Weather Shocks and Nutrition Protection: the Role of Forests

Kelvin Mulungu[1] & Dale Manning

Colorado State University

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[1] Corresponding author: kelvin.mulungu@colostate.edu

Abstract:

We empirically examine the nutrition-protection role of non-timber forest products extracted from common property forests in Malawi. Agricultural households that experience negative weather shocks increase collection of common property forest products, suggesting that forests provide a form of natural insurance. As a result, households with better access to common property forests experience a smaller decline in dietary diversity. Further, communities with better forest quality are better placed to smooth nutrition through the consumption of non-timber forest products. These results imply that efforts to manage forest resources must consider the important role they play for rural households exposed to climate shocks. While managing the extraction of common pool resources can lead to higher net earnings and better resource quality, flexible institutions that consider returns in alternative economic activities can maintain access to natural insurance, particularly in regions without robust agricultural insurance markets.

1. Introduction

Extraction of common pool natural resources (CPRs) can provide direct benefits to households in rural regions of the developing world. In particular, rural households often rely on non-timber forest products (NTFPs) for food, income, and employment (Mulenga et al, 2012; Perge, 2011; Angelsen & Wunder, 2003; Johnson et al, 2013). Common NTFP include fuelwood (both firewood and charcoal burning), wild foods, and edible insects (Kohlin & Parks, 2001; Murphy, Berazneva, & Lee, 2018; Robinson, Albers, Ngeleza, & Lokina, 2014). While unrestricted access to a resource can lead to resource degradation and a tragedy of the commons (Hardin, 1968; Manning, Taylor, Wilen, & Taylor, 2018; Ostrom, 2000), it may also allow vulnerable households to smooth consumption and maintain adequate nutrition in the face of negative shocks to private activities such as agriculture (López-Feldman, 2014; Morduch, 1995; Pattanayak & Sills, 2001). The ability of CPRs to provide natural insurance has been explored theoretically (Fisher, Chaudhury, & McCusker, 2010; Pattanayak & Sills, 2001; Smith, Hudson, & Schreckenberg, 2017; Takasaki, Barham, & Coomes, 2004). Empirically, Oviedo & Moroz (2014) and Rose (2001a) demonstrate that forest access can diminish but not eliminate decreases in income during negative shocks. Nevertheless, most NTFPs remain non-marketed (Ambrose-Oji, 2003; Mulenga, Richardson, Tembo, & Mapemba, 2014; Mutenje, Ortmann, & Ferrer, 2011) and thus a focus on income may underestimate the ecosystem services provided by forest access in the face of negative shocks.

In this paper, we provide empirical evidence that households in rural villages in Malawi use NTFP extraction from common property forests as a form of natural insurance, with a focus on nutritional outcomes. First, we test if households access forests more frequently during extreme weather events that harm agricultural productivity. Then, we explore if households with better access to common property forests experience smaller declines in nutrition outcomes such as dietary diversity. Finally, we use information on forest quality to determine if degraded forests provide less robust natural insurance.

Results suggest that households increase the use of NTFP extraction by 6% during a negative weather event. As agricultural income falls, households with access to common pool forest resources experience smaller drops in dietary diversity and are less likely to deplete their assets. Finally, we provide evidence that less-degraded forests provide more robust insurance for nutritional outcomes. This suggests that forest management that decreases extraction on average may increase the capacity of forests to provide insurance but that institutions must remain flexible enough to allow increased access during events that reduce returns in other economic activities.

This analysis contributes to the environmental and development economics literature by highlighting the importance of NTFP for household nutrition in the face of weather and climate uncertainty. Many studies have established a connection between idiosyncratic and covariate shocks and the use of CPRs (Agarwal, 1990; López-Feldman, 2014; Pattanayak & Sills, 2001; Paumgarten & Shackleton, 2011). Despite this, the connection between NTFP extraction and nutritional outcomes remains poorly understood in the literature. Most studies have focused on commercialization (cash crop production and marketing) of NTFP and the impact on welfare, including nutrition (Benfica et al, & Mouzinho, 2017; Lenjiso et al, 2016), with relatively little information on the ability of forests to insure nutritional outcomes. Our focus on the impact of forest quality on its capacity to provide insurance presents an important complementarity between forest management and natural insurance. The literature often examines a choice between using free access to a CPR as natural insurance OR managing the resource as a natural capital (Cubbage, Harou, & Sills, 2007; Hartter & Ryan, 2010). Our results suggest that management institutions that improve forest quality on average while allowing increased access during negative shocks can lead to better economic and ecological outcomes over time.

The remainder of this paper is laid out as follows. In the next section, we provide an overview of the current literature related to resource management, natural insurance, and nutrition outcomes. This review leads us to several testable hypotheses. Then, we describe the context in which we empirically examine the linkages between shocks and nutrition, and the data used. Section 5 describes our empirical strategy while section 6 presents results and robustness checks. Finally, section 7 concludes with a discussion of policy implications and avenues for future work.

2. Non-timber Forest Products, Insurance, and Nutrition

This research contributes to three strands of literature. First, the economics literature has revealed many strategies that rural household use for coping with negative shocks. Next, many have examined the role of natural resources as both capital stocks and natural insurance. Finally, there is a well-developed literature exploring the connections between NTFP use and household outcomes, including nutrition. We now provide an overview of each of these literatures, followed by hypotheses drawn from the literature that we test empirically.

2.1 Rural Household Coping Strategies

In developing countries, social safety nets are less developed (Dercon, 2002) and this leaves the poor vulnerable to both covariate and idiosyncratic shocks. Lack of potential markets, high rates of poverty, and other institutional factors mean that insurance programs that are supposed to protect the poor in times of shocks do not exist (Delacote, 2009; Janzen & Carter, 2018). Lack of insurance and state welfare often coincides with high poverty rates and inequalities between the haves and the have-nots.

