1. . It can be seen from the figure that each of the major shocks in 2006 attracted a variety of responses. Temporary migration was used as a major response to rising agricultural input prices (22 percent) and to large falls in sale prices for crops (12 percent). While getting support from social networks was an important strategy to cope with rising food prices, illness, large falls in sale prices for

[6] According to DFID (2007), the price for subsidized fertilizer in 2007 was only US$7 per 50 kg bag, which was less than a third of the market price.

crops and rising input prices, it was less important in dealing with the main covariate shock, drought.

Figure 1: Major Shocks Reported and Households' *Ex-post* Responses in 2006 (Percentage of Households that Reported Each Shock)



Source: Own compilation

Figure 1 further shows that the majority of households that reduced their food consumption did so to address the problem of rising food prices (32 percent), rising input prices (17 percent) and drought (13 percent), among others.

Use of cash savings was an important *ex-post* strategy to cope with illness which is the main idiosyncratic shock among the major shocks. Asset depletion appeared to be the major response to deal with falling crop sale prices in 2006. Since the asset depletion variable encompasses a range of strategies including sale of farmland, livestock and sale of more crops, it is the latter that the majority of households used to cope with low prices for crops between 2004 and 2006. Further, safety nets were clearly the major response to drought (42 percent) with sale of temporary labour and reduced food consumption being the second and third important strategies, respectively. Finally, a number of households

did not have any strategy to cope with illness (19 percent of all households that reported illness as the most important shock) and rising input prices (11 percent).

5.3 Vulnerability and Recurrent Drought

Vulnerability profiles of 2004 were classified based on the households' exposure to several shocks in 2006.

Table 3: Poverty and Vulnerability Profiles by shocks Reported in 2006

Shock	Poverty Headcount	Vulnerability Headcount	Vulnerability to Poverty Ratio
Drought	0.51	0.47	0.92
Illness	0.49	0.45	0.92
Rising food prices	0.55	0.53	0.96
Falling crop sale prices	0.30	0.29	0.97
Rising farm input prices	0.35	0.32	0.91

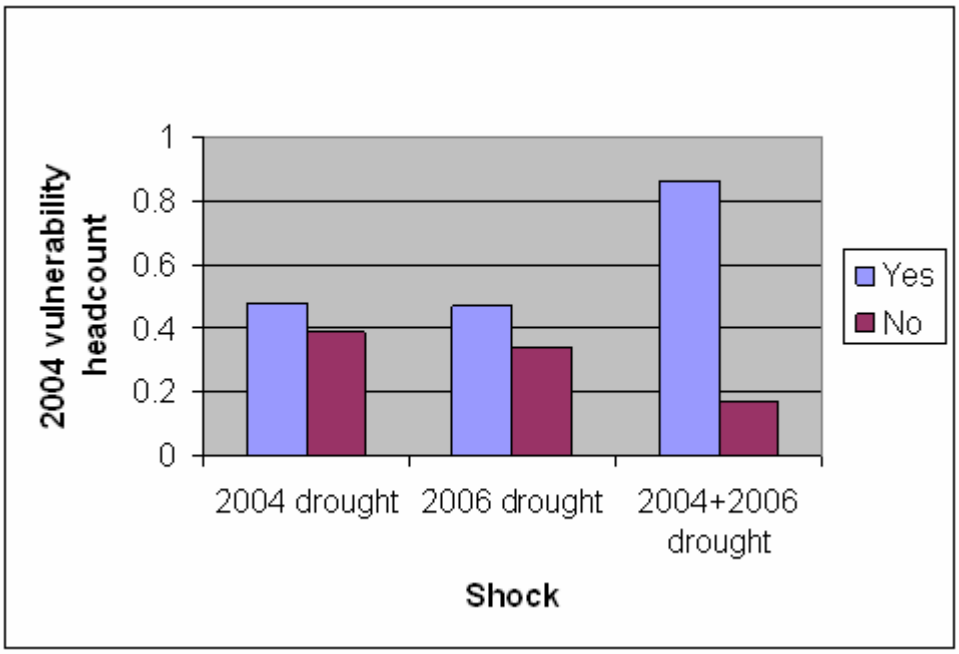
Source: Own compilation

The results (reported in table 3) show that 47 percent of the households that reported experiencing a drought between 2005 and 2006 were vulnerable to poverty in 2004. The same pattern emerges for rising food prices, where 53 percent who reported this shock were vulnerable in 2004. However, levels of vulnerability were low for households that reported experiencing falling crop sale prices as well as rising input prices. An examination of the poverty headcount shows that these two shocks tend to affect households that have low levels of poverty. Indeed, the majority of the poor households are likely not affected by falling prices for cash crops since they do not produce any crops for sale, as their crop production is for subsistence only. On the other hand, during the study period the majority of the poor households had access agricultural input subsidies that the Government was running. It is, therefore, surprising that the majority of those that reported this shock were both non-poor and non-vulnerable.

