DOES INSURANCE IMPROVE RESILIENCE?

MEASURING THE IMPACT OF INDEX-BASED LIVESTOCK INSURANCE ON DEVELOPMENT RESILIENCE IN NORTHERN KENYA[*]

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ABSTRACT: Weather shocks, such as drought, have catastrophic impacts on vulnerable populations in arid and semi-arid pastoral regions of Sub-Saharan Africa. In the past decade, several countries have considered index insurance as a promising approach to help households manage weather risk and cope with catastrophic shocks. Taking advantage of a quasi-experimental, multi-round, household panel dataset, this paper evaluates the impact of an index-based livestock insurance product in Northern Kenya on development resilience in terms of both household herd size, the primary productive asset in the region, and child health. Given the hundreds of millions of dollars currently being spent on "building the resilience" of vulnerable populations in developing countries, this paper—the first causal impact assessment of a project on empirically measured resilience—demonstrates how researchers may go about assessing the resilience-building impacts of those projects. We find that index-based livestock insurance increases the household resilience to drought in terms of household livestock holdings. Insurance is also associated will substantially higher nutritional resilience in the children of drought-affected households.

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I. INTRODUCTION

Northern Kenya is one of the poorest regions of the world. The primary livelihood in the region is nomadic pastorialism, although some households have become sedentarized in recent decades, meaning that while they still may rely on animal husbandry for their livelihoods, they no longer migrate with their herds. These pastoral and agro-pastoral households are incredibly vulnerable to weather shocks, particularly drought. Yet, as is common in remote rural communities in developing countries, formal insurance and credit markets are highly imperfect in northern Kenya. As a result, households must employ a variety of *ex ante* risk mitigation and *ex post* risk coping strategies, including excess livestock accumulation and sales, asset smoothing, and informal borrowing. In the most extreme cases, these multiple financial market failures create poverty traps (Barrett & Carter 2013).

Recurrent droughts and humanitarian appeals in the Horn of Africa have propelled calls for resilience building and other interventions to help pastoral communities manage drought risk and cope with shocks without falling into poverty traps or relying on increasingly scarce humanitarian assistance. One such intervention, an index-based livestock insurance (IBLI), was commercially piloted in Northern Kenya in 2009. The multi-year project was introduced to help vulnerable pastoral and agro-pastoral populations manage drought risk by allowing them to insure their livestock against drought. Given that pastoralism is the predominate livelihood strategy in the region, livestock was the natural asset to insure.

In this paper, we implement the empirical strategy for estimating development resilience proposed by Cissé & Barrett (2016) in order to evaluate the impact of IBLI on participant resilience in terms of herd size and child health. If a household has a high probability of achieving or maintaining satisfactory well-being with regards to those measures, it is considered resilient. As the first (as far as we are aware) paper evaluating the causal impacts of an insurance program on empirically-measured resilience, this paper contributes to two nascent literatures. First, we contribute to the resilience measurement literature, demonstrating that resilience estimation can and should have an important role in evaluating the well-being of vulnerable populations. Secondly, we contribute to the index insurance literature by documenting the causal impacts of an index insurance product on well-being and resilience in a developing country.

We begin by identifying household- and child-level conditional distributions of well-being. We predict household and child development resilience by evaluating the probability, based on their individual distributions, that a household or child will achieve a satisfactory level of well-being based on specific, normative thresholds. We then evaluate the impact of insurance on resilience (probabilities) and explore how changing the normative well-being thresholds affect the impacts of the index insurance product.

We find that, for a well-being threshold of just over two animals per capita, holding an IBLI contract in the previous season increases a household's resilience in terms of livestock holdings, regardless of whether a drought occurred. The impact of insurance on resilience is significantly greater, however, during droughts. For large herd sizes of over five animals per capita, we find that having insurance during a drought increases the probability that a household will achieve the threshold by a statistically significant fifteen percentage points. We also find that IBLI is positively associated with child health resilience during droughts, increasingly the probability that a child will be well-nourished by four percentage points. There appears to be no relationship between insurance holdings and probabilities of subsequently becoming severely acutely malnourished in non-drought years.

The paper is organized as follows: section II provides a brief background on the extant pastoralist risk and insurance literatures in development economics. Section III describes the context and presents information on the IBLI project. Section IV overviews the Cissé & Barrett (2016) empirical approach for development resilience estimation. Section V empirically evaluates the impact of index insurance in terms of development resilience and presents results. Section VI concludes.

II. RISK, INSURANCE, AND RESILIENCE

Pastoral Livelihoods and Risk

Although different pastoral strategies are practiced by the various pastoral ethnic groups (Fratkin 1986) in Africa's arid and semi-arid lands (ASALs), African pastoralists are generally considered to be among the poorest and most-vulnerable populations in the world (Rass 2006). Many pastoralist households in Northern Kenya earn most or all of their income from their livestock. Unfortunately, these households, who have few other livelihood options, are incredibly vulnerable to weather shocks, such as drought, which can decimate animal populations (Chantarat et al. 2013). As such, households rationally accumulate large herds, as income increases in herd size and large herds serve as self-insurance in the face of shock (McPeak 2005). This phenomenon is not unique to Sub-Saharan Africa; for example, there is evidence of path dynamics in reindeer herd size and protective herd accumulation practices in Norway (Næss & Bårdsen 2010).

Herd stocks are commonly aggregated in terms of tropical livestock units, allowing researchers to compare aggregate livestock holdings across a variety of species. One tropical livestock unit (TLU) is equivalent to one cow, 0.7 camel, ten sheep, or ten goats. Although estimates differ, there is substantial evidence of asset thresholds and asset-based poverty traps among pastoral households in Northern Kenya and Ethiopia, with five to six animals or TLU per capita needed to sustain subsistence pastoral households in Northern Kenya (Pratt & Gwynne 1977; Barrett et al. 2006). The estimates in neighboring Ethiopia are a bit lower, ranging anywhere from one to five TLU per person (Coppock 1994), although more recent work in Southern Ethiopia finds evidence for the existence of at least two stable dynamic equilibria, with an unstable equilibrium between 10 and 15 animals (about two TLU per capita), above which households are able to engage in extensive pastoralism (Lybbert et al. 2004).

Given the potential impact of drought on herd size and the presence of poverty trap thresholds, some argue there is a need for safety net programs that protect livestock assets above the critical threshold level to prevent households from falling into a low equilibrium poverty trap (Barrett et al. 2006). In the absence of such programs, dramatic decreases in livestock herd size as a result of severe shocks prevents pastoralists from maintaining nomadic or semi-nomadic livelihoods, pushing households towards sedentarization (McPeak & Barrett 2001). Unfortunately, sedentary households who have lost the productive assets necessary for pastoral production are general considered the most vulnerable in the region, and face increased competition for unskilled or low-cost non-pastoral livelihoods (Little et al. 2008). Perhaps of even greater concern, child anthropometric measures from Northern Kenya demonstrate that children in nomadic pastoral communities are much healthier than those in sedentarized communities (Fratkin, Roth, & Nathan 2004). Other research shows that children from sedentary households are much more likely to suffer from malnutrition during dry years, as nomadic children are able to consume more milk than their sedentary counterparts are, even during drought (Nathan, Fratkin, & Roth 1996).

Resilience

Soon after much of the empirical work discussed above was completed, the Horn of Africa suffered the worst drought in sixty years, causing famine in the most politically and geographically isolated regions (Maxwell & Fitzpatrick 2012). The 2011 drought was followed soon after by drought and famine in the Sahel in 2012. Citing projections showing continued need for humanitarian intervention in these vulnerable regions in the future, exacerbated by shocks of increasing frequency and severity, the United States Agency for International Development (USAID) launched guidance in 2012 aimed at "Building Resilience to Recurrent Crisis" (USAID 2013). USAID and other humanitarian actors quickly called for the need to bridge the humanitarian-development divide by implementing projects that would reduce drought risk and increase the resilience of families living in the Sahel and the Horn of Africa (Hillier & Dempsey 2012). Since then, hundreds of millions of dollars have been spent on resilience building initiatives in the two regions. Given this focus on resilience, it makes sense to evaluate potential safety net programs, including index insurance interventions, through a resilience lens, as we will describe below.

Risk Management, Coping, and Insurance

Despite the cyclical nature of droughts and crisis in the ASALs, households in Northern Kenya have similar risk mitigation and coping strategies available to them as in other part of the continent. Those with access to credit and/or insurance may employ intertemporal risk sharing in order to smooth consumption and investments (Besley 1995) while avoiding asset-based poverty traps (Carter & Barrett 2006). While actuarially-fair, formal insurance is often the preferred risk-management mechanism in the absence of market failures, most poor, rural households do not have access to formal insurance (Skees & Barnett 2006; Barnett, Barrett, and Skees 2008). Insurance- and credit-constrained households in developing countries have developed a variety of second-best insurance strategies, including informal borrowing, selling off assets, and risk-averse production decisions (Morduch 1994). Some of these risk mitigation strategies—such as on-farm diversification, on- and off-farm production, migration—can be considered *ex ante* risk management while others—borrowing, saving, selling off assets, etc.—are primarily concerned with *ex post* risk coping (Alderman & Paxson 1992). Insurance, therefore, can be expected to impact behavior both 1) in response to shock and 2) via *ex ante* production and investment decisions (Mobarak & Rosenzweig 2012; Janzen & Carter 2013; Karlan et al. 2014).

Although there is evidence from other countries in Sub-Saharan African that asset sales in response drought (a covariate shock) do appear to temper the impacts of shock for some households and in some situations (Hoddinott 2006), asset sales generally provide more protection against idiosyncratic shocks, as increased supply in times of covariate shock will likely decrease the asset price (Morduch 1994), In fact, droughts in the area of study in Northern Kenya have been found to decrease the price of female camels, cattle, goats, and sheep by 5, 52, 17, and 34% , respectively (Barrett et al. 2003). Informal, community-based mechanisms are also more suited to insuring against idiosyncratic shocks than covariate shocks (Dercon 2002). For example, by separating non-food from food consumption, Skoufias & Quisumbing (2005) show that idiosyncratic income shocks are correlated with non-food consumption in Ethiopia, but that food consumption is partially shielded from these shocks, which they presume to be the result of informal food consumption insurance mechanisms.

On the other hand, even relatively mild covariate shocks may have permanent impacts, particularly for poorer households (Hoddinott 2006). Index insurance is one mechanism that has been proposed to deal with covariate weather-related risk in poor, primarily agricultural communities (Barnett & Mahul 2007; Chantarat et al. 2007). Index insurance works by insuring households or individuals against bad weather, as opposed to insuring them against particular outcomes. Weather can be monitored remotely by satellite, reducing the cost substantially compared to traditional insurance (Mude et al. 2009). These index-based risk transfer products, as they are also known, may allow households to avoid poverty traps by correcting a critical market failure (Barnett, Barrett, and Skees 2008).

Although index insurance has many supporters, some have pointed out the potential weaknesses of index-based insurance products. Households already caught in poverty may not be able to benefit from un-subsidized insurance (Kovacevic & Pflug 2011). In addition to the cost to insure, the main limitation of index insurance is basis risk, *i.e.*, that some shock-affected households may not receive an indemnity or that non-affected households may receive a payout (Barnett, Barrett, and Skees 2008; Jensen, Barrett, & Mude 2016). However, informal insurance mechanisms can help share the burden of basis risk where they exist (Mobarak & Rosenzweig 2012). Nonetheless, among pastoral communities in Southern Ethiopia, Lybbert et al. (2004) find that household-specific idiosyncratic shocks and characteristics account for more variability in well-being dynamics than do covariate shocks, which calls into questions the appropriateness of weather-based index insurance.

III. CONTEXT AND PROJECT BACKGROUND

Despite the limitations of index insurance mentioned above, an index-based livestock insurance (IBLI) product was commercially piloted in Northern Kenya beginning in January 2010 in order to help pastoral and agro-pastoral populations manage drought-related livestock mortality. IBLI aims to protect against catastrophic livestock mortality by allowing households to insure their most important assets against shock (Mude et al. 2009).

This paper evaluates the impact of IBLI on the development resilience of households in the project implementation zone. We provide the technical definition of resilience in the next section but, in general, we define resilience as the probability that a household will achieve a satisfactory level of well-being in a particular period (following Barrett & Constas (2014)). We are therefore interested in evaluating how holding an IBLI contract increases (or not) households' probabilities of achieving well-being above a particular threshold (e.g., poverty line).

Some previous work has studied the impact of IBLI on well-being. Janzen & Carter (2013) examine how insured households anticipate reducing coping behaviors during a drought. They explore how these expected behavioral responses may differ around a critical livestock asset threshold. Other impact assessments find positive impacts of IBLI on material well-being—particularly in terms of reduced risk exposure through reductions in herd size and investments in herd health (Jensen, Barrett, & Mude 2015; Jensen, Ikegami, & Mude 2015)—and on subjective well-being (Tafere et al. 2015).