To cope with shocks, rural households, who are mostly smallholder farmers, have developed several strategies to protect income and consumption. These strategies include both those that are employed before the shock happens (ex-ante) and those that are employed after the shock (ex-post). Other scholars categorize them as anticipatory strategies and reactive strategies. One of the ex-ante strategies that the poor employ is the adoption of conservative practices at the expense of high returns such as adoption of drought-resistant varieties that are low yielding (Hansen et al., 2018). Crop diversification, another strategy employed ex-ante, has helped insure against effects of rainfall variability, as different crops are affected differently by climatic events (Hansen et al., 2018). For example, in Zambia, farmers allocate labor to conservation tillage methods such as minimum tillage that trap moisture, improve soil quality, and minimize soil erosion, resulting in decreased dependency on rain (Lekprichakul, 2007)

The most common ex-ante coping strategy is allocating labor to more activities including supplying labor to the market. Rose (2001) found that households facing a riskier distribution of weather are more likely to participate in the labor market, both *ex-ante* and *ex-post*. By adjusting labor supply i.e. moving away labor from own production to the labor market, households buffer the effect of weather shocks by about 10-12% on income. Ito & Kurosaki (2009) estimate the impact of weather risks on wages and labor supply using the case of a developing country and find that there is an increase in labor market participation after a weather shock. The results indicate that when weather risk increases (amount of rainfall increases from its minimum to its maximum), the percentage of households participating in off-farm wage work increases from 46% to 84%. There is also increased demand for payment-in-kind in exchange for labor supplied compared to the demand for cash, and they explain this as consideration for food security. Takasaki, Barham, & Coomes (2004) show that labor allocation depends on the available alternatives. Farmers, in their study, responded to a weather shock by ex-post labor allocation to upland cropping for those who had access to upland farms, while others allocated labor to fishing when there was a flood. For idiosyncratic shocks, most households responded through precautionary savings such as livestock sales.

Additionally, there are various institutions that help farmers diversify their income as a coping mechanism by empowering them in industrial projects to reduce their dependence on agriculture. For example, micro-credit programs helped women in a drought-stricken area of Mali learn to make soap and energy-efficient stoves so that they were less reliant on the sale of valuable assets to cope with droughts (Dercon, 2011). As an ex-ante strategy, smallholder farmers may also participate in group weather-insurance that provides financial protection when natural disasters result in crop failure. In Malawi, farmers can obtain loans from micro-finance institutions to purchase high yielding groundnut seeds that would otherwise be unaffordable (Fisher et al, 2010). However, credit institutions are weak and almost non-existent in most parts of rural Africa (Hallegatte et al., 2015). Households in poor developing countries are typically ill-equipped to cope with large risks or shocks to their production (Dercon and Christiaensen, 2011).

2.2 Natural Resources as Insurance

There is a host of literature that has demonstrated the safety net role of forests and other common property resources. One of the notable studies is Pattanayak & Sills (2001) who derive a theoretical model of household dependence on forest collection in times of a shock and show that the number of trips to the forest (as an indicator of use/dependence) increases in the event of a shock that affects agricultural production. The commons often act as a resource of last resort in times of economic hardships (Agarwal, 1990; Baland & Francois, 2005). The insurance providing advantage of the commons follows directly from linking of resource rents to labor allocations. Those in most need, i.e., those with relatively poor outside earning chances allocate relatively higher effort to gathering resources from the commons and obtain a relatively high share of the resource rent when not dissipated (Baland and Francois, 2005). The poor, therefore, depend more on CPR extraction to cope with shocks. Argawal (1990) in India finds that the poor depend on forests for survival in lean seasons. Dasgupta (1987) shows that households with low agricultural productivity are the ones who are more dependent on common property resources. McSweeney (2003) reveals that the young household heads that have not acquired assets are the ones that depend more on CPR extraction when there is a shock while those with assets liquidate them to cope. Liquidated assets are used to buffer income, which is a costly coping mechanism compared to extracting from the forests.

More recent studies have continued to show the dependence of the poor on CPR. Fisher, Chaudhury, & McCusker (2010) find that, in Malawi, it is households headed by less educated adults, those with a less marketed surplus and living near the forest that depend more on forests. These findings are corroborated by Mulwa, Marenya, Rahut, & Kassie (2017). We add to this literature by explicitly focusing on the nutrition protection role of forests and how collecting fuelwood impacts on this.

Among the shocks that affect rural households are weather shocks. It is predicted that Africa will be affected more from the frequency of extreme events and bear the negative consequences of climate change more (Connolly-Boutin & Smit, 2016; Hallegatte et al., 2015; Schlenker & Lobell, 2010). Malawi, for example, has experienced 40 weather-related disasters between 1970-2006 and these have had negative effects on the population in terms of poverty, healthy, food insecurity and nutrition (Fisher, Chaudhury, & McCusker, 2010; Nangoma, 2007). An assessment by Patt et al. (2010) shows that least developed countries, including Malawi, will be more vulnerable to weather shocks between now and the mid-half of the century. In the second half of the century, socioeconomic development that increases the adaptive capacity will begin catching up. This means shocks in the short to medium term will have even greater effects.