Using the vulnerability headcount, the paper further analyzes the extent to which households that reported experiencing drought in both survey rounds were vulnerable. As figure 2 shows, around 48 percent of the households that reported experiencing a drought only in 2004 were vulnerable, and the proportion was similar in 2006. On the other hand,

over 85 percent of the households that reported experiencing drought both in 2004 and 2006 were vulnerable to poverty.

Figure 2: Vulnerability Headcount and Recurrent Drought, 2004-2006



Source: Own compilation

For the households that did not report experiencing drought in both rounds, only 19 percent were vulnerable. These results show that experiencing recurrent drought is associated with higher levels of vulnerability. Indeed, for the majority of the smallholder farming households who derive their livelihoods from rain-fed agriculture, occurrence of drought in two subsequent agricultural seasons means that their source of livelihood is severely compromised to an extent that they become susceptible of falling into poverty, (if currently non poor) or moving deeper into poverty (if already poor).

Conclusion and Implications for Policy

The paper has shown that rural households in Malawi experienced multiple shocks between 1999 and 2006, with drought remaining the most prominent shock in both survey rounds. The study has further shown that recurrent droughts are associated with higher levels of vulnerability to poverty. It has also shown that rural households depend on safety net programs to cope with drought. It is in this respect that targeted direct

welfare transfers, especially in the form of direct food transfer, should be promoted as a short-term intervention to help poor households to be able to smooth their consumption in the face of drought. However, development practitioners agree that social protection interventions should go beyond direct welfare transfers to incorporate productivity-enhancing safety nets. These interventions, which are targeted at economically active, input-constrained farmers in the case of Malawi, are important because they do not only transfer resources to the poor and the vulnerable but they also build household assets. The agricultural input subsidy program[7] that the Government of Malawi has been running since 2005 should therefore be encouraged as a short-term strategy. In the long-term, however, small and medium scale irrigation schemes need to be promoted in order to enhance food crop production. As it is acknowledged in the Malawi Growth and Development Strategy for 2006-2011, irrigation would contribute towards the reduction in the overall dependence on rain-fed agriculture. It is therefore imperative that irrigation should continue to be promoted, especially among poor communities where the impact of drought is most severe.

The use of weather-indexed insurance, which is being piloted in Malawi since 2005/6 agricultural season should also be promoted. The insurance, whose payout is based on the deficit in cumulative rainfall at specific dates in the crop growth cycle, is being piloted for groundnut farmers in Malawi (Alderman and Haque, 2007). The potential for linking a social protection payout to an index-based insurance which was initiated by World Bank researchers should be explored further[8].

[7] Imperial College London *et al*. (2007) evaluates the Malawi Input Subsidy Program 2005-2007 and also undertook a livelihood impact of the program. The study concluded that the incremental maize production that is attributed to the subsidized fertilizer was between 300,000 and 400,000 metric tonnes in 2005/6 season and between 600,000 and 700,000 metric tonnes in 2006/7. Further, a cost-benefit analysis of the programme shows that the value of the extra maize production in 2006/7 was between US$ 100 million and US$ 160 million, which far exceeds the US$ 70 million cost of the seed and the fertilizer subsidy in 2006 (DFID, 2007).

[8] Alderman and Haque (2007) describe simulation exercises on how the index-based insurance can be linked to social protection in the face of drought.

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APPENDIX

Derivation of the Vulnerability Model

The study adopts the methodology for analyzing household vulnerability proposed by Christiaensen and Subbarao (2004). The model follows a vulnerability as expected poverty (VEP) approach and uses consumption as a measure of well-being.

Let the poverty index for person *i* at time *t* be denoted as $p_{it}(C_{it}, Z)$, where C is the level of consumption and Z is the poverty line. The vulnerability V of person *i* at period t = 0, with respect to his future consumption ($C_{i,t\geq 1}$) can be expressed as

$$\begin{aligned} V_{i,t=0} &= \mathrm{E}\left[p_{it}(C_{it}, Z) \mid F(C_{it})\right] \\ &= \int_{\underline{C}_t}^{Z} p_{it}(C_{it}, Z) dF(C_{it}) \\ &= F(Z) \int_{\underline{C}_t}^{Z} p_{it}(C_{it}, Z) \frac{f(C_{i,t})}{F(Z)} dC_{it} \end{aligned} \tag{1}$$

Where $\underline{C}_t$ is the lower bound of future consumption C_t and F(.) is the cumulative distribution function associated with the density function f(.)