The IBLI project was implemented in Northern Kenya, in the semi-arid county of Marsabit (see Figure 1). According to the 2005-2006 Kenya Integrated Household Budget Survey, Marsabit is the second-poorest district in Kenya, with a poverty rate[3] of 91.7% (Kenya National Bureau of Statistics, National Data Archive). Marsabit is a large county that borders Ethiopia to the north and Lake Turkana to the west. The county contains six administrative divisions, all of which were targeted by the program: Central, Gadamoji, Laisamis, Loiyangalani, Maikona, and North Horr.

Beginning in 2009, five annual rounds[4] of the survey were administered in Marsabit, covering the period before the introduction of IBLI and four subsequent periods, including an indemnity payout period. In general, insurance contracts are offered for sale prior to each rainy season (two sales periods per year) and each contract lasts for a full year. IBLI payouts are based on a statistical model that identifies the relationship between the normalized difference vegetation index (NDVI) and livestock mortality. NDVI is a satellite-derived measure of vegetative greenness, which is correlated with rainfall and pasture conditions. When the NDVI falls below a certain pre-determined threshold, catastrophic livestock mortality is predicted and insurance holders receive an indemnity payout. The IBLI project piloted a 15 percent strike contract, meaning that when the statistical model predicted that livestock mortality would surpass 15%, the insurance product would pay out (Chantarat et al. 2013). Given that only predicted covariate risk can be insured through IBLI, idiosyncratic risk remains formally uninsured.

Figure 2 illustrates the timing between the seasons, survey collection rounds, insurance contract coverage, and weather shock. Each survey round covers two climactic seasons, the short-rainy-short-dry (SRSD) season and the long-rainy-long-dry season (LRLD). Although the survey was administered after each LRLD season, the enumerators asked respondents to recall livestock sales, deaths, births, etc. that occurred during the SRSD season, allowing us to construct ten seasons of livestock holdings over the five year period. IBLI insurance sales occur in the two months prior to the contract periods shown in the figure. Note that while IBLI sales occurred prior to both the LRLD and SRSD seasons, each contract lasts for a full year, insuring the purchaser through both upcoming seasons. A total of five contract periods are evaluated here.

The baseline survey was conducted in October and November 2009, prior to the first round of IBLI sales. Additional survey rounds were conducted in October and November of subsequent years. A catastrophic drought occurred in 2011 when the predicted livestock mortality (PLM) index surpassed the 15% threshold and triggered indemnity payments for Contracts 2 (in all six divisions) and 3 (only in select divisions).

Insurance uptake was encouraged through the use of premium discount coupons, which were randomly provided to 60% of the surveyed households. Among those households that received a coupon in a given round, the coupon amount varied randomly, with approximately equal numbers of households receiving coupons for 10%, 20%, 30%, 40%, 50%, and 60% off the IBLI insurance premium amounts for the first 15 TLU insured. Households were re-randomized in each sales period (meaning that prior coupon receipt had no impact of the probability of receiving a coupon in any given period), ensuring within-household random variation in

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[3] Bbased on the rural Kenya poverty line of 1,562 Kenyan shillings per month

[4] A sixth round has recently become available, but it differs from previous rounds in a few important ways and therefore is not included in this analysis.

insurance premiums over time. Coupons were distributed during each sales period, in the two months prior to the contract sales windows listed in Figure 2. The randomization of the coupon distribution was largely achieved. For more information, see Jensen, Barrett, and Mude (2015).

IV. EMPIRICAL APPROACH TO DEVELOPMENT RESILIENCE ESTIMATION

As mentioned above, this paper evaluates the impact of IBLI on development resilience. Estimating household resilience is a multi-step process. In the first step, we employ the approach described by Cissé & Barrett (2016) to estimate household-level conditional probability density functions (pdfs) of well-being, otherwise known as the development resilience approach, in order to estimate the impact of index insurance on well-being. The benefit of this approach is that it looks beyond simple mean effects to understand the impact of a program on households' probabilities of achieving some minimum standard of well-being. These are conditional probabilities, based on the household's well-being in the previous period, allowing us to account for path dynamics of well-being.

In order to allow for nonlinear path dynamics, including S-shaped dynamics, as suggested by Barrett & Constas (2014), Cissé & Barrett (2016) model well-being (W_{it}) parametrically as a polynomial function of lagged well-being ($W_{i,t-1}$), and a series of household characteristics, including shocks and insurance coverage, $\boldsymbol{X}_{it}$:

$$(1) \qquad W_{it} = g_M(W_{i,t-1}, \boldsymbol{X_{it}}, \beta_M) + u_{Mit}.$$

The first central moment (conditional mean, or μ_{1it}) is:

$$(2) \qquad \hat{\mu}_{1it} \equiv E\left[W_{it} | W_{i,t-1}, \boldsymbol{X_{it}}\right] = g_M(W_{i,t-1}, \boldsymbol{X_{it}}, \hat{\beta}_M).$$

where E represents the expectation operator and the random error term u_{Mit} is mean zero. In the second step, we take the residuals from equation (1) and square them. The conditional variance (μ_{2it}) is thus:

$$(3) \qquad \hat{\mu}_{2it} = E[u_{Mit}^2] = \hat{\sigma}_{it}^2,$$

where $\sigma_{it}^2 = g_V(W_{i,t-1}, \boldsymbol{X_{it}}, \beta_V) + u_{Vit}$ and $E[u_{Vit}] = 0$.

Following the Barrett & Constas (2014) conceptual framework, in the third step we define development resilience (ρ) as the probability that household i will have well-being in a future period (t) above some normative threshold, $\underline{W}$. Assuming that the conditional well-being pdf for each household comes from a two parameter distribution (e.g., normal, lognormal, gamma, or Weibull), the conditional mean (μ_{1it}) and conditional variance (μ_{2it}) are sufficient to completely describe the conditional distribution and therefore the conditional probability of achieving well-being greater than $\underline{W}$. This permits us to estimate their resilience:

$$(4) \qquad \rho_{it} \equiv \Pr\left(W_{it} \geq \underline{W} | W_{i,t-1}, X_{it}\right) = \bar{\mathrm{F}}_{\mathrm{W_{it}}}\left(\underline{W}; \hat{\mu}_{1it}(W_{it}, X_{it}), \hat{\mu}_{2it}(W_{it}, X_{it})\right),$$

where $\bar{\mathrm{F}}_{\mathrm{it}}$ is the complementary cumulative distribution function. As explained by Cissé & Barrett (2016), the impact of any plausibly exogenous component of $\boldsymbol{X}$ on resilience may be estimated: $\partial\hat{\rho}_{it}/\partial X_{it}$.

$$(5) \qquad \hat{\rho}_{it} = g_R(W_{i,t-1}, \boldsymbol{X_{it}}, \beta_R) + u_{Rit}$$

Aside from demonstrating how to measure development resilience at the household level, Cissé & Barrett (2016) develop a decomposable development resilience measure similar to the class of poverty measures developed by Foster, Greer, and Thorbecke (1984). This feature allows us to attribute shares of the overall development resilience measure to various subgroups, as we demonstrate below.

V. IMPACT OF INSURANCE ON DEVELOPMENT RESILIENCE

Data

The data used in this analysis were collected by the International Livestock Research Institute (ILRI), Cornell University, University of California-Davis, and Syracuse University in collaboration with private sector insurance providers using an elaborate multi-year impact evaluation strategy (Ikegami & Sheahan 2016). The household surveys were designed to capture a wealth of household livelihood and welfare variables for survey households and include general demographic questions as well as questions regarding livestock holdings and production, risk and insurance, livelihood activities, expenditure and consumption, assets, and savings and credit. Researchers determined the number of households that would need to be surveyed in order to identify the impacts of the project, and randomly selected households from the divisions mentioned above (with the exception of North Horr) to ensure representativeness. This resulted in a final sample of 924 households that were followed over the length of the project.[5]

Table 1 provides household-level summary statistics. The first column presents the sample mean (all ten seasons pooled) for household-level covariates. All 924 households are included, but some are lost to attrition (discussed below), so there are 8,670 observations across the ten seasons. On average, households have 14.3 TLU. However, six percent of households have zero animals, so the average TLU holdings conditional on having any animals is 15.3. A histogram of TLU holdings can be found in Figure 3. The PLM index varies by division and season, with mean predicted livestock mortality at about 12%. The *contract* variable is an indicator variable taking the value of one if a household purchases any IBLI insurance during a given season. On average, one in eight households holds an insurance contract in a given season. Household can insure any number of animals, but the average number of TLU insured is about 0.6, however conditional on purchasing insurance the average number of TLU insured is nearly five TLU. The treatment indicator takes a value of one if a household receives a coupon to purchase insurance in a given season. On average across the ten seasons, the treatment rate is just under 50% (this includes two baseline seasons when no coupons were distributed).

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[5] Details on the sample household selection methodology are available in Ikegami & Sheahan (2016).

The remaining summary statistics provide information on household characteristics. Over a third of households are headed by women. The dependency ratio[6] is just about two, meaning the average household has twice as many dependents as able-bodied adults of working age. Household heads have very little formal education (about one year). Over a third of households are fully settled, although some of these may be formerly nomadic or partially-nomadic. Given the reliance on animal products in the region and the poor conditions for agricultural production, milk production is important for home consumption, sale, and consumption at satellite camps by those moving with the animals. On average, households produce about two-thirds of a liter of milk a day at the primary homestead or base camp, while production at satellite camps is about twice as much. Average weekly food consumption expenditure is nearly 5,000 Kenyan shillings (nearly $60/week), although the median is about a third of that. Information on where the households live and insure is also provided.

Since our identification strategy, discussed below, relies of the random distribution of the insurance coupons, we check to ensure balance between households that received coupons and those that did not. Panel A presents Season 1 summary statistics, broken down by future treatment. Untreated households are those who would not receive a coupon for IBLI purchases in Season 4, while treated households are those who would receive a coupon in Season 4. There is no statistically significant difference in means between treated and untreated households.

Table 1, Panel B provides summary statistics for households that appear in all rounds of the survey and those who attrit. We see a statistically significant difference between the means of the two groups in terms of dependency ratios, education, nomadism, and milk production at satellite camps. Note that while only 89% of the sample appears in all rounds, most of the "attrited" households do not drop out completely, but rather are missing for one or more rounds before reappearing in the sample. All analyses below control for the possibility of non-random attrition; see Appendix A for more information on our method.

Table 2 provides summary statistics at the child level. Data was collected during each round for all children in surveyed households under the age of five, for a total of 1,083 eligible children. Since new children are born and some children age out of the sample (or their households attrit), the same children are not present in all rounds. The first column presents sample averages for the eligible children as often as they are present (for a total of 2,358 observations). We are interested in child health, measured anthropometrically using the child's mid-upper arm circumference (MUAC). While other common child anthropometric measures such as weight-for-height and height-for-age are relevant, these measures are more prone to measurement error. In community-based management of malnutrition, children (aged 6 – 59 months) are generally at risk for acute malnutrition when their MUAC falls below 13.5 cm. The sample mean MUAC is 14.4 cm, which is considered well-nourished. Figure 4 presents a histogram of MUAC, which is relatively normally distributed, if a bit peaked towards the mean. Just under half of the children are girls. Most of the sample means are close to the household-level means presented in Table 1, although the dependency ratio is slightly higher in the child sample (not surprisingly). Milk production at both the homestead and satellite camp is higher in the child sample.

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[6] The dependency ratio gives a sense of how many individuals are being cared for by the family. In this case, the dependency ratio equals the number of children under 18, plus seniors over 55 and disabled or chronically ill household members, divided by the number of able-bodied adults (between the ages of 18 and 55) in the household.

Panel A compares pooled summary statistics for children in untreated and treated households in any given round. This is not a balance test since randomization was not at the child level and because some of the covariates may be impacted by the treatment. In fact, we do see that MUAC is higher for children in treated households. The means for consumption and milk production at the base camp are also statistically significantly higher among children in treated households, although milk production at the satellite camp and TLU holdings overall are lower. There are also some differences in terms of where the household lives and insures. Panel B presents the means for children that are present in each round for which they are eligible (as long as their family did not attrit) and for "missing" children, or children that are not surveyed, despite being eligible and their family not attriting. Thankfully, according to survey results none of the children are missing due to death nor have they been sent away to live with their biological parents. We see that children from female headed households are more likely to be missing, as are children from settled households. The mean weekly food expenditure is much higher in households from which children are subsequently missing. There is also a geographical component to missingness. Panel B demonstrates that missing children are not missing at random. We therefore correct survey weights to control for this missingness, as discussed in Appendix A.