The other strand of literature our study contributes is on rationalization of CPRs and allowing for flexibility for greater access. While open access allows members of the communities to freely access the resource and offers the greatest level of freedom on use, it does lead to a tragedy of the commons as resource too much effort is used in extraction and resource rents are dissipated (Hardin, 1968; Wilen, 2013). By leaving the resource as open access, it offers greatest opportunity to be used by the poor as natural insurance in times of shocks. Rationalization of a resource, which is any form management that aims at maximizing rents and is good for both the users and biological condition of the resource, generates wealth by limiting the amount of effort used for extraction. By reducing effort or the type of effort (in our case, fuelwood would be for example be restricted to optimally the forest for wild foods and other products that do not degrade its quality), this would lead to resource stock improving and hence the quality of the resource or forest. In rationalized setting, the quality of the resource is higher while labor allocation is lower than in an open access setting (Homans and Wilen, 1997). The extreme case of rationalization is privatization. While this was regarded as the solution by early economists, there is new literature demonstrating that a more flexible approach that can ensure better quality of the resource with higher but strategic access may offer more benefits for communities to use the resource as insurance but still be able to generate sustainable rents (Delacote, 2009; McSweeney, 2004; Wilen, 2013). We offer insights by investigating how others labor allocation and quality of the resource reduce the nutrition protection role of forests.

2.3 NTFP Use and Nutritional Outcomes

The impact of weather shocks on nutrition has particularly been given attention in the literature. Weather shocks affect nutrition because households reduce consumption, reduce the number of meals, or resort to less nutritious food as a coping strategy. Ibrahim & Alex (2008) show that in Malawi, more than 80% of the households respond by reducing the number of meals and reducing the meals eaten in a day. The other mechanism is by affecting income through agricultural productions. Focusing on rural households in Tanzania, Bengtsson (2010) uses an instrumental variable approach to link income to nutrition and finds that female children's body weight is more responsive to weather shocks as they affect income compared to adults and boys. In Mexico, Skoufias & Vinha(2012) finds that positive rainfall shocks are associated with lower weight-for-height scores while negative rainfall shocks (defined as 2 standard deviations below the long term mean) have mixed effects depending on the altitude and region. Temperature shocks do not significantly affect nutritional status for their study. Other studies (Grace, Davenport, Funk, & Lerner, 2012) find that it is the level of rainfall and not rainfall that is associated with malnutrition. Even when other factors are controlled for, the effect of weather and weather shocks on malnutrition remains significant. This effect is not only in developing countries. In the USA, Bhattacharya, DeLeire, Haider, & Currie (2003) showed that extreme weather events are associated with poor nutrition among poor families as they reduce expenditure on food while increasing heating costs. The impact of weather-induced nutritional shocks on children impact their school performance and cognitive abilities (Tiwari, Jacoby, & Skoufias, 2017). These effects experienced in the first years of life are hard to reverse even when parents have managed to overcome poverty later (Alderman, 2010; Hoddinott, Alderman, Behrman, Haddad, & Horton, 2013).

There are mainly two main ways that extraction of NTFPs can affect nutritional outcomes; through direct consumption and through income. In cases where markets for forest products are not well developed, the income channel is of less significance (Manning & Taylor, 2015). While others (Abdulla, 2013) have found that participation in the commons contributes significantly to household income, others (Delacote, 2009) have theorized that the returns to labour by participating in the commons are lower than engaging in a private enterprise, hence making those households that participate worse off (poverty trap in the commons). Empirically, for example, Mujawamariya and Karimov (2014) find that participating in the extraction of NTFPs in Kenya does not improve income. In Zambia, Mulenga et al. (2014) find that NTFPs contribute about 35% to income of the households extracting, even though they do not determine if participation reduces or increases income

2.4 Hypotheses from the Literature

From the literature above, we draw hypotheses which we test empirically. From literature on labor allocation between agriculture or private enterprise and CPR, we hypothesize the following;

1. H1: Households allocate labor away from agriculture to the CPR in the event of a shock

2. H2a: Households with access to the forest (CPR) are able to reduce the impact of a shock on nutrition

   H2b: Access to forests reduces the reliance on asset depletion as a coping mechanism
3. H3a: Less degraded or better-quality forests are able to offer better protection against the negative impact of weather shocks

   H3b: Increased labor allocation to the CPR at the community level degrades the forest and reduces its protection role

3. Empirical Context

Malawi is a good case study to understand the role that forests play in nutrition protection. Firstly, Malawi is chosen because it has the Living Standards Measurement Survey (LSMS) data which is a unique panel data that also collects anthropometric indicators. Secondly, Malawi has one of the worst child malnutrition in the world. It has the fifth highest stunting rate in the world at 53% of the children under the age of five while wasting is estimated at 15 % (UNCEF, 2009). Micronutrient deficiency is equally high, with vitamin-A deficiency estimated at 60% and 47% of preschool-aged children and pregnant mothers respectively (WHO, 2008). Zinc and Iron deficiencies are also prevalent among children and pregnant women. The nutrition statistics are worse in rural areas and among the poor, for example, stunting rate among the richest (20% wealth quintile) is 31% but rises to 54% among the poorest (NSO and ICF Macro, 2011). These poor households also depend on NTFP extraction for their nutrition and income more than the rich households.

Geographically, Malawi has a vast range of geographical features, with mountains to the south and high plateaus in the north and central areas. The country boasts a diverse array of flora and fauna made up of a variety of woodlands, tropical rain forests, open savannah high altitude grasslands and scrub. Malawi has bimodal two main seasons, cold-dry and hot-wet with unimodal rainfall. From November to April is the dry season while December to March is the wet (rainfall) season. Figure 1 shows the rainfall distribution, with most parts having annual rainfall between 800-1000 mm. Temperatures on average range from averaging 14 to 32 degrees Celsius. The country has experienced several climate shocks including the period considered by this study. For example, between 1970-2006, the country experienced 40 weather-related disasters mostly droughts and floods, losing 1.7% of its GDP to the same (droughts and flood)

(Pauw, Thurlow, Bachu, & Van Seventer, 2011). This makes it a good case-study for understanding the impact of weather shocks.