Equation 1 shows that the person *i*'s vulnerability is measured as the current probability of becoming poor in the future (F(Z)) multiplied by the conditional expected poverty. Based on the Foster-Greer-Thorbecke (FGT) measures of poverty, the poverty index can be expressed as:

$$p_{it}(C_{it}, Z) = \left[\max\left(0, \frac{Z - C_{it}}{Z}\right) \right]^{\gamma}$$

Therefore (1) can be written as:

$$V_{i,t=0,\gamma} = F(Z) \int_{\underline{C}_t}^{Z} \left[\frac{Z - C_{it}}{Z} \right]^{\gamma} \frac{f(C_{i,t})}{F(Z)} dc_{it} \tag{2}$$

From (2) it is apparent that a person's vulnerability is measured as a product of the probability that a person's consumption falls below the poverty line (F(Z)), and the weighted probability function of relative consumption shortfall. It should be pointed out that if $\gamma = 0$, equation (2) simplifies to F(Z), and vulnerability is measured as the probability of consumption shortfall (V_0). If $\gamma = 1$, vulnerability (V_1) is the product of the probability shortfall and the conditional expected gap (Christiaensen and Subbarao, 2004). When $\gamma>1$, larger shortfalls are converted into greater vulnerability, given the same conditional probability of occurrence.

In order to empirically estimate the vulnerability measure V_γ provided in (2), the methodology involves the following steps:

1. There is need to determine the time horizon over which potential future shortfalls will be assessed. In this study it will be done for two years (2004 -2006) because of the data limitations;

2. Household consumption expenditure per capita is used as the indicator of well-being. The choice of consumption as a measure of welfare is guided by a number of reasons. Although welfare is measured by income in more developed countries, measuring income is a big challenge in developing countries, such as Malawi. First, many Malawians do not have a regular income, making it difficult to assess one's current income at one point in time. Second, income from farming activities may be hard to enumerate since households do not keep formal accounts of revenues and expenditure (Malawi Government and World Bank, 2006). Third, there is a tendency among households to deliberately under-report earnings from informal activities.

3. Consumption poverty line (Z) is used to define a threshold for well-being. In our study, the official poverty line for Malawi in 2006 of MK 16,164 per capita per year is used.

4. A probability threshold θ = 0.5 is used, such that a household is considered vulnerable if that household's probability of shortfall exceeds θ[9].

5. An *ex-ante* probability distribution ($f_{t=0}(C_t)$) of *ex-post* consumption is then estimated.

The consumption generating process for the household depends on, among other things, its current endowments, its setting (environment) and the risk factors it faces. The risk factors, whether idiosyncratic or covariate, affect the level and variability of the household's endowments and income. In this respect, the level and variability of a household's future consumption stream depend on the risk factors which are stochastic, the risk exposure and the household's coping capacity. The household consumption can therefore be expressed in the following reduced form:

$$C_{ijt} = c\left(X_{ijt-1}, S_{ijt}, \varphi_{ij}, \theta_{ij}, u_{ijt}\right) \qquad (3)$$

Where: X_{ijt-1} denotes the bundle of observed household and location-specific characteristics of household *i* in location j at time *t-1*;

S_{ijt} denotes observed local covariate and idiosyncratic shocks that the household experiences between time *t* and *t-1*;

φ represent a vector of parameters describing the returns to the locality and household; endowments, and the effect of the shocks S_{ijt};

θ_{ij} denotes unobserved time invariant household and locality effects;

U_{ijt} represent unobserved idiosyncratic shocks.

[9] θ is the threshold for vulnerability such that households whose probability of consumption shortfall exceeds the threshold are classified as vulnerable. Although the choice of θ is quite arbitrary, two threshold points are reported in the literature. The most common vulnerability threshold is 0.5, implying that a household whose probability shortfall is greater than 0.5 is more likely than not to end up poor. Most authors including Christiaensen and Subbarao (2004), Dercon (2001), Harrower and Hoddinott (2004) use this vulnerability threshold. The second threshold is setting θ equal to the observed current poverty rate in the population. The reasoning is that because the observed poverty rate represents the mean vulnerability level in the population, any household whose vulnerability level lies above this threshold faces a risk of poverty that is greater than the average risk in the population and can therefore be classified as vulnerable (Chaudhuri *et al.* 2002). In their study on vulnerability in Indonesia, Chadhuri *et al*. (2002) use both thresholds and they referred to the θ=0.5 threshold as high vulnerability threshold while the observed incidence of poverty threshold was referred to as relative vulnerability threshold.