IBLI and Mean Well-being

Households in the IBLI program area decide whether or not to purchase the product, as well as how many animals to insure. As mentioned above, should the predicted livestock mortality index surpass contractual 0.15 strike point, the insurance holder receives a payout. In order to evaluate the impact of insurance on mean well-being, we estimate a nonlinear polynomial parametric regression model of stochastic well-being, W, for household i $(i = 1, \dots, N)$ in season s $(t = 1, \dots, S)$:

$$(6) \qquad W_{is} = g_M\big(\beta_M W_{i,s-1}, \delta_{M1} PLM_{s-1}, \delta_{M2} I_{s-1}, \delta_{M3}(D_{s-1} * I_{s-1}), \boldsymbol{\delta_{M4} H_{is}}\big) + u_{Mis}.$$

Suppressing household subscripts for now, the regression model describes current well-being as a possibly nonlinear function of lagged well-being (W_{s-1}) and a series of explanatory variables, including previous season predicted livestock mortality (PLM_{t-1}), an indicator for holding an IBLI contract in the previous season $(I_{s-1})^{7}$, and an interaction term indicating holding an IBLI contract in the previous season when the PLM surpassed the 0.15 strike point ($D_{s-1} * I_{s-1}$). For simplicity we shall henceforth refer to seasons in which the PLM surpasses the indemnity threshold as droughts, indicated here by the indicator variable D. Since the impact of PLM on mean well-being is potentially nonlinear, PLM_{s-1}^2 is also included in all specifications. Current season household level characteristics ($\boldsymbol{H_{is}}$) such as education and nomadic status (as described in the summary statistics) are also included. As discussed below, polynomial terms for lagged well-being are included in most specifications to capture nonlinearities, with a minimum third-order polynomial required to capture S-shaped well-being dynamics.

The βs and δs are coefficients and u_{Mit} is the household- and season-specific residual for this mean (M) estimation. The coefficients of primary interest are therefore those on the indicator for holding and IBLI contract (δ_{M2}) and for holding a contract during a drought (δ_{M3}). The

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[7] For robustness, regressions were also computer controlling instead for the number of TLU insured in the past season, interacted with the drought. These estimates are available from the author by request.

dependent well-being variables of interest (W_{it}) are household livestock holdings in TLU and child anthropometry. Using both a productive asset/wealth measure and a health measure allows us to understand how insurance impacts the two key aspects of household wealth holdings in this context: their livestock and their children. Household aggregate livestock holdings are measured in TLUs (recall 1 TLU = 1 cow, 0.7 camel, 10 sheep, or 10 goats) held by each household in each round of the survey. In Northern Kenya, TLUs (which we will also refer to as herd size) allow households to store wealth, as there is limited access to formal banking. Animal are also productive assets, providing milk for household consumption and offspring, which can be sold for cash or saved. TLU holdings in any given period is strongly associated with past period TLU holdings (correlation coefficient = 0.8700), as demonstrated by the kernel regression of lagged TLU holdings on current period holdings (Figure 5). The second dependent variable of interest is child anthropometry (measured in MUAC). We check to see if there is evidence of dynamics in MUAC. Figure 6 provides the kernel regression of lagged MUAC on MUAC, showing a positive association between the two (correlation coefficient = 0.4135).

Given that TLU are necessarily non-negative, we assume the dependent variable is distributed Poisson and estimate a generalized linear model (GLM)[8] log link regression using maximum likelihood. Table 3 presents the marginal effects at mean values of all covariates. In all specifications, we cluster standard errors at the household level and include attrition-corrected survey weights and season fixed effects. While there are important theoretical reasons why lagged dependent variables should be included in dynamic well-being models, it is necessary to test empirically whether there is evidence of path dynamics in our well-being indicators, as well as to evaluate the extent to which serial correlation may cause us to underestimate standard errors on our coefficient estimates. Column (1) provides coefficient estimates and standard errors estimated without including a lagged dependent variable on the right hand side, while column (2) includes polynomial terms up to the third-order and column (3) up to the fourth-order. The marginal effects of the lagged terms are statistically significant in both cases where they are included, and the fit in improves substantially (as evidenced by the increased pseudo R^2). The final row shows the correlation coefficient between the residuals and lagged residuals. We see incredibly strong serial correlation in column (1), but we control for serial correlation fully when the first- through fourth-order lagged terms are included in the specification.

It is not possible to include household fixed effects in a nonlinear model due to the incidental parameters problem. To avoid this issue, Table 3 columns (4) through (6) include the Mundlak (1978) cluster-level means of all covariates. We will henceforth refer to these simply as household fixed effects (FE) for the nonlinear models. Otherwise, columns (4)-(6) are identical to (1)-(3). Marginal effects for the lagged dependent variables continue to be positive and statistically significant in the FE models. Serial correlation is a problem, as evidenced by the very large correlation coefficient on the FE specification in column (4). We can almost completely correct for the serial correlation by including the polynomial lagged terms up to the fourth-order as in column (6), although the correlation coefficient is still higher than in column (3).

We retain the third specification (with up to a fourth-order lagged dependent variable, no household FE) as our preferred specification. In that specification (column (3)) we see that the

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[8] We prefer the GLM estimator over a simple log linear regression since we do not need to transform zero-valued dependent variables, of which there are many. Nor do we need to adjust predicted values to transform them from ln(TLU) to TLU.

coefficient on insurance in a non-drought season is negative, but not statistically significant. Holding an IBLI contract during a drought, however, is positively and statistically significantly associated with increased future herd size. A Wald test confirms that the two coefficients are statistically significantly different from each other ($Prob > \chi^2 = 0.0797$). Ordinary least squares (OLS) and fixed-effects (using the within regression estimator) estimates are provided in Appendix B, Table B1 for robustness. Signs and magnitudes are similar between the nonlinear and linear estimators, although serial correlation in the linear model in minimized without the fourth-order polynomial term. Many of the coefficients in the preferred nonlinear specification are statistically significant while they are not in the corresponding (Table B1, column (3)) OLS estimate.

In order to make a causal statement about the impact of IBLI on average herd size, we take advantage of the quasi-experimental design of the data to instrument for endogenous insurance uptake. As discussed above, the project randomly distributed coupons to decrease the cost of insurance to a subset of the sample. The coupons introduce the random variation needed to instrument for the endogenous decision to purchase insurance. Table 4 presents the first stage and two-stage least squares (2SLS) estimation results, including the first-, second-, and third-order lagged dependent variables found to minimize serial correlation (Appendix Table B2). There are three instrumental variables (IVs): past season coupon values when there was no drought, past season coupon values when there was a drought, and current season coupons received, which are used to instrument for current period insured TLU, which is used as a control variable. We do not instrument for lagged well-being given the correlation between TLU and its lagged values. We see that the signs in the 2SLS model are consistent with those in the nonlinear model we prefer and although the magnitudes are larger in the 2SLS specification, they are not statistically significantly different from zero. However, a Wald test confirms that the coefficients on IBLI during drought and not during drought are statistically significantly different from each other ($Prob > \chi^2 = 0.0506$).

Turning to child health, we similarly run serial correlation tests on the MUAC mean well-being regressions using Poisson MLE (Table 5) and OLS (in Appendix B, Table B2). Enumerators collected child health information annually, during each survey round. Therefore, MUAC data is only available for even seasons. We still regress MUAC on previous season PLM and insurance holdings, as in equation (6), but must proxy previous season MUAC ($W_{i,s-1}$) with previous round MUAC (i.e., $W_{i,s-2}$), which is only available for seasons 4, 6, 8, and 10. Once again, we assume the dependent variable is distributed Poisson and estimate a GLM regression with a log link using maximum likelihood. Table 5 presents the marginal effects at mean values for all covariates, using survey weights corrected as described in Appendix A and standard errors clustered at the child level. Despite the longer lag period between rounds, we continue to see evidence of path dynamics in child health. The serial correlation in the specification without lags (column (1)) is lower than we see with TLU, but still sufficiently high to be concerned about the impact on our standard errors. Including the lagged terms, however, substantially reduces the serial correlation[9]. There is no different in serial correlation between the third-order (column (2)) and up to fourth-order (column (3)) specifications, although the pseudo R^2 is slightly higher in the former specification. The marginal effect coefficients on our variables of interest in the fixed

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[9] In fact, it appears to over correct to the point that serial correlation becomes negative. The magnitude is smaller however, and negative serial correlation is less of a concern as it may cause us to overstate rather than underestimate standard errors.

effects models (columns (4) through (6)) do not change, although we lose magnitude and statistical significance on some of the time-invariant child characteristics, as we would expect. We select the specification in column (2) as the preferred nonlinear MUAC specification and note that the coefficients on the two variables of interest—the association between previous season insurance holdings and child MUAC during non-drought and drought seasons—are both negative, but small in magnitude and not statistically significantly different than zero. Nor are they statistically significantly different from each other. Appendix B, Table B2 presents the OLS and FE results. The coefficients of interest are similar in sign, magnitude, and significance. Serial correlation is a particular problem in the FE specifications.

We would like to explore the causal impact of insurance on child health, and attempt to do so using 2SLS using the same IVs discussed above. Table 6 presents the first stage regressions and 2SLS estimates of the impact of insurance on child MUAC with and without drought. While there is positive coefficient on the impact of insurance during non-drought seasons on MUAC, the coefficient on insurance during drought is negative. Neither coefficient is statistically significant, although the F statistics indicate that at least two of the IVs are incredibly weak.

The Variance of Well-being

As described in Section III, there are three steps involved in predicting households' well-being pdfs. We begin by predicting their mean well-being, using equation (6). In order to ensure that predictions are non-negative, we predict mean well-being values from our preferred nonlinear specifications discussed above (i.e., the TLU specification in Table 3 column (3) and the MUAC specification in Table 5 column (2)). Given the nonlinear nature of these estimates, we present the marginal effects at important representative values of the PLM index in the first panels of Tables 7 and 8, which we discuss below.

As described above, the second step is to predict household well-being variance. We square the residuals estimated in equation (6) and regress them on the polynomial lagged well-being terms, last season PLM, last season insurance holdings disaggregated by non-drought and drought seasons, and the same vector of household or child characteristics. Using the subscript V to indicate this is the variance equation, we estimate:

$$(7) \qquad \hat{u}_{Mis}^2 = g_V\big(\beta_V W_{i,s-1}, \delta_{V1} PLM_{s-1}, \delta_{V2} I_{s-1}, \delta_{V3}(D_{s-1} * I_{s-1}), \boldsymbol{\delta_{V4} H_{is}}\big) + u_{Vis}.$$

Variance is necessarily non-negative, so we estimate equation (7) for both the squared TLU residuals and squared MUAC residuals using Poisson MLE. The right panels of Tables 7 and 8 provide the marginal effects for variables of interest at representative values of the PLM index. Specifically, we provide marginal effects at $PLMindex = 0.039$ and $PLMindex = 0.265$, which are the sample mean PLM for non-drought and drought years, respectively. Table 7 panel (1), therefore, shows the marginal effects of various covariates during average non-drought (column (A)) and drought (column (B)) years. All other covariates are taken at their means. Recall that this is the same specification as Table 3 column (3), with marginal effects presented at specific values of the PLM index rather than at its mean. Coefficients are therefore consistent with the previously discussed analysis, although it is interesting to note that the marginal effect on mean herd size of increasing predicted livestock mortality is much greater at lower values of the index, demonstrating the importance of allowing PLM to impact herd size nonlinearly.

Panel (2) reports the marginal effects, again at two PLM index values, associated with increases in the variance or herd size. Since we previously estimated the dependent variable, report bootstrapped standard errors, clustered at the household or child level, for all variance equations. We see that holding insurance during a non-drought season is correlated with increased variance in herd size, while holding an IBLI contract during a drought is associated with a large decrease in the variance of herd size. Despite these interesting correlations, the coefficients are not statistically significant. We predict the variance of herd size for each household in each season and use this, along with the predicted mean TLU to parameterize the household's TLU well-being distribution, as discussed below.

Turning to child anthropometry in Table 8, panel (1) presents the marginal effects at the two (non-drought and drought) PLM index levels from the preferred MUAC specification (i.e. Table 5, column (2)). The association between IBLI and mean child MUAC is negative, small, and not statistically significant, regardless of drought conditions. Increased past season PLM is associated with higher MUAC, which is surprising, although the marginal effect does fall for high PLM. Panel (2) presents the variance estimates per equation (7). We see that IBLI in associated with decreases in the future variance of MUAC, both in drought and non-drought seasons, although the marginal effects are not statistically significant. The pseudo R^2 on the variance estimates is very low, meaning there is a lot of variation in the variance of child anthropometry that we do not explain.