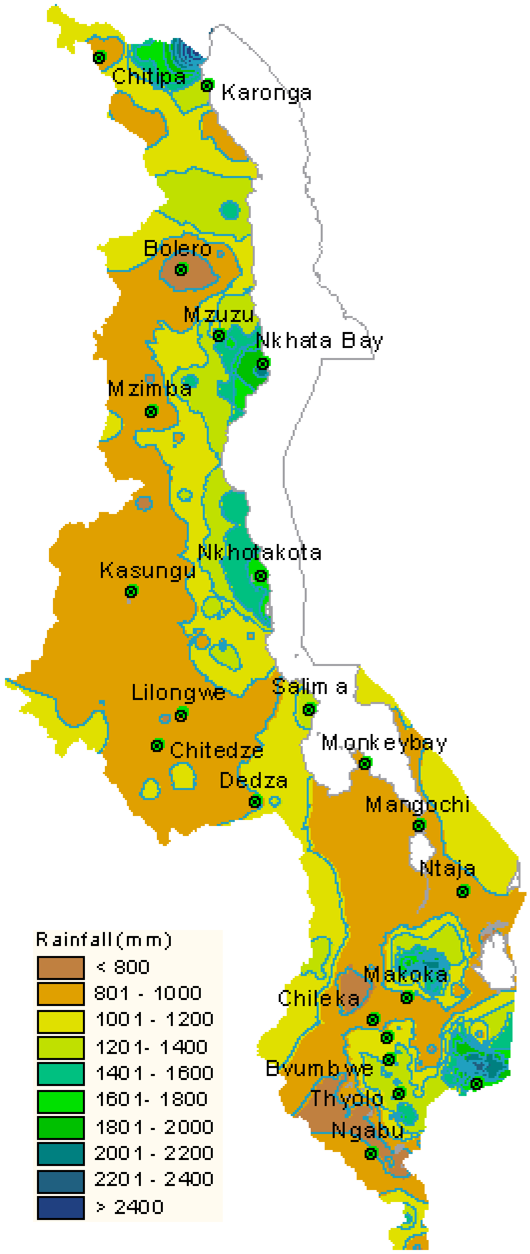

Figure 1: Rainfall patterns in Malawi. Source: Department of Climate Change and Meteorological Services, Malawi

Forests in Malawi play a huge role in the livelihoods of rural households with about 80% of the households depending on them (Fisher et al., 2010). Forest cover for the country stands at about 36% of which 33% is categorized as primary cover—the most diverse form of forest (Munthali & Murayama, 2015). Concerns over deforestation resulting from agricultural expansion and dependency on forest biomass for energy are increasing. Malawi s considered to have one of the highest deforestation rates at 2.4% per annum (FAO, 2001). However, others argue that the extraction of fuelwood and charcoal burning contribute little to deforestation compared to agricultural expansion and is part of early 1970s simplistic and alarmist energy narratives (Zulu, 2010).

Despite the importance of NTFPs in nutrition and income generation, policymakers often do not accord sufficient attention to the potential role played by NTFPs, partly because quantitative measures of the impact on improving nutrition and health. With the Malawi government committed to using forests as a poverty alleviation tool, this study will make a contribution towards understanding the exact role that forests through providing NTFPs can play.

4. Data

The Integrated Household Long-term Panel Survey 2010-2013-2016 is used for this analysis. The IHPS is collected by the Government of Malawi with support from the World Bank studies trends in poverty, socioeconomic and agricultural characteristics over time through a longitudinal survey. This dataset offers unique opportunities to probe the above research questions as it has measures on household food consumption and dietary diversity, consumption and sell (very negligible) of NTFPs such as caterpillars, mushrooms, and other insects. Panel data allow us to understand how extraction and marketing decisions for NTFPs have impacted household nutrition as measured by dietary diversity. Even though the data contains information on self-reported weather shocks, we do not use these for two reasons. First, self-reported weather shocks are not reliable and are not standardized across households. Second, poor households may overreport shocks, leading to problems of endogeneity. Instead, we take advantage of the rainfall data that is collected as part of the data to construct an objective measure of weather shocks using the Standardized Precipitation Index (SPI). The SPI has been used to measure weather shocks such as floods and droughts and is found to perform well at even predicting these events (Beguería, Vicente-Serrano, Reig, & Latorre, 2014; Livada & Assimakopoulos, 2007; Wu, Svoboda, Hayes, Wilhite, & Wen, 2007).

The second data we make use of to fully understand the relationship between dietary diversity and forest use is data that gives us a measure of the size and quality of the forest. For this, we turn to a famous dataset on global forest cover that is accessible for Malawi at the traditional authority (TA) level (Hansen et al., 2013), which is equivalent roughly to an enumeration area used for sampling purposes in the livelihoods data. The forest data has time-varying variables on forest loss in hectares for different forest categories that are based on canopy cover. It also has the size of the forest at the TA level for 2010, which is time-invariant for the period under study. From the forest data, we construct a new variable to measure forest quality and pressure. It is calculated by dividing the 50% canopy cover forest size in hectares by the 10% canopy cover forest size in hectares (g50/g10 in table 1) and dividing this by the population of each TA, this gives a measure of the potential people depending on a given forest, measured by canopy cover. The forest data is merged with the livelihoods data using the TAs that are available in both datasets.

Primary variables that are time-varying are summarized in table 1 for each year. There are some missing variables data, hence the differences in the number of observations for some variables.