X_{ijt-1} is a function of its initial endowment base and the shocks it experiences, such that:

$$X_{ijt-1} = x\left(X_{ij0}, S_{ijt-k}, \eta_{t-1}, \varepsilon_{t-1}\right) \tag{4}$$

Where: X_{ij0} is the initial endowment base;

S_{ijt-k} denote the series of shocks experienced by the household between time 0 and t-1, with k=1,…,t-1;

η_{t-1} is the vector of coefficients relating the initial endowments and past shocks to the current asset base X_{ijt-1};

ε_{t-1} denote the different unobserved factors that contribute to changes in the asset base over time.

Putting equation (4) into (3) yields:

$$C_{ijt} = c\left(X_{ij0}, S_{ijt-k}, \phi_t^*, \theta_{ij}, u_{ijt}^*\right) \qquad \text{with k} = 0,..., \text{t} - 1 \tag{5}$$

Econometric Specification

Christiaensen and Subbarao (2004) extend the approach proposed by Just and Pope (1979) to specify the consumption function in equation 3 into a flexible heteroscedastic form:

$$\begin{aligned} \ln C_{ijt} &= X_{ijt-1}\beta + S_{ijt}\gamma + S_{ijt}\varphi' X'_{ijt-1} + \theta_{ij} + u_{ijt} \\ &= X_{ijt-1}\beta + S_{ijt}\gamma + S_{ijt}\varphi' X'_{ijt-1} + \theta_{ij} + h^{1/2}\left(X_{ijt-1};\alpha\right)^* e_{ijt} \end{aligned} \tag{6}$$

where $e_{ijt} \sim N(0,\sigma^2_e)$

The conditional mean and variance from equation 6 can be expressed as:

$$E\left(\ln C_{ijt} \mid X_{ijt-1}\right) = X_{ijt-1}\beta + E\left(S_{ijt}\right)\left[\gamma + \varphi' X'_{ijt-1}\right] + E\left(\theta_{ij}\right) \tag{6.7}$$

$$V\left(\ln C_{ijt} \mid X_{ijt-1}\right) = \left[\gamma + \varphi' X'_{ijt-1}\right] V\left(S_{ijt}\right)\left[\gamma + \varphi' X'_{ijt-1}\right] + \sigma^2_\theta + h\left(X_{ijt-1};\alpha\right)^* \sigma^2_e \tag{6.8}$$

The heteroscedastic specification in equations 7 and 8 has special features:

1. It enables the variance of household consumption to differ across households depending on three factors. The first factor is the household and location-specific characteristics $h\left(X_{ijt-1};\alpha\right)^* \sigma^2_e$. The second factor is the variance of the shocks the

household faces $\gamma^2 V\left(S_{ijt+1}\right)$. The third factor is the differential effect of the shock on the household expressed as $\left[\phi' X'_{ijt}\right]' V\left(S_{ijt+1}\right)\left[\phi' X'_{ijt}\right]$.

2. The explanatory variables do not have to affect the mean and variance of future household consumption in the same direction.

3. The shocks can be modelled explicitly by decomposing the variance of household consumption into idiosyncratic and covariate components, as shown below:

Let s_i and s_c denote idiosyncratic shock and covariate shock, respectively; and θ denote constant variance-unobserved household and locality characteristics. Then the variance in equation 8 can be split into:

$$V\left(\ln c_{ijt} X_{\partial ijt-1}\right) = \left[\gamma_{sc} + \phi_{sc}' X'_{ijt-1}\right]^2 \sigma^2_{sc} + \left[\gamma_{si} + \phi_{si}' X'_{ijt-1}\right]^2 \sigma^2_{si} + h\left(X_{ijt-1};\alpha\right) * \sigma^2_e \quad (9)$$

Where the first variance is that resulting from observed covariate shocks, the second is from observed idiosyncratic shocks, and the third variance is accruing from unobserved idiosyncratic shocks.

4. The interaction terms between household characteristics, location characteristics and the shock included in the specification would ensure that shocks do not affect all households in the same way, since households' incomes and their consumption smoothing capacity differ.

Equations 7 and 8 can then be used to estimate the *ex-ante* mean and variance of household's future consumption which depend on the *ex-ante* household and locality characteristics,X_{ijt-1}, the mean, the variance and covariance of the observed covariate and idiosyncratic shocks, S_{ijt}, and the regression coefficients β, γ, φ, and α of the mean and variance equations (Christiaensen and Subbarao, 2004). However, the estimation of the

regression parameters requires a three-step heteroscedastic correction procedure[10] proposed by Just and Pope (1979). This will enable one to obtain efficient estimates of β, γ, and φ.

Finally, the methodology requires combining the efficient estimates with the household and locality characteristics, X_{ijt-1}, and the mean, the variance and the covariance of the shocks to predict the household mean and variance of the future consumption. With the assumption of lognormality, one would then be able to estimate vulnerability for each household V_γ two periods ahead due to data limitations.

[10] This is also known as a feasible generalized least squares (FGLS) method.