Development Resilience Estimation

We use the household-season conditional predicted means from equation (6) and variances from equation (7) to parameterize household well-being distributions, which we assume to be distributed gamma10. As described in Section 3, we must select a well-being threshold, $\underline{W}$, for each of our well-being indicators. Given a household's well-being distribution in a particular season, the household's resilience (in that season) as the probability that the household surpasses the threshold $\underline{W}$, as in equation (4) above. So household i's TLU resilience in season s (ρ_{is}) is the area under its TLU well-being distribution beyond the threshold $\underline{W}$.

Figure 6 provides a concrete example, using a specific household from our dataset. For simplicity, we display only four rounds (rather than eight seasons). The household's TLU holdings in each round are marked with the stars. The four distributions show the household TLU well-being distribution for the given round. Naturally, the realized TLU holdings lie on each of the curves. The red vertical line marks the TLU threshold $\underline{W}^{TLU} = 14$. So for a threshold of 14 TLU, Household 5008's TLU resilience in Round 2 is the integral of their distribution beyond $\underline{W}$ (this can also be calculated using the complementary cumulative distribution function, as in equation (4)). We can see from the legend that 46% of the area under the black Round 2 curve lies to the right of $\underline{W}$, meaning $\hat{\rho}_{5008,2}^{TLU} = 0.46$. We can see that the household is affected by the drought, as their Round 3 distribution shifts to the left, causing a decrease in their TLU resilience. The household begins to recover in Round 4 and has achieved nearly complete resilience in Round 5.

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[10] For a two-parameter distribution, the gamma distribution is much more general than the normal, and is entirely non-negative.

As the figure clearly demonstrates, the resilience scores depend on the selection of $\underline{W}$. In order to identify the impact of IBLI on TLU and MUAC resilience for any given threshold, the household- and child-specific development resilience scores are regressed on the same set of regressors used in the well-beings equations, as in equation (8), below.

$$(8) \qquad \hat{\rho}_{is} = g_R\big(\beta_R W_{i,s-1}, \delta_{R1} PLM_{s-1}, \delta_{R2} I_{s-1}, \delta_{R3}(D_{s-1} * I_{s-1}), \boldsymbol{\delta_{R4} H_{is}}\big) + u_{Ris}.$$

Since the resilience scores are necessarily between zero and one, we would prefer to use a fractional response specification. Unfortunately, the estimation of binomially distributed dependent variables using maximum likelihood is currently infeasible in the presence of endogenous explanatory variables. For the TLU specification, we instead estimate the impact of IBLI on TLU resilience via 2SLS, instrumenting for endogenous past season IBLI holdings interacted with drought with past season coupon receipts interacted with drought, as discussed above. Table 9 presents that 2SLS estimates for the impacts of IBLI on TLU resilience at various values of $\underline{W}^{TLU}$. Figure 7 presents these coefficients visually. We see in Table 9 that the coefficients on IBLI holdings in non-drought seasons are smaller in magnitude than those during drought. In terms of interpretation, the -0.0497 coefficient on drought/IBLI interaction in Table 9 column (1) means that holding IBLI in the past season, a drought season, increased a household's probability of having at least two TLU by nearly 5 percentage points.

The coefficients on both variables appear to drop initially before rising and remaining above zero. Interestingly, the coefficient on holding insurance during a drought season is not statistically significant unless our threshold value $\underline{W}^{TLU} \geq 20$, above which the coefficient estimates are large and positive. As we can see clearly in Figure 7, the coefficients on both variables are maximized when the threshold is set around 30 or 31 TLU. This means that we see the largest causal impact of IBLI on TLU resilience when we consider households' probabilities of maintaining or accumulating at least 30 TLU. The 30 TLU threshold is economically meaningful, as it is the lower bound on the bifurcation point identified non-parametrically in a similar context by Barrett et al. (2006). For robustness, we provide the full regressions results for $\underline{W}^{TLU} = 14$ estimated via 2SLS and MLE Tobit[11], each with and without household FE in Appendix B, Table B4. The results are incredibly robust; the 2SLS and Tobit estimates are nearly identical.

Given the weak IV problem in the MUAC estimates, we assume MUAC resilience is distributed binomially and fit the GLM logit link regression using maximum likelihood without using any instruments. Table 10 presents the coefficients and standard errors for our two explanatory variables of interest for different values of $\underline{W}^{MUAC}$. The coefficients are plotted visually in Figure 8. Note that the various threshold values are important indicators of child health; in community-based management of severe acute malnutrition (SAM), children under five are generally admitted for treatment of SAM when their MUAC falls below 11.5 cm (Binns et al. 2014). With MUAC below 12.5 cm children are considered at risk for acute malnutrition, while above 13.5 cm child are considered well nourished.

We see that the coefficient on IBLI without drought is initially positive and significant for very low threshold levels ($\underline{W}^{MUAC} = 11.5$, column(1)), although the magnitude is very small. There appears to be no relationship between past seasons IBLI holdings and probabilities of

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[11] ivtobit in Stata, censoring at 0 and 1.

subsequently becoming severely acutely malnourished in non-drought years. As the threshold increases, the coefficient on IBLI in non-drought seasons drop precipitously. However, the coefficients on IBLI during drought are positive and statistically significant, taking their maximum coefficient value around a threshold of $\underline{W}^{MUAC} = 13.5$. This indicates that in both drought and non-drought seasons, IBLI is associated with positive (but small) increases in the probability of a child not being severally acutely malnourished the following season. Holding an IBLI contract during a drought season is associated with a nearly 4 percentage point increase in the probability of a child being well-nourished the following season, but holding an IBLI contract during a non-drought season is associated with a 2.5 percentage point decrease in the child's probability of being well-nourished the following season. For robustness, Table B5 in Appendix B provides the full binomial MLE specification, presented in panel (1) at representative values of the PLM index. Panel (2) presents the intent-to-treat impact of randomly receiving a coupon in a given season on the following season's child MUAC. While not statistically significant, the signs are consistent with those in the binomial specification.

VI. CONCLUSION

This paper evaluates the impacts of the IBLI insurance product on the development resilience of children and households in pastoral areas of Northern Kenya. Like much of the ASALs in Sub-Saharan Africa and the Horn, Marsabit County is prone to droughts. Although the climate is more suited to pastoralism than agricultural cultivation, pastoral and agro-pastoral households are nonetheless extremely vulnerable to drought. The index-based livestock insurance program was designed to "manage the [weather] risks faced by vulnerable pastoral and agro-pastoral populations and provide them with a productive safety net" (Mude et al. 2009).

The cycle of droughts and humanitarian response in this region, and in the ASALs in general, has motivated donor and governmental interest in building resilience with the goal of improving vulnerable populations' abilities to manage risk and cope with shocks and in the hopes of reducing demands for humanitarian assistance. Given the goals of the IBLI project and the focus on resilience in the region, it is appropriate to evaluate the impacts of IBLI in terms of resilience. In order to do so, we predict household distributions of well-being in terms of two highly important indicators, livestock holdings and child health. Using both linear and nonlinear methods, we assess the impact of insurance on the probability that a household or child will have a high level of well-being, that is of their resilience.

We find that holding an IBLI contract in the previous season increases a household's TLU resilience—whether a drought occurred or not—when we consider the probability of having more than 15 TLU, although the household's resilience is increased more if the previous season was a drought season. The positive impacts of past season insurance on TLU resilience are statistically significant for thresholds of 20 TLU and above. With regards to child health, we see a positive association between past season IBLI holdings and resilience during droughts. However, during non-drought season there is a negative association between insurance and future MUAC resilience for higher thresholds of child well-being. There appears to be no relationship between past season's IBLI holdings and probabilities of subsequently becoming severely acutely malnourished in non-drought years.

There are a few limitations to this analysis. Unfortunately, the small sample of children and weak instruments prevented us for looking at the causal impact of IBLI on child MUAC resilience, although the intent-to-treat analysis was consistent with the associational analysis. Future studies of this kind may increase the number of households surveyed with a particular focus on households with small children if they are interested in understanding the impact of policies or projects on child health and resilience. It may be worth following children even after their fifth or sixth birthdays in order to avoid highly unbalanced panels of children. Secondly, this paper emphasizes inference, taking advantage of the quasi-experimental nature of the IBLI data. We focus on variables that are typically associated with well-being in the rural Kenyan context, but future work may substantially improve on the predictive performance of our analysis using ensemble learning methods.

Despite these shortcomings, this paper contributes to the body of evidence demonstrating the positive impact of IBLI on well-being. The relatively low cost of IBLI compared to safety net programs of similar impact (Jensen, Barrett, & Mude 2015) recommends it as the primary means of managing covariate drought risk in pastoral communities. While the findings are encouraging, IBLI should be piloted and assessed in other ASALs, such as in Mali and Niger, in order to establish the external validity of these findings.

VII. TABLES

Table 1: Household Summary Statistics

	Pooled	**Panel A: Season 1 only**			**Panel B: Season 1 only**		
	Sample Mean	Untreated Season 4	Treated Season 4	T*	Unattrited	Attrited	T*
TLU[12]	**14.3**	15.9	17.1		17.1	13.9	
Conditional TLU	**15.3**	17.1	18.4		18.2	15.9	
PLM Index	**0.119**						
Contract (0/1)	**0.125**						
# Insured TLU	**0.595**						
Conditional # Insured TLU	**4.77**						
Treatment (0/1)	**0.456**						
Female headed	**0.376**	0.369	0.388		0.377	0.327	
Dependency Ratio[13]	**2.03**	1.97	2.05		2.03	1.74	*
Education (yrs)	**1.03**	1.20	0.947		0.970	2.59	***
Settled (0/1)[14]	**0.375**	0.258	0.221		0.229	0.317	**
Milk Prd [15]- Base	**0.644**	0.764	0.775		0.775	0.816	
Milk Prd - Sat	**1.21**	1.54	1.41		1.45	1.93	**
Consumption[16]	**4620**	1400	1420		1430	1280	
Division[17]							
Central and Gadamoji	**0.240**	0.239	0.244		0.244	0.202	
Laisamis	**0.147**	0.139	0.132		0.137	0.125	
Loiyangalani	**0.325**	0.336	0.340		0.330	0.346	
Maikona	**0.282**	0.286	0.284		0.289	0.327	
North Horr	**0.007**						
N (households)	**8,670 (924)**	**360 (40.5%)**	**529 (59.5%)**		**820 (88.7%)**	**104 (11.3%)**	

*T-test on difference of means: *** p<0.01, ** p<0.05, * p<0.10

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[12] A tropical livestock unit (TLU) is an aggregate measure of livestock holdings. 1 TLU = 1 cow = 0.7 camel = 10 sheep or goats.

[13] The dependency ratio gives a sense of how many individuals are being cared for by the family. In this case, the dependency ratio equals the number of children under 18, plus seniors over 55 and disabled or chronically ill household members, divided by the number of able-bodied adults (between the ages of 18 and 55) in the household. If there are no working aged adults in the households, the number of dependents is divided by 1.

[14] Indicates that a household is fully settled. "Partially nomadic" (i.e. agro-pastoral) and nomadic households not settled.

[15] Daily average milk production in liters. This is disaggregated for the base camp (homestead) and satellite camp.

[16] Winsorized (top 1%) weekly food consumption expenditure in Kenyan shillings, including value of produced foods consumed at home. The mean value is approximately $60/week. Median expenditure is much lower – closer to $20/week.

[17] For households that insured, the division is listed as the division in which the household chose to insure, not the division of residence. For all other households, the division of residence is used.

Table 2: Child Summary Statistics

	Pooled	**Panel A: Pooled (5 rounds)**			**Panel B: Pooled**		
	Sample Mean	Untreated in round	Treated in round	T*	Not missing	Missing[18]	T*
MUAC[19] (cm)	**14.4**	14.3	14.5	**	14.4	14.3	
PLM Index	**0.136**						
Contract (0/1)	**0.124**						
# Insured TLU	**0.636**						
Conditional # Insured TLU	**5.12**						
Treatment (0/1)	**0.412**						
Female headed	**0.328**	0.335	0.305		0.318	0.458	**
Girl (0/1)	**0.481**	0.468	0.500		0.483	0.417	
Dependency Ratio	**2.33**	2.36	2.28		2.33	2.22	
Head Educ (yrs)	**1.12**	1.16	1.05		1.12	1.04	
Settled (0/1)	**0.362**	0.355	0.373		0.356	0.556	***
Milk Prd - Base	**1.15**	1.08	1.25	*	1.16	0.847	
Milk Prd - Sat	**2.41**	2.54	2.23	**	2.42	2.24	
Consumption	**4960**	3080	7660	***	4800	10000	***
HH TLU holdings	**15.2**	16.3	13.5	***	15.1	16.6	
<u>Division</u>[20]							
Central and Gadamoji	**0.210**	0.203	0.220		0.208	0.278	
Laisamis	**0.160**	0.154	0.170		0.163	0.0694	**
Loiyangalani	**0.352**	0.379	0.314	***	0.347	0.500	***
Maikona	**0.272**	0.263	0.284		0.276	0.153	**
North Horr	**0.006**	0.001	0.011	***	0.006	0	
N (children<5)	**2,358 (1,083)**	**1,387 (58.8%)**	**971 (41.2%)**		**2,286 (96.9%)**	**72 (3.1%)**	

*T-test on difference of means: *** p<0.01, ** p<0.05, * p<0.10

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[18] A child may not reappear for many reasons, including (random) aging out and (non-random) household attrition. Missingness here means unexplained missingness not caused by aging out or household attrition (which is already corrected for in the probability weights).