Table 1: Summary of time-varying variables used in regressions

Year	2010		2013		2016	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
10 % canopy cover forest (g10) in hectares	33292.78	29822.57	33286.14	29562.09	33292.78	29822.57
50% canopy cover forest (g50) in hectares)	1605.451	4480.276	1603.304	4424.322	1605.451	4480.276
Dietary diversity	7.947507	1.697358	8.067028	1.592744	7.713255	1.764108
Family size	4.841864	2.264646	5.173324	2.2685	5.219816	2.330162
Labor to agriculture (hrs/week)	17.11122	29.43379	18.4107	31.20884	10.71686	18.80531
Fuel labor	10.09711	8.766293	8.066486	7.571236	9.357218	8.029168
Shocks (0/1)	0.108924	0.311646	0.101557	0.302167	0.136483	0.343413
Real income (MWK)	8398.853	41113.55	11532.85	34275.71	9783.669	27555.66
Labor to CPR (proxy)	0.451217	0.615376	0.46381	0.434904	0.427834	0.477963

Notes: Weather shock is measured using the standardized precipitation index. Forest loss is the loss of any type of forest in hectares.

Our main variable (dependent) is dietary diversity and the distribution is plotted in figure 2.

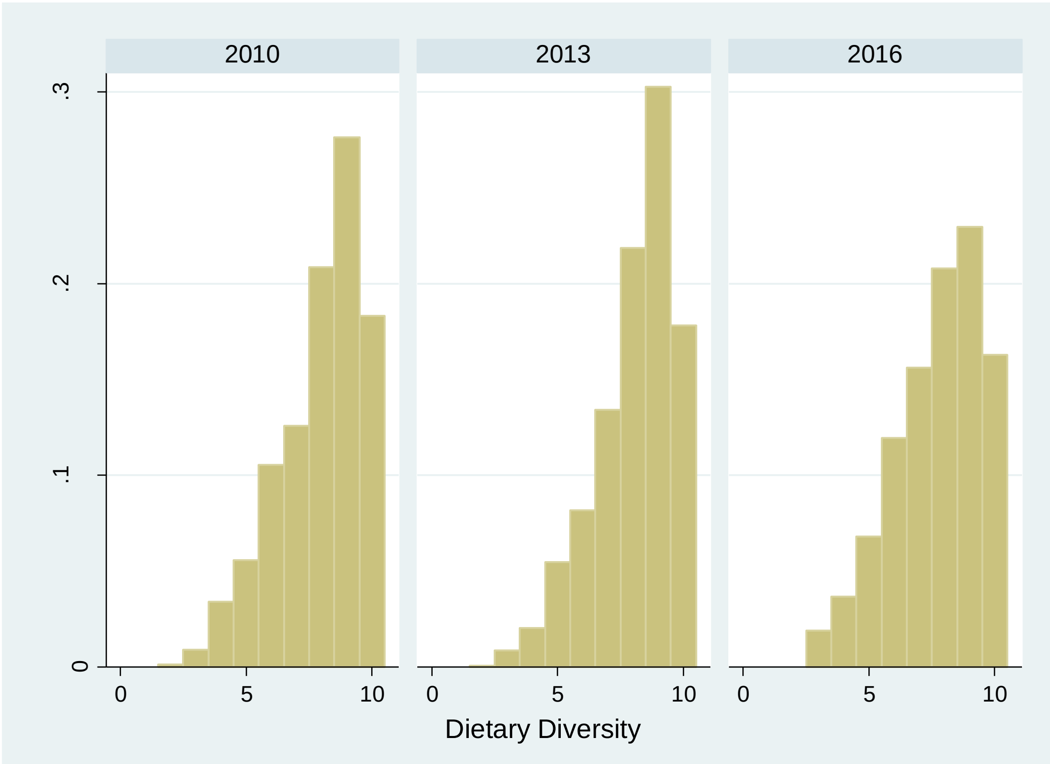

Figure 2: Distribution of dietary diversity

5. Empirical Specifications

In this section, we describe the econometric models used to explore the use of common property forests as protection against declines in nutrition. First, we identify the effect of weather shocks on the use of common property forests. Then, we test if forest access mitigates drops in nutrition outcome. Finally, we examine the importance of forest quality.

5.1 Weather Shocks and Use of Common Property Forests

The first estimation involves understanding how labor allocated (L_{it}) to the NTFPs and agriculture responds to weather shocks. Different NTFPs are collected primarily for health and nutrition using family labor. We estimate equation (1)

$$L_{it}^{\ j} = \alpha_i + \beta_0 S_{vt} + \beta_1 x_{it} + \gamma_t + \varepsilon_{it} \qquad (1)$$

j is sector (CPR or agriculture), α_i is a household FE, S_{vt} is the village level shock, x_{it} are household controls, γ_t is a year FE, ε_{it} is idiosyncratic shock.

Labor allocation to agriculture is measured in hours, while labor allocation to CPRs is measured as value of output from CPR collection. Using value of output proxy for CPR labor assumes constant output per unit labor. Further, any difference in labor productivity from CPR collection that are household specific and do not change overtime are taken into account by the FE specification. The dentification assumption for this model is; conditional on household FE that controls for weather distribution, year FE that control for market prices, intra-year changes in policy, a draw of the weather is exogenous so that if a shock is experienced, it is exogenous to the household.