[19] Mid upper arm circumference in cm.

[20] For households that insured, the division is listed as the division in which the household chose to insure, not the division of residence. For all other households, the division of residence is used.

Table 3: Poisson MLE[21] of mean TLU – specification and serial correlation checks (marginal effects at mean values)

VARIABLES	(1) MLE TLU	(2) MLE TLU	(3) MLE TLU	(4) MLE TLU	(5) MLE TLU	(6) MLE TLU
TLU_{s-1} [22]		0.449***	0.663***		0.363***	0.557***
		(0.0287)	(0.0251)		(0.0250)	(0.0251)
PLMindex_{s-1}	-13.07***	-10.03***	-8.410***	1.347	-3.377*	-2.721
	(2.734)	(1.702)	(1.726)	(3.318)	(1.808)	(1.954)
(No drought # insurance) $_{s-1}$	**-0.192**	**0.285**	**-0.0830**	**-0.361**	**-0.0713**	**-0.0801**
	(0.630)	**(0.350)**	**(0.338)**	**(0.423)**	**(0.291)**	**(0.309)**
(Drought # insurance) $_{s-1}$	**0.734**	**1.096****	**0.899****	**0.186**	**0.451**	**0.626**
	(0.855)	**(0.427)**	**(0.409)**	**(0.616)**	**(0.389)**	**(0.417)**
Female Headed HH (indicator)	0.0170	-0.448	-0.517**	-0.544	-0.185	0.0160
	(0.758)	(0.273)	(0.222)	(0.729)	(0.670)	(0.672)
Dependency Ratio	-0.411*	-0.0859	-0.159**	-0.182	-0.238	-0.209
	(0.227)	(0.0798)	(0.0722)	(0.208)	(0.146)	(0.164)
Education of head in yrs	-0.135	-0.0774	-0.0141	0.199	0.269**	0.297**
	(0.181)	(0.0568)	(0.0623)	(0.205)	(0.129)	(0.116)
Settled HH (indicator)	-6.543***	-1.904***	-1.717***	0.229	0.566	0.153
	(0.772)	(0.323)	(0.321)	(0.665)	(0.415)	(0.365)
Milk Production at Base	0.362	0.235***	0.222***	0.0633	-0.0252	0.00369
	(0.234)	(0.0797)	(0.0777)	(0.111)	(0.0713)	(0.0767)
Milk Production at Satellite Camp	1.291***	0.524***	0.453***	0.228*	0.282***	0.280***
	(0.233)	(0.115)	(0.112)	(0.117)	(0.0827)	(0.0852)
Ln(consumption)	0.549**	0.170	0.103	0.0266	0.0958	0.127
	(0.237)	(0.123)	(0.100)	(0.147)	(0.112)	(0.109)
# Insured TLU $_s$	0.00386	0.00597	0.00588**	-0.00504	0.000715	0.00311
	(0.00905)	(0.00372)	(0.00242)	(0.00772)	(0.00396)	(0.00284)
HH FE[23]	N	N	N	Y	Y	Y
Pseudo R^2 [24]	0.0441	0.664	0.679	0.234	0. 699	0.701
Correlation Coefficient	**0.7666**	**0.2405**	**-0.0089**	**0.8027**	**0.2752**	**0.0420**

Clustered (HH) standard errors in parentheses. Season fixed effects included in all specifications. N=6,807.
*** $p<0.01$, ** $p<0.05$, * $p<0.10$

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[21] TLU is assumed to be distributed Poisson and fit using the canonical log link. This is essentially a log-linear model estimated using maximum likelihood.

[22] First, second, and third order polynomial terms included in (2) and (5) and up to fourth order terms included in (3) and (6).

[23] In the nonlinear setting, rather than including HH fixed effects, household-level mean values of all covariates are included (Mundlak 1978).

[24] All MLE pseudo R^2 values are the correlation between the response and the fitted or predicted response, calculated using Stata's *glmcorr* by Nicholas J. Cox.

Table 4: 2SLS estimates of mean TLU

VARIABLES	(1) 1st Stage I_{s-1}	(2) 1st Stage $(D_{s-1} * I_{s-1})$	(3) 1st Stage # Insured TLU	(4) 2SLS TLU
IV1: (No drought # coupon)$_{s-1}$	0.00323***	-0.000811***	0.00820	
	(0.000497)	(0.000119)	(0.0165)	
IV2: (Drought # coupon)$_{s-1}$	-0.000864***	0.00423***	0.0106	
	(0.000263)	(0.000716)	(0.0128)	
IV3: Coupon$_{s}$	6.17e-06	5.86e-05	-0.0111	
	(0.000218)	(0.000162)	(0.0152)	
TLU_{s-1}	0.000863	0.000508	0.0281	0.904***
	(0.000725)	(0.000390)	(0.0237)	(0.0373)
TLU_{s-1}^{2}	-1.50e-05**	-6.65e-06*	-0.000381	-0.00201***
	(7.38e-06)	(3.87e-06)	(0.000258)	(0.000618)
TLU_{s-1}^{3}	3.38e-08**	1.57e-08*	8.90e-07	3.92e-06***
	(1.56e-08)	(8.16e-09)	(5.81e-07)	(1.46e-06)
PLMindex_{s-1}	-0.358***	0.641***	2.253	-21.62***
	(0.0944)	(0.0811)	(7.695)	(5.706)
$\text{PLMindex}_{s-1}^{2}$	0.599***	-1.150***	-1.756	42.09***
	(0.191)	(0.174)	(15.42)	(11.38)
(No drought # insurance)$_{s-1}$				**-1.812**
				(2.532)
(Drought # insurance)$_{s-1}$				**3.003**
				(2.822)
Female Headed HH (indicator)	-0.0121	-0.0198***	0.778	-0.385
	(0.0135)	(0.00732)	(0.716)	(0.470)
Dependency Ratio	-0.00414	-0.00103	-0.220	-0.184*
	(0.00443)	(0.00207)	(0.134)	(0.112)
Education of head in yrs	-0.000572	-0.00149	-0.0161	-0.0184
	(0.00230)	(0.00110)	(0.0153)	(0.0389)
Settled HH (indicator)	0.0378***	-0.000544	-0.331	0.145
	(0.0124)	(0.00807)	(0.317)	(0.420)
Milk Production at Base	-0.000127	0.00194	-0.145	0.0782
	(0.00415)	(0.00210)	(0.166)	(0.151)
Milk Production at Satellite Camp	0.00483	-0.00167	-0.0578	1.035***
	(0.00403)	(0.00187)	(0.136)	(0.165)
Ln(consumption)	-0.000853	-0.00689**	-0.177	0.194
	(0.00676)	(0.00334)	(0.212)	(0.132)
# Insured TLU$_{s}$				-0.0323
				(0.511)
Constant	0.0349	-0.0110	1.103	0.686
	(0.0495)	(0.0274)	(2.072)	(1.916)
R^2	0.13	0.19	0.01	0.75
F-stat / Wald χ^2	25.59	41.12	0.73	12018.85
				(0.0000)

Clustered (HH) standard errors in parentheses. Season fixed effects included in all specifications. N=6,807. *** $p<0.01$, ** $p<0.05$, * $p<0.10$

Table 5: Poisson MLE[25] of mean MUAC – specification and serial correlation checks (marginal effects at mean values)

VARIABLES	(1) MLE MUAC	(2) MLE MUAC	(3) MLE MUAC	(4) MLE MUAC	(5) MLE MUAC	(6) MLE MUAC
MUAC_{s-2}		0.393***	0.394***		0.383***	0.384***
		(0.0573)	(0.0576)		(0.0556)	(0.0526)
PLMindex_{s-1}	3.062***	3.487***	3.519***	2.420***	3.369***	3.401***
	(0.711)	(0.891)	(0.894)	(0.697)	(0.883)	(0.887)
(No drought # insurance) $_{s-1}$	**-0.0202**	**-0.174**	**-0.179**	**-0.0532**	**-0.165**	**-0.170**
	(0.132)	**(0.156)**	**(0.154)**	**(0.130)**	**(0.155)**	**(0.153)**
(Drought # insurance) $_{s-1}$	**0.189**	**-0.138**	**-0.148**	**0.172**	**-0.113**	**-0.123**
	(0.194)	**(0.209)**	**(0.208)**	**(0.188)**	**(0.211)**	**(0.210)**
Female Headed HH (indicator)	-0.255**	-0.356***	-0.349***	0.286	0.301	0.308
	(0.113)	(0.0991)	(0.0994)	(0.338)	(0.359)	(0.359)
Girl (indicator)	-0.0492	-0.0867	-0.0945	-0.0631	-0.0971	-0.105
	(0.0906)	(0.0832)	(0.0833)	(0.0893)	(0.0848)	(0.0849)
Dependency Ratio	-0.0723***	-0.0246	-0.0251	0.00204	-0.0138	-0.0161
	(0.0277)	(0.0286)	(0.0281)	(0.0467)	(0.0487)	(0.0484)
Education of head in yrs	0.0685***	0.0421***	0.0433***	0.0274	0.0164	0.0168
	(0.0171)	(0.0132)	(0.0134)	(0.0520)	(0.0501)	(0.0503)
Settled HH (indicator)	0.217**	0.0925	0.0881	0.120	0.0468	0.0431
	(0.0923)	(0.0912)	(0.0915)	(0.0967)	(0.104)	(0.104)
Milk Production at Base	-0.00857	-0.00862	-0.00834	-0.0144	-0.0130	-0.0127
	(0.0155)	(0.0154)	(0.0152)	(0.0199)	(0.0206)	(0.0205)
Milk Production at Satellite Camp	-0.0124	-0.00376	-0.00255	0.00465	-0.00279	-0.00176
	(0.0125)	(0.0135)	(0.0135)	(0.0142)	(0.0172)	(0.0172)
Ln(consumption)	0.114**	0.0232	0.0259	0.00616	-0.0417	-0.0396
	(0.0485)	(0.0622)	(0.0617)	(0.0560)	(0.0802)	(0.0796)
TLU	-0.000405	0.00111	0.000884	-2.32e-05	-0.000766	-0.000978
	(0.00193)	(0.00165)	(0.00164)	(0.00553)	(0.00632)	(0.00650)
# Insured TLU $_{s}$	0.00239	0.0147***	0.0146***	0.00246***	0.0137***	0.0135***
	(0.00152)	(0.00505)	(0.00500)	(0.000938)	(0.00502)	(0.00498)
Child FE[26]	N	N	N	Y	Y	Y
Observations	1,882	1,257	1,257	1,882	1,257	1,257
Pseudo R^2	0.0851	0.246	0.244	0.132	0.255	0.253
Correlation Coefficient	**0.3667**	**-0.1237**	**-0.1237**	**0.3463**	**-0.1205**	**-0.1199**

Clustered (child) standard errors in parentheses. Round FE included in all specifications. *** p<0.01, ** p<0.05, * p<0.10

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[25] MUAC is assumed to be distributed Poisson and fit using the canonical log link. This is essentially a log-linear model estimated using maximum likelihood.

[26] In the nonlinear setting, rather than including child fixed effects, child-level mean values of all covariates are included (Mundlak 1978).

Table 6: 2SLS estimates of mean MUAC

VARIABLES	(1) 1st Stage I_{s-1}	(2) 1st Stage $(D_{s-1} * I_{s-1})$	(3) 1st Stage # Insured TLU	(4) 2SLS MUAC
IV: (No drought # coupon) $_{s-1}$	0.00248***	-0.00107***	-0.00884	
	(0.000687)	(0.000252)	(0.00705)	
IV: (Drought # coupon) $_{s-1}$	-0.000623	0.00641***	0.00365	
	(0.000710)	(0.00174)	(0.00505)	
IV: Coupon $_{s}$	-2.23e-05	0.000351	0.00456	
	(0.000426)	(0.000322)	(0.00588)	
MUAC_{s-2}	1.136	-0.218	0.824	-8.806
	(1.040)	(0.430)	(3.864)	(11.52)
MUAC^2_{s-2}	-0.0803	0.0175	-0.0182	0.588
	(0.0776)	(0.0310)	(0.290)	(0.763)
MUAC^3_{s-2}	0.00187	-0.000442	-0.000448	-0.0124
	(0.00192)	(0.000733)	(0.00720)	(0.0168)
PLMindex_{s-1}	-1.006***	1.541***	-4.048	13.16
	(0.383)	(0.390)	(5.677)	(20.09)
PLMindex^2_{s-1}	1.431**	-2.118***	4.496	-15.66
	(0.609)	(0.545)	(8.464)	(27.13)
(No drought # insurance) $_{s-1}$				**3.324**
				(7.917)
(Drought # insurance) $_{s-1}$				**-0.328**
				(1.334)
Female Headed HH (indicator)	-0.0235	-0.00428	-0.235*	-0.00234
	(0.0258)	(0.0144)	(0.138)	(0.638)
Girl	0.0191	0.0211	0.187	-0.346
	(0.0210)	(0.0144)	(0.215)	(0.631)
Dependency Ratio	0.00227	0.000392	-0.00722	-0.0231
	(0.00652)	(0.00367)	(0.0508)	(0.0661)
Education of head in yrs	-0.00300	-0.00281	-0.0163	0.0691
	(0.00323)	(0.00268)	(0.0184)	(0.0562)
Settled HH (indicator)	0.0406*	-0.0202	-0.0382	-0.0114
	(0.0210)	(0.0157)	(0.120)	(0.261)
Milk Production at Base	-0.00182	0.00705**	0.0481	-0.0494
	(0.00460)	(0.00333)	(0.0363)	(0.0849)
Milk Production at Satellite Camp	0.00798	-0.00421*	-0.00783	-0.0237
	(0.00514)	(0.00230)	(0.0491)	(0.0478)
Ln(consumption)	0.0155	-0.00202	0.0395	-0.0670
	(0.0132)	(0.00615)	(0.0479)	(0.182)
TLU	-0.000469	0.000186	0.00364	-0.00163
	(0.000503)	(0.000228)	(0.00626)	(0.00846)
# Insured TLU $_{s}$				1.075
				(1.548)
Constant	-5.268	0.592	-5.804	55.44
	(4.589)	(1.952)	(17.59)	(56.41)
R^2	0.11	0.38	0.01	
F-stat / Wald χ^2	4.87	23.37	3.94	104.44
				(0.0000)

Clustered (child) standard errors in parentheses. Round fixed effects included in all specifications. N=1,257. *** $p<0.01$, ** $p<0.05$, * $p<0.10$

Table 7: Poisson MLE of TLU and its variance– marginal effects at representative values of the PLM index

VARIABLES	(1) MLE TLU		(2) MLE V(TLU)	
	(A)	(B)	(A)	(B)
PLM =	**.039**	**0.265**	**.039**	**0.265**
TLU_{s-1}	0.642***	0.543***	4.875	2.889
	(0.0142)	(0.0188)	(65.14)	(38.32)
PLMindex_{s-1}	-20.56***	0.815	-624.7	5.834
	(4.336)	(1.739)	(7,728)	(123.4)
(No drought # insurance) $_{s-1}$	**-0.118**	**-0.0998**	**8.192**	**4.855**
	(0.479)	**(0.406)**	**(105.9)**	**(62.31)**
(Drought # insurance) $_{s-1}$	**1.275****	**1.080****	**-62.64**	**-37.13**
	(0.588)	**(0.492)**	**(762.8)**	**(448.6)**
Female Headed HH	-0.733**	-0.621**	58.83	34.86
	(0.318)	(0.268)	(715.1)	(420.5)
Dependency Ratio	-0.225**	-0.191**	-4.520	-2.679
	(0.104)	(0.0875)	(58.67)	(34.49)
Education of head in yrs	-0.0201	-0.0170	3.511	2.081
	(0.0885)	(0.0749)	(41.99)	(24.69)
Settled HH (indicator)	-2.436***	-2.063***	-9.826	-5.823
	(0.470)	(0.400)	(125.3)	(73.58)
Milk Production at Base	0.316***	0.267***	2.828	1.676
	(0.110)	(0.0938)	(35.67)	(20.99)
Milk Pr, Satellite Camp	0.643***	0.545***	20.91	12.39
	(0.163)	(0.137)	(257.4)	(151.4)
Ln(consumption)	0.146	0.123	-5.670	-3.360
	(0.142)	(0.120)	(67.77)	(39.86)
Insured TLU $_{s}$	0.00834**	0.00706**	-0.0182	-0.0108
	(0.00346)	(0.00291)	(3.157)	(1.871)
Pseudo R^2	0.679		0.614	

Clustered (HH) standard errors in parentheses. Variance standard errors are bootstrapped (reps=400). Season fixed effects included in all specifications. N=6,807.

*** p<0.01, ** p<0.05, * p<0.10.

Table 8: Poisson MLE of MUAC and its variance– marginal effects at representative values of the PLM index

VARIABLES	(1) MLE MUAC		(2) MLE V(MUAC)	
	(A)	(B)	(A)	(B)
PLM =	**.039**	**0.265**	**.039**	**0.265**
MUAC_{s-2}	0.351***	0.370***	0.108	0.134
	(0.0401)	(0.0434)	(0.0732)	(0.114)
$\mathrm{PLMIndex}_{s-1}$	4.588***	2.058***	1.533	0.794
	(1.261)	(0.710)	(2.536)	(1.707)
(No drought # insurance) $_{s-1}$	**-0.169**	**-0.178**	**-0.308**	**-0.383**
	(0.152)	**(0.161)**	**(0.290)**	**(0.361)**
(Drought # insurance) $_{s-1}$	**-0.134**	**-0.141**	**-0.533**	**-0.664**
	(0.203)	**(0.215)**	**(0.355)**	**(0.586)**
Female Headed HH	-0.346***	-0.365***	0.0870	0.108
	(0.0961)	(0.102)	(0.190)	(0.230)
Girl	-0.0845	-0.0890	0.239	0.297
	(0.0811)	(0.0853)	(0.170)	(0.240)
Dependency Ratio	-0.0240	-0.0253	0.0287	0.0357
	(0.0278)	(0.0294)	(0.0581)	(0.0695)
Education of head in yrs	0.0410***	0.0432***	-0.0184	-0.0229
	(0.0129)	(0.0135)	(0.0248)	(0.0328)
Settled HH (indicator)	0.0902	0.0950	0.246	0.307
	(0.0888)	(0.0936)	(0.180)	(0.227)
Milk Production at Base	-0.00840	-0.00885	-0.0610	-0.0760
	(0.0150)	(0.0158)	(0.0376)	(0.0541)
Milk Pr, Satellite Camp	-0.00366	-0.00386	0.000414	0.000515
	(0.0131)	(0.0138)	(0.0228)	(0.0284)
Ln(consumption)	0.0226	0.0238	0.0348	0.0434
	(0.0605)	(0.0639)	(0.120)	(0.159)
TLU	0.00108	0.00114	-0.00290	-0.00361
	(0.00160)	(0.00169)	(0.00321)	(0.00451)
# Insured TLU $_{s}$	0.0144***	0.0151***	-0.00604	-0.00752
	(0.00491)	(0.00520)	(0.0257)	(0.0319)
Pseudo R^2	0.246		0.022	

Clustered (child) standard errors in parentheses. Variance standard errors are bootstrapped (reps=400). Round fixed effects included in all specifications. N=1,257.

*** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Table 9: 2SLS Coefficient Estimates on TLU resilience at various values of $\underline{W}^{TLU}$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\underline{W}^{TLU}$:	**2**	**8**	**14**	**20**	**26**	**32**	**38**
(No drought # insurance) $_{s-1}$	-0.019	-0.0442	-0.00675	0.0311	0.0554	0.0627	0.0502
	(-0.0322)	(-0.0391)	(-0.0446)	(-0.0474)	(-0.0476)	(-0.0428)	(-0.0362)
(Drought # insurance) $_{s-1}$	0.0497	-0.0447	0.00522	0.0861*	0.141***	0.154***	0.133***
	(-0.0345)	(-0.0405)	(-0.0424)	(-0.0467)	(-0.0499)	(-0.0475)	(-0.0405)

Clustered (HH), bootstrapped (reps=400) standard errors in parentheses. N=6,807.
*** p<0.01, ** p<0.05, * p<0.10.

Table 10: Binomial MLE Coefficient Estimates on MUAC resilience at various values of $\underline{W}^{MUAC}$

	(1)	(2)	(3)	(4)
$\underline{W}^{MUAC}$:	**11.5**	**12.5**	**13.5**	**14.5**
(No drought # insurance) $_{s-1}$	0.000356*	-0.000755	-0.0254***	-0.0808***
	(0.000205)	(0.00114)	(0.00348)	(0.00593)
(Drought # insurance) $_{s-1}$	0.00430***	0.0238***	0.0386***	-0.0215***
	(0.000551)	(0.00241)	(0.00707)	(0.00776)

Clustered (child), bootstrapped (reps=400) standard errors in parentheses. N=1,257.
*** p<0.01, ** p<0.05, * p<0.10.

VIII. FIGURES

Figure 1: Map of Kenya and Marsabit County

Adapted from Wikipedia

Figure 2: Timeline of IBLI Sales and Surveys

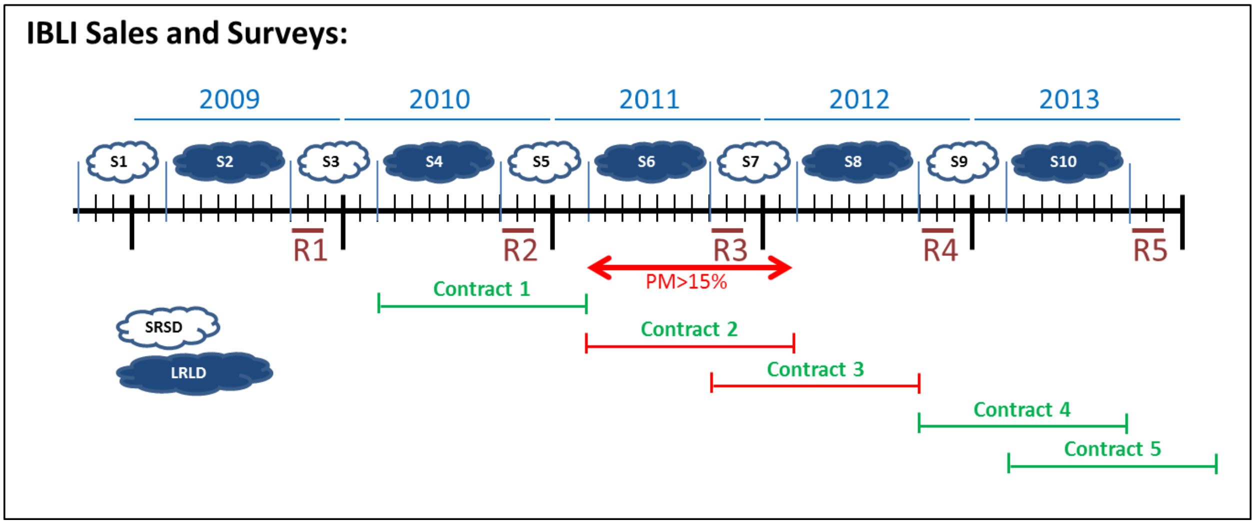


Figure 3: Histogram of TLU[27]