5.2 Weather Shocks, Forest Access, and Nutrition

In the second estimation, we answer if forests, and having access to them, can help buffer the effect of shocks on nutrition, measured both as dietary diversity. Dietary diversity is measured using the household dietary diversity score (HDDS), obtained from a 1-week recall of the foods eaten by the household. HDDS is not only positively correlated with children's nutritional status, but also a significant predictor (Arimond & Ruel, 2004; Kennedy, Pedro, Seghieri, Nantel, & Brouwer, 2007). Therefore, when evaluating outcomes at the household level, it can be used as a proxy for children' nutritional status. Therefore, equation (12) is estimated as a poisson regression to understand the nutrition protection (natural insurance) role of having access to forests in times of shocks.

$$E[H_{ivt}] = e^{\beta_0 + \beta_1 (Acc)_v S_{ivt}{}^j + \beta_2 S^j{}_{vt} + \beta_k Z_{ivt} + D_i + T_t} \qquad (2)$$

Access ($(Acc)_v$) is defined at the village level using the community level questionnaire that asks the community if they have access to a communal forest resource. Because access at the community level does not change over time, it is not included as an independent explanatory variable with a fixed effects specification. It is rather taken up by the fixed effects. Community-level access instead of household use is used as an identification strategy (explained further on estimation issues). H_{ivt} is the household dietary diversity score. This is a formal test of hypothesis 2. Z_{ivt} are the household controls.

One potential problem relates to the estimation of equation (2). Dietary diversity, which is the dependent variable, might be correlated with forest use, while forest dependency means low income and hence poor diets. If forest use is included as the explanatory variable, there is potential endogeneity (in the sense of reverse causality) as people who use the forest more might be poor to start with. The second issue has to do with the fact the questions relating to forest use in the survey do not exhaust the list of possible products the household could extract from the forest. For example, summary statistics show that less 50% of the household use the forest, far below what most studies find in Malawi (Brouwer, Hoorweg, & Van Liere, 1997; Fisher et al., 2010; Kamanga, Vedeld, & Sjaastad, 2009; Smith et al., 2017; Zulu, 2010). If use was measured as a continuous variable, the first solution would be the use of instrumental variables. However, since it is nonlinear and so is the outcome variable (HDDS), this approach is not feasible (J. M. Wooldridge, 2010, 2018). Instead, we study the impact of exogenous ‘access,’ akin to studies like (Sekhri, 2013; Swaminathan, Salcedo Du Bois, & Findeis, 2010) .

We take advantage of the community-level focus group discussions data collected together with the household surveys. The data has community-level questions asking the community members and leaders if they have access to a community common pool resource such as a forest. We use this to define access, as the presence of a forest or not in the community is exogenous and will not be influenced by income, at least in the medium-term where depletion of a whole forest is not conceivable

So, conditioned on the household fixed effects to account for any heterogeneity, year fixed effects for any changes in prices or other shocks not captured by weather shocks, and exogenous variation in shocks at the household, we further assume that there is no self-selection into villages with and without access to CPRs, then β_1 is identified. Our assumption that households do no deliberately sort themselves into living in communities with access or without is important and is supported by literature and reality on the ground. This means access to the forest must be exogenous at the household level. If it were not true, it would mean only those in need of using the forest, mostly poor in this case, would move to live in areas with access. However, given the land ownership pattern in Malawi, this threat is not valid. The most common land tenure system is communal, and the land markets are almost non-existent(Kaarhus, 2010; Place & Otsuka, 1997), this means that any migration from one traditional authority to the other is rare (Potts, 2006). In her analysis of inter-rural migration, Peters (2001) notes that it is extremely difficult for people to move to another chiefdom and "beg" for land. Land is inherited along matrilineal or patrilineal lines and for one to leave their family land, it is usually after the rupture of a family and "a rupture always occurs through increasingly bitter quarrels, often including accusations of witchcraft." (Peters, 2002: 158).

5.3 Weather Shocks, Forest Quality, and Nutrition

To test for the if less degraded forests offer better protection compared to less degraded forests, we re-estimate equation (2) but include forest quality as variable.

$$E[H_{ivt}] = e^{\beta_0 + \beta_1^a Q_v (Acc)_v S_{ivt}^j + \beta_2 (Acc)_v S_{ivt}^j + \beta_3 S^j_{vt} + \beta_k Z_{ivt} + D_i + T_t} \tag{3}$$

All variables remain as before, but now Q_v is the quality of the forest. Because quality of the forest is time-invariant, we estimate the equation (3) by splitting the sample for poor quality forests and better-quality forests. More labor will be allocated to better quality forests, implying they offer more protection as the individual allocates more labor when there is a shock. This means better quality forests may offer more protection compared to poor quality forests. Not only through allocating more labor, but through the productivity of labor as well. The identification strategy as outline above still applies, but in addition, we assume that households do not sort themselves into living near forests of different quality. Further, that the impact of local communities allocating labor for collection of NTFPs has little impact on forest depletion (Gbetnkom, 2009; Sassen, Sheil, & Giller, 2015). Rather, the extraction of timber is the one associated more with forest depletion and hence forest quality. Timber processing companies are hardly owned by locals and therefore their exploitation of these forests is not a local decision if the forest is exploited (Gbetnkom, 2009; Meilby et al., 2014). In contrast, most forests (mosaic land cover) in Malawi had actually a net gain except for the expansion of urban areas that resulted in an overall net forest loss of just 5 % between 1970 and 2010 (Bone, Parks, Hudson, Tsirinzeni, & Willcock, 2017).

6. Results

In this section, we present the results of our hypothesis tests. Results to test if indeed there is increased labor allocation to the CPR and reduced labor allocation to agriculture are presented first. Then, we test the nutrition-protection role of forest by using access as proxy for use. Lastly, we show that better quality forests offer more protection compared to poor quality forests. In most of the results, we test if access to forests is able to offset the negative impact of the shock.