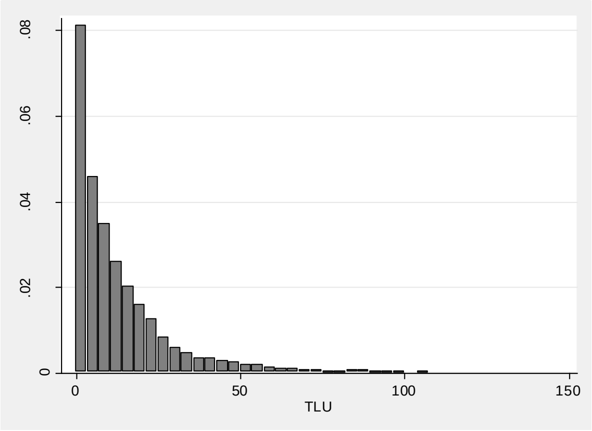


Figure 4: Histogram of MUAC

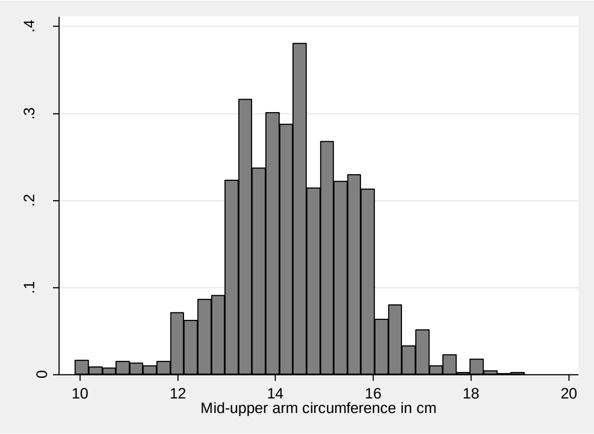
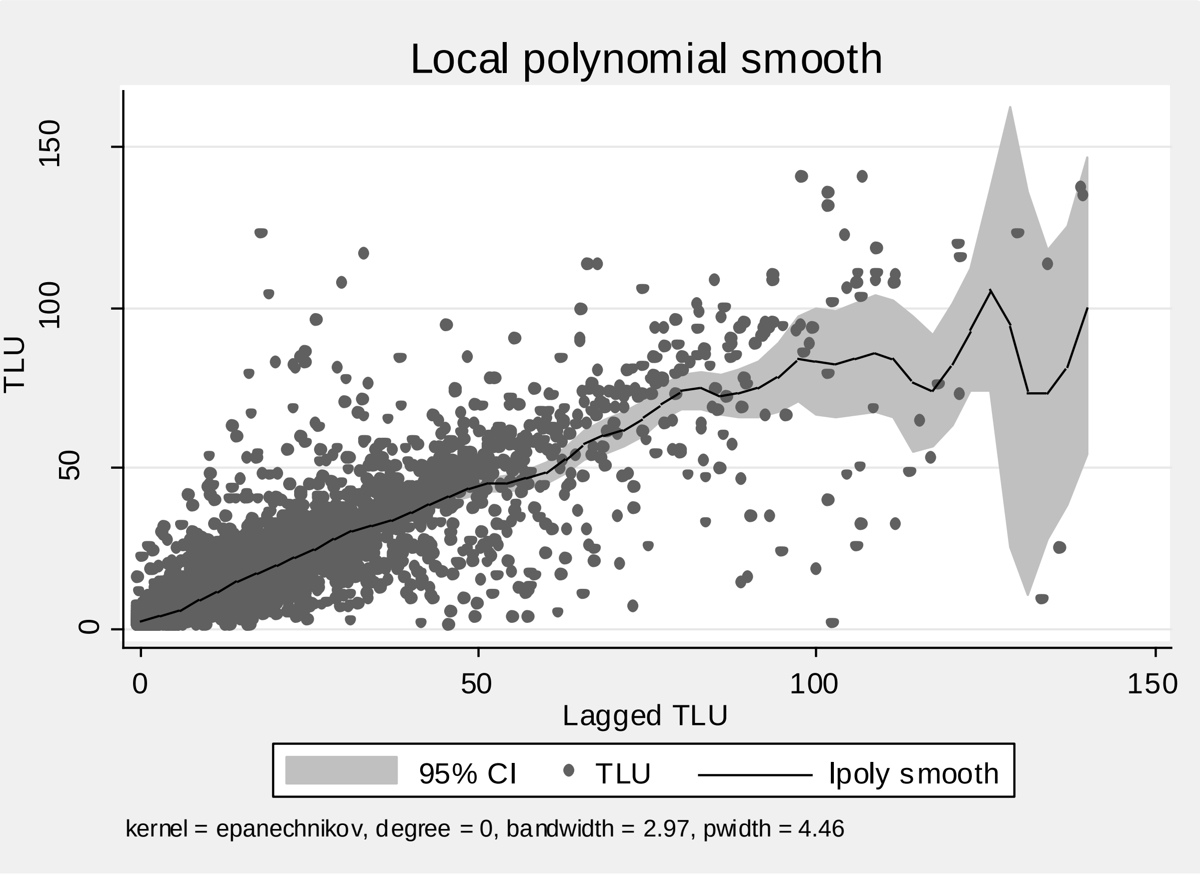


Figure 5: Kernel Regression of Lagged TLU and TLU



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[27] In order to facilitate interpretation, outliers above 150 TLU have been censored from all figures.