6.1 Weather Shocks and Use of the Forest

We begin with formal tests of hypothesis 1 and move on to answer other questions that are relevant to forest conservation and livelihoods. In table 2 are presented the results of the test for proposition 1

Table 2: Labor allocation to CPRs and agriculture as a response to weather shocks

VARIABLES	(1) Labor to agric	(2) Labor to CPR	(3) Labor to agric	(4) Labor to CPR
Weather shock	-5.25321**	0.06189**	-6.07984**	0.06404**
	(2.56020)	(0.02478)	(2.59509)	(0.02540)
HH controls	NO	NO	YES	YES
Individual FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Constant	17.70522***	0.31708***	-6.79291**	0.16868***
	(0.69155)	(0.00669)	(3.00868)	(0.02945)
Observations	4,525	4,525	4,432	4,432
R-squared	0.02834	0.0062	0.08190	0.01367
Number of id	1,524	1,524	1,524	1,524

Standard errors in parentheses
*** p<0.01
** p<0.05
* p<0.1
Model (1) and (3) is labor allocation to agriculture with hours allocated as the dependent variable, model (2) and (4) is labor allocation to CPR with hours allocated proxied by log of value of NTFPs collected. (3) and (4) include family size, average family age, and distance to road as household controls.

From table 2, we see that in the presence of a shock, there is an increase in labor allocated o the CPR by 6%. Hours of labor allocated to agriculture would reduce by between 5.2-6 hours per week in the event of a weather shock. These results hold even when we control for some time-varying household characteristics as a way of capturing any confounders not captured by the FE which assume time-invariant heterogeneity. These findings generally confirm the prediction of hypothesis 1 that labor to CPR would increase while labor allocated to agriculture would reduce. So, based on these results, the conclusion that labor allocated to agriculture reduces while that to CPR increases is consistent with the findings of other studies (Belayneh, 2017; Rose, 2001).

6.2 Weather Shocks, Forest Access, and Nutrition

Now that we understand there is increased labor allocation to the CPR, which makes it act as natural insurance, the second question we investigate relates to if CPRs can offer protection for nutrition. Forests, when used for extraction of NTFPs, mostly provide food that is rich in its diversity and nutrients (Fentahun & Hager, 2009; Wunder, Angelsen, & Belcher, 2014) reflecting the diversity of forests (Bone et al., 2017; Johnson, Jacob, & Brown, 2013). We begin the analysis with a whole-sample model, then we split the sample into at the median of wealth (measured by assets) and estimate for 'poor' households and for 'rich households'.

Results in table 3 indicate that if there is a weather shock, nutrition of the households as measure by HDDS becomes worse, and this is higher poor households compared to rich household using the linear model to compare. In both the whole sample and the sub-samples, we find that having access to a forest is able to protect against the effect of the shock. While weather shocks reduce HDDS by about 6 %, those with access to a CPR or forest in the event of a shock have a better HDDS by about 8%. This protection seems to better for the poor (descriptively) as they are better off by 13% compared to their poor counterparts without access, while for the rich they are only better off by 7%.

However, the protection offered by access to the CPRs is not enough to completely offset the effect of the shock on dietary diversity. For all regression, we fail to reject the null hypothesis that $|\beta_2| = |\beta_3|$. This means that the two coefficients cannot be differentiated in magnitude. So, while access to CPR offers some protection against shock, the protection is not enough to completely offset the negative effects of the shock.

Table 3: Nutrition (dietary diversity) protection role of forests

VARIABLES	(1) Whole sample	(2) Poor households	(3) Rich households
Weather shock	-0.05786***	-0.10416***	-0.03825*
	(0.01796)	(0.02620)	(0.02061)
[Weather shock]X[CPR Access]	0.08064***	0.13802***	0.06577*
	(0.02885)	(0.04974)	(0.03421)
Individual FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	4,525	1,904	1,919
Number of id	1,524	751	759
LR stat	69.98	43.20	19.78
Prob>chi2	0	9.41e-09	0.000553
Log-likelihood	-5394	-2034	-2065
Test of equality int he magnitude of coefficient on weather shock and on shock by access			
estimate	0.0228	0.0339	0.0275
standard error	0.0218	0.0418	0.0265
t statistic	1.044	0.810	1.039
p-value	0.296	0.418	0.299

Robust standard errors in parentheses
*** p<0.01
** p<0.05
* p<0.1
Dependent variable is dietary diversity

Even with the rich diversity of primary forests in Malawi (Bone et al., 2017), they can only partly improve dietary diversity in the event of a shock. Forests mostly offer access vitamins and micronutrients and less access to macronutrients such as calories and proteins (except for some seasonal insects) (Ambrose-Oji, 2003; Powell, Maundu, Kuhnlein, & Johns, 2013).

In table 4, we estimate if shocks, as suggested in literature, lead to selling of assets as a coping mechanism and if access to forests is able to protect the assets. We find that in the event of a shock, there is value of assets decrease by about 0.4% while access to a CPR given that there is a shock is able to protect the assets—their value goes up by 0.6%, even though it is not enough offset the effect of the shock as indicated by the coefficient tests.

Table 4: Does access to CPR reduce reliance on selling off assets

VARIABLES	Coefficient
Weather shock	-0.41279*
	(0.24937)
[Weather shock]X[CPR Access]	0.66545**
	(0.29489)
Constant	8.96650***
	(0.01644)
Observations	4,091
R-squared	0.00203
Number of id	1,510
Test of equality int he magnitude of coefficient on weather shock and on shock by access	
estimate	0.253
standard error	0.157
t statistic	1.605
p-val	0.109

Robust standard errors in parentheses
*** p<0.01
** p<0.05
* p<0.1

6.3 *Weather Shocks, Forest Quality, and Nutrition*

To test hypothesis 2 that forest of better quality is able to protect against the negative impact of weather better than forests of poor quality, we split the sample at the median of forest quality (R) and label those forests above the median as good quality and those below the median at poor quality. The results of the sub-samples estimation are presented in table 5. The impact of a weather shock is still negative for both households in poor quality forests and those in forests of good quality.

Table 5: Forest quality and nutrition protection

VARIABLES	(1) Poor quality forest	(2) Better quality forest
Weather shock	-0.03715*	-0.08321***
	(0.01907)	(0.02509)
[Weather shock]X[CPR Access]	0.02544	0.14615***
	(0.04116)	(0.03770)
Individual FE	YES	YES
Year FE	YES	YES
Observations	2,092	2,343
Number of id	723	797
LR stat	40.71	43.94
Prob>chi2	3.09e-08	6.61e-09
Log-likelihood	-2465	-2767
Test of equality int he magnitude of coefficient on weather shock and on shock by access		
estimate	-0.0117	0.0629
standard error	0.0358	0.0265
t statistic	-0.327	2.376
p-value	0.744	0.0175

Robust standard errors in parentheses
*** p<0.01,
** p<0.05
* p<0.1

The results offer interesting insights. As hypothesized, better quality forests are able to protect against the negative effects of weather shocks while poor quality forests are not able to. Not only are better quality able to protect against the effects of weather shock, but we find that when a household has access to better quality forests, they are able to completely offset the negative effects of weather shocks on nutrition, as indicated by the p-value for the tests of the equality of coefficients which leads to failure to reject the null hypothesis. While weather shocks reduce dietary diversity by about 8% (or 0.08 units), access to better quality forests in the event of a shock results in better dietary diversity by 14%.

6.4 Robustness Check: A Control Function Approach

The robustness of the main finding, that forest use offers protection against weather shocks, even though partial for some cases, is tested using a different identification strategy. We use a control function approach (Terza, Basu, & Rathouz, 2008; J. M. Wooldridge, 2015) and include actual forest use interacted by weather shocks. For all three years of data, we are able to observe forest use as households reported the collection of some products such as wild vegetables, wild insects, fuel, and some small wild animals. Because our suspicion is that actual forest use is endogenous, this means that even the interaction of weather shocks and forest use is also endogenous. We regress this on a set of exogenous variables including weather shocks, and household level variables (family size and real income) with their time averages and get the predicted residuals, which are included in the estimation equation to control for endogeneity of use. The results are presented in Table 7.

Table 6: Robustness check on main results

VARIABLES	Coefficient
Weather shock	-0.43130***
	(0.14774)
Weather Shock by CPR use	1.06678***
	(0.32726)
Weather shock by CPR quality	0.00203
	(0.00580)
Residuals from first stage	-1.06770***
	(0.32838)
HH controls	YES
Year FE	YES
Individual FE	YES
Observations	4,525
Number of id	1,524
LR stat	74.47
Prob>chi2	0
Log-likelihood	-5394

Robust standard errors in parentheses
*** p<0.01
** p<0.05
* p<0.1
Dependent variable is dietary diversity. The first stage estimated $[CPR_{ivt}]\bullet[S_{vt}] = S_{ivt} + Z_{ivt} + \bar{Z}_{ivt} + e_{ivt}$ and got the predicted residuals.

Even when we use a different identification strategy, we confirm the main results that shocks reduce nutrition while the use of the forest protects against this negative impact. We find no significant result on forest quality and nutrition this in this model.

Wooldridge, (2007; 2015) shows that a test of the null hypothesis that the coefficient on the residuals is equal to zero (that forest use is exogenous), is enough to show whether the variables are exogenous or endogenous. In our case, we find that indeed forest use is endogenous as we reject the null hypothesis that it is exogenous ($p<0.000$).

7. Discussion and Conclusion

In this study, we have tested three hypotheses and found interesting results. Using panel data from Malawi, an interesting case study in natural resource management given the population's dependence on natural resource (Bone et al., 2017; Zulu, 2010) is high, we find that indeed rural households reduce the labor allocation from private (agricultural) enterprises and allocate more labor to the CPR in the event of a shock. Weather shocks have negative effects on agriculture and since they reduce the productivity of agriculture, households shift away to the CPR which in most cases has products that are more resilient to weather shocks (Shackleton, 2014; Wunder et al., 2014). This labor re-allocation seems to be able to offer nutrition protection against shocks, albeit not sufficient to eliminate the nagtive effects of shocks for most. However, for forests that are of better quality, we find that they are able to offer full nutrition protection against the negative effects if shocks.

These results add to the literature on the natural insurance role of CPRs. Even though in some studies that focus on market show that CPRs are not able insure against income (Kalaba, Quinn, & Dougill, 2013; Rose, 2001) we show that they forests, especially better quality forests are able to offer protection when there is access. This presents interesting policy options on the management of CPRs. While open access may grant the maximum accessibility which is associated with use of CPRs in times of shock, management options that offer can improve biological state of the resource will result in better returns from use—offsetting the negative impacts of the shock for those with access. Rationalizing approaches that aim at balancing flexibility in access and strategic rules that ensure the resource stock or quality improves are more likely to succeed at allowing users get the maximum benefits from the resources and protect both livelihoods and resources. Safety nets like insurance programs that can reduce labor allocated to the resource when there is a shock can ultimately lead to better improved resource stock and better protection.

While our study estimated the labor response to shocks, one weakness was the lack of actual labour data on CPR exploitation. The use of value of relies on labour productivity being constant. Future research that has actual labor data and range of products collected could investigate in detail if some forests are better suited for one type of use e.g. some forests offer more nutrition protection while others are better suited for timber. This could reduce the blanket recommendation made in this study on the use of forests. Overall, we show that indeed forests remain a major part of the rural people's livelihoods and if well managed, they have the ability to be used to improve lives of the rural poor.

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