Figure 5: Kernel Regression of Lagged MUAC and MUAC

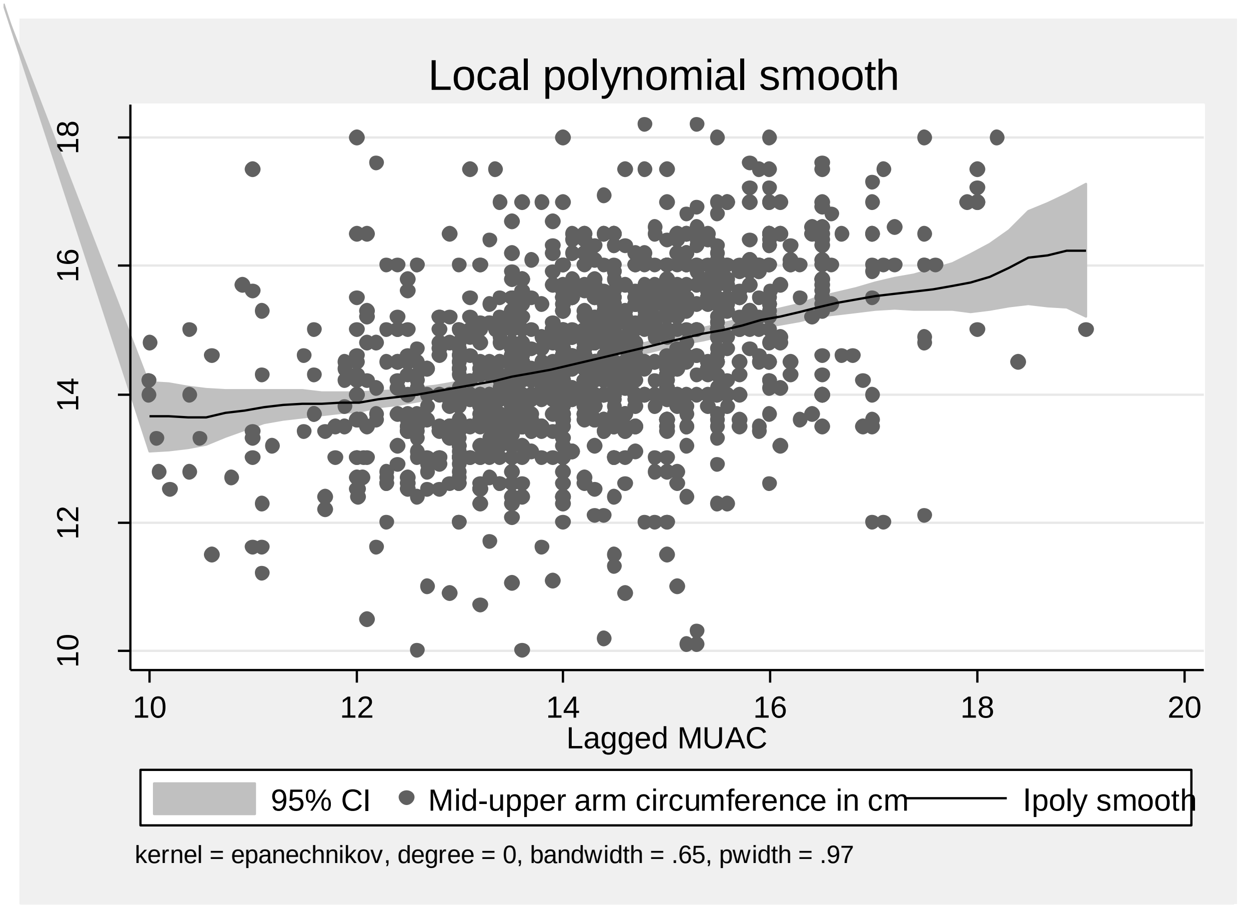


Figure 6: Household 5008's distributions of TLU well-being over time

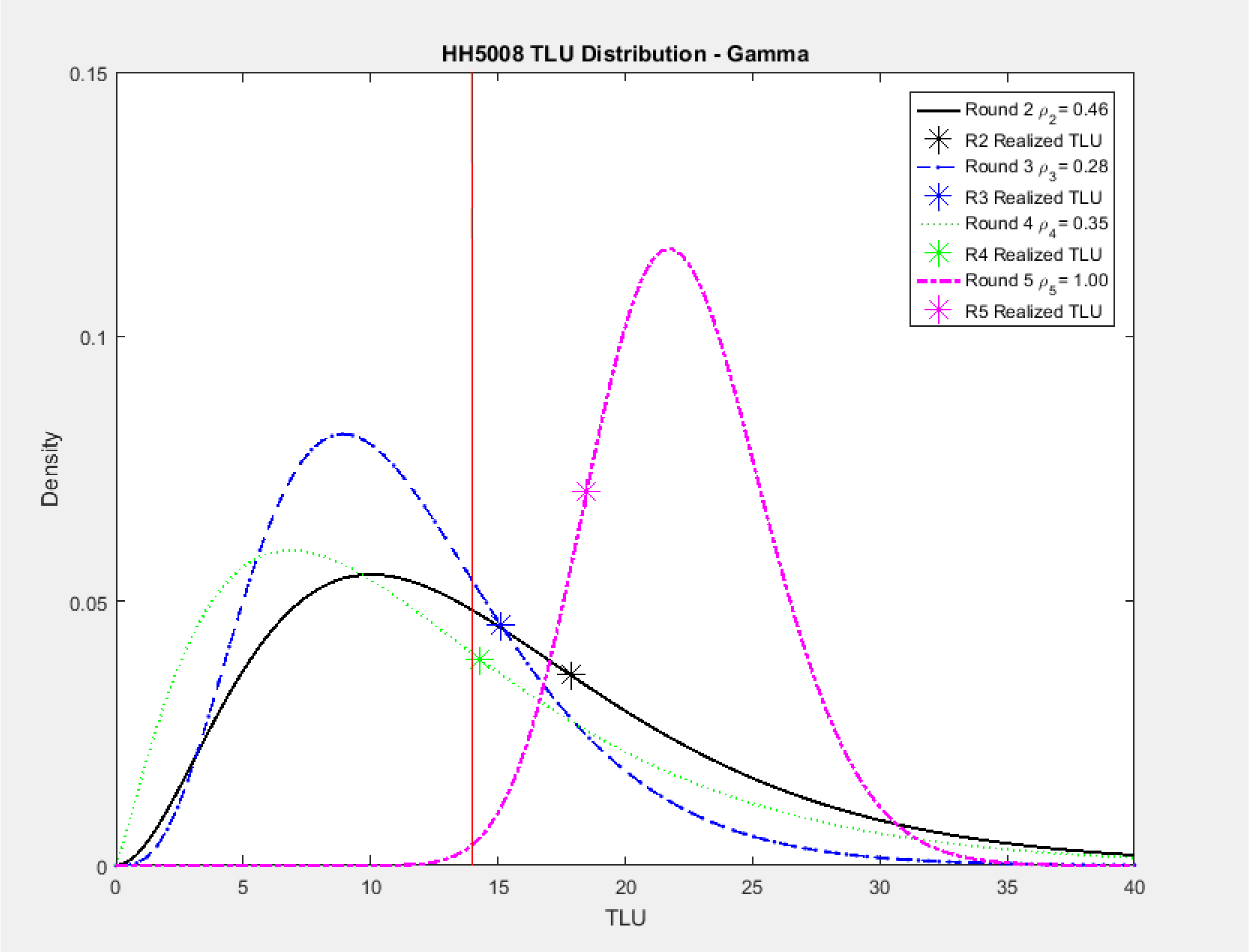


Figure 7: 2SLS Coefficients Estimates of IBLI on TLU resilience

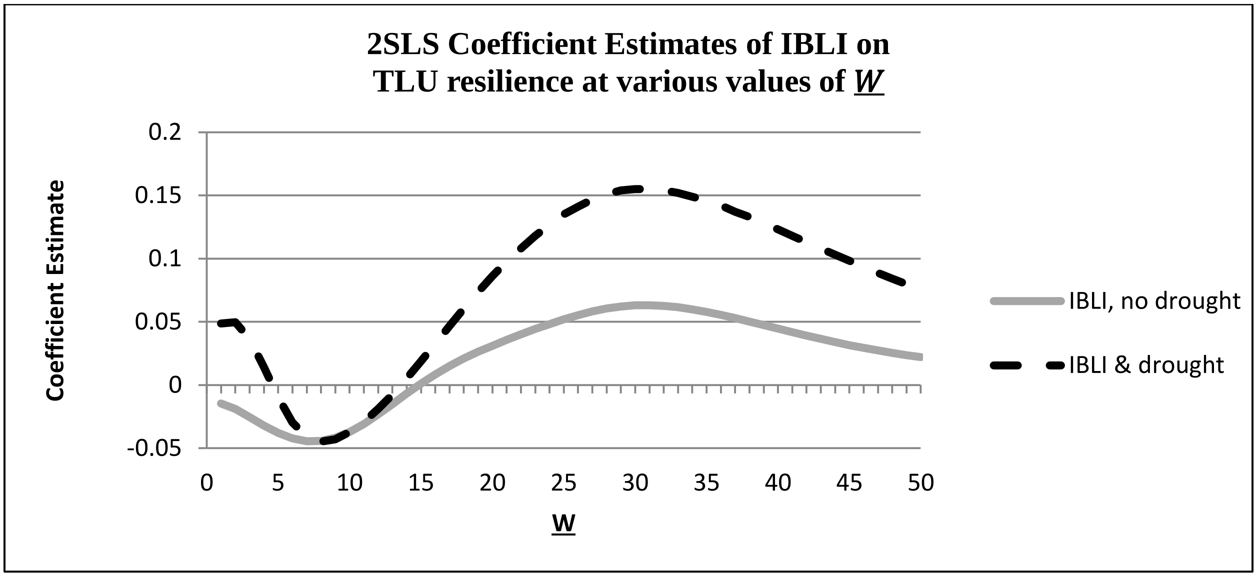
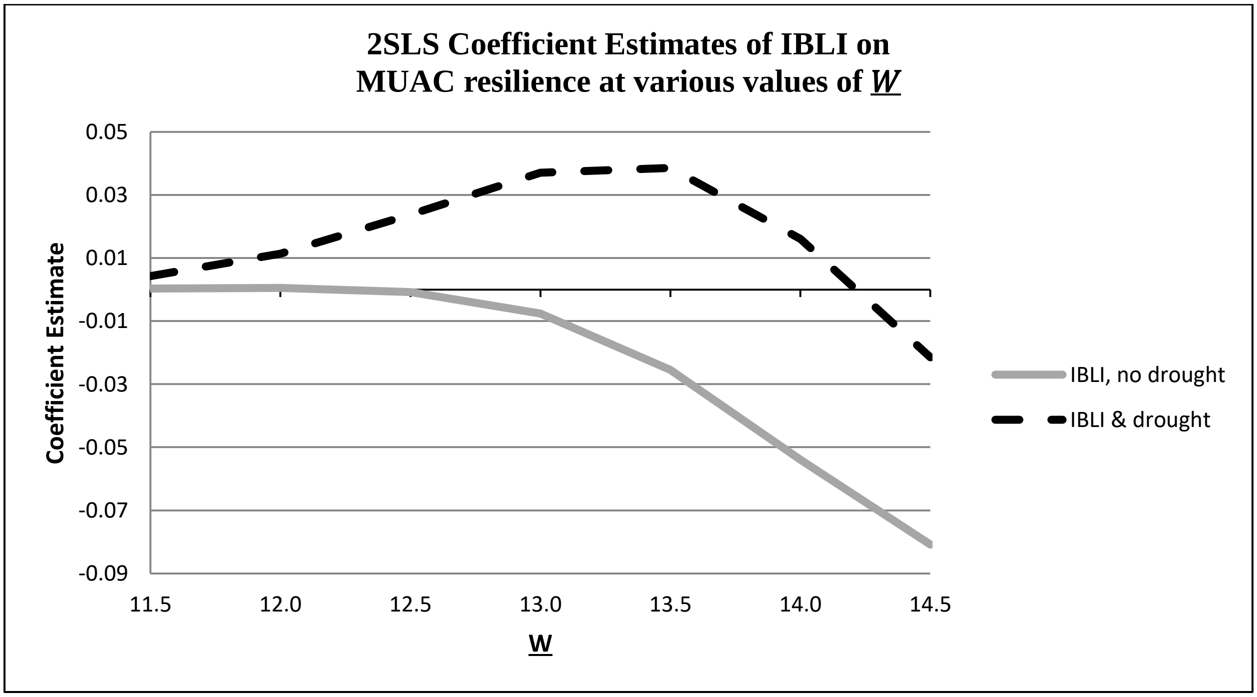


Figure 8: 2SLS Coefficients Estimates of IBLI on MUAC resilience



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X. APPENDIX A: ATTRITION

There is evidence of non-random attrition by households, as shown in the summary statistics. To avoid bias due to attrition, we adjust the survey probability weights to oversample households similar to those who attrited based on observables. We calculate these attrition-correcting inverse probability weights following Baulch & Quisumbing (2011) and multiply them by the survey probability weights. The probits used in this calculation are below (Columns (1) and (2)). Note that following Wooldridge (2002), only households that are surveyed at baseline (in Round 1) are included in the analysis (throughout the paper) despite the inclusion of replacement households when originally surveyed households could not be resurveyed.

Columns (3) and (4) present the probit results on non-missingness for children. As mentioned in above, children may (randomly) enter and leave the child survey sample as they are born or age out. Some children are lost to follow-up because their families attrit. Eligible (age appropriate) children that are missing from the child sample and whose households have not attrited are considered missing. The household survey confirms that no children are missing due to death or moving back home to live with their biological parents. Nonetheless, child missingness is not random, as can be seen in the probit below. The predicted missingness from columns (3) and (4) are used to correct survey weights for missingness in the MUAC regressions above.

Table A1: Probit estimates on non-attrition and non-missingness

VARIABLES	(1) Probit HH remains	(2) Probit HH remains	(3) Probit Child not missing	(4) Probit Child not missing
Female Headed HH (indicator)	-0.167	-0.0873		
	(0.136)	(0.115)		
Girl (indicator)			0.0965	0.134
			(0.110)	(0.106)
Dependency Ratio	0.0594	0.0373	0.0278	0.0297
	(0.0397)	(0.0348)	(0.0446)	(0.0400)
Education of head in yrs	-0.0560*	-0.0541***	0.0437	0.0231
	(0.0337)	(0.0166)	(0.0591)	(0.0188)
Head literate (indicator)	-0.128		-0.328	
	(0.310)		(0.520)	
HH head age (yrs)	-0.00625		-0.00153	
	(0.00382)		(0.00407)	
Child age (months)			0.00789**	0.00799**
			(0.00340)	(0.00330)
Settled HH (indicator)	-0.0859	-0.0730	-0.403***	-0.378***
	(0.0834)	(0.0781)	(0.130)	(0.116)
Sublocation attrition rate	-4.973***		-0.649	
	(1.113)		(0.938)	
Sublocation child missing rate			-4.664*	
			(2.592)	
Milk Production at Base	-0.00217	0.0216	0.00208	0.0272
	(0.0336)	(0.0335)	(0.0336)	(0.0297)
Milk Production at Satellite Camp	0.00168	0.00530	0.00797	-0.00444
	(0.0225)	(0.0228)	(0.0217)	(0.0189)
Ln(consumption)	0.0309	0.0762	-0.114*	-0.0824
	(0.0473)	(0.0550)	(0.0599)	(0.0582)
HH TLU Holdings				-0.00254
				(0.00189)
Season FE	Y	Y	N	N
Division FE	Y	N	Y	N
Religion FE	Y	N	Y	N
Constant	2.283***	0.709*	3.341***	2.239***
	(0.490)	(0.405)	(0.586)	(0.492)
Observations	8,664	8,664	2,348	2,355
Pseudo R^2	0.1575	0.0901	0.0781	0.0344

Clustered standard errors in parentheses, clustered at HH ((1) & (2)) and child-level ((3) and (4).
*** $p<0.01$, ** $p<0.05$, * $p<0.10$

XI. APPENDIX B: ROBUSTNESS CHECKS

Table B1: Linear estimates of mean TLU – specification and serial correlation checks

VARIABLES	(1) OLS TLU	(2) OLS TLU	(3) OLS TLU	(4) FE[28] TLU	(5) FE TLU	(6) FE TLU
TLU_{s-1}		0.903***	1.001***		0.448***	0.693***
		(0.0324)	(0.0651)		(0.0823)	(0.106)
TLU^2_{s-1}		-0.00199***	-0.00480**		0.000572	-0.00549*
		(0.000553)	(0.00196)		(0.00114)	(0.00308)
TLU^3_{s-1}		3.87e-06***	2.39e-05*		3.71e-07	4.07e-05*
		(1.31e-06)	(1.31e-05)		(2.46e-06)	(2.16e-05)
TLU^4_{s-1}			-3.60e-08			-7.00e-08*
			(2.25e-08)			(3.81e-08)
PLMindex_{s-1}	-52.83***	-18.46***	-16.98***	-4.635	-9.826*	-9.537*
	(12.65)	(4.810)	(4.848)	(9.487)	(5.719)	(5.677)
PLMindex^2_{s-1}	131.0***	37.07***	33.75***	19.35	20.37	20.00
	(30.81)	(10.30)	(10.51)	(21.07)	(12.70)	(12.68)
(No drought # insurance) $_{s-1}$	**-0.753**	**-0.0939**	**-0.135**	**-0.358**	**-0.207**	**-0.249**
	(0.753)	**(0.379)**	**(0.378)**	**(0.699)**	**(0.519)**	**(0.520)**
(Drought # insurance) $_{s-1}$	**0.794**	**0.626**	**0.551**	**1.227**	**0.842***	**0.786**
	(1.054)	**(0.479)**	**(0.476)**	**(0.751)**	**(0.510)**	**(0.507)**
Female Headed HH (indicator)	-0.549	-0.444**	-0.389**	0.618	0.690	0.797
	(0.857)	(0.182)	(0.196)	(1.003)	(0.858)	(0.842)
Dependency Ratio	-0.548**	-0.173***	-0.173***	-0.340	-0.264	-0.250
	(0.248)	(0.0646)	(0.0660)	(0.282)	(0.201)	(0.203)
Education of head in yrs	-0.0900	-0.0201	-0.0116	-0.0637	0.0784	0.0743
	(0.147)	(0.0379)	(0.0383)	(0.251)	(0.153)	(0.149)
Settled HH (indicator)	-5.440***	0.106	0.267	0.744	0.705	0.709
	(0.784)	(0.307)	(0.362)	(1.008)	(0.551)	(0.538)
Milk Production at Base	0.650	0.0863	0.0519	0.0797	0.0326	0.0347
	(0.453)	(0.126)	(0.126)	(0.200)	(0.150)	(0.150)
Milk Production at Satellite Camp	4.118***	1.023***	0.979***	1.234***	0.959***	0.931***
	(0.443)	(0.157)	(0.151)	(0.280)	(0.184)	(0.185)
Ln(consumption)	0.574**	0.182*	0.172*	0.144	0.136	0.146

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[28] Probability weights in the fixed effects equations are average household-level probability weights.

	(0.275)	(0.0983)	(0.0975)	(0.193)	(0.140)	(0.140)
# Insured TLU $_s$	0.00484	0.00202	0.00126	-0.00929	-0.00179	-0.000299
	(0.0162)	(0.00558)	(0.00542)	(0.0190)	(0.0104)	(0.00929)
HH FE	N	N	N	Y	Y	Y
Constant	14.65***	3.478***	2.919***	13.67***	7.482***	5.977***
	(2.527)	(0.939)	(1.031)	(2.006)	(1.329)	(1.603)
Adjusted R^2	0.232	0.754	0.755	0.0541	0.407	0.412
Number of HH				889	889	889
Correlation Coefficient	**0.7434**	**0.0152**	**0.0207**	**0.8347**	**0.3872**	**0.3640**

Clustered (HH) standard errors in parentheses. Season fixed effects included in all specifications. N=6,807.

*** p<0.01, ** p<0.05, * p<0.10

Table B2: Linear Estimates of mean MUAC – specification and serial correlation checks

VARIABLES	(1) OLS MUAC	(2) OLS MUAC	(3) OLS MUAC	(4) FE[29] MUAC	(5) FE MUAC	(6) FE MUAC
MUAC_{s-2}		-3.729	-38.08		6.332	-55.01
		(3.809)	(30.43)		(5.565)	(35.69)
MUAC^2_{s-2}		0.273	3.994		-0.446	6.231*
		(0.280)	(3.317)		(0.393)	(3.759)
MUAC^3_{s-2}		-0.00600	-0.183		0.00970	-0.310*
		(0.00682)	(0.159)		(0.00921)	(0.174)
MUAC^4_{s-2}			0.00314			0.00568*
			(0.00283)			(0.00301)
$\mathrm{PLMindex}_{s-1}$	5.024***	5.290***	5.314***	5.459***	6.130***	6.123***
	(1.277)	(1.540)	(1.540)	(1.357)	(1.562)	(1.519)
$\mathrm{PLMindex}^2_{s-1}$	-7.190***	-6.158**	-6.154**	-10.29***	-13.88***	-13.76***
	(2.545)	(2.767)	(2.762)	(2.857)	(3.604)	(3.531)
(No drought # insurance) $_{\mathbf{s-1}}$	**-0.0207**	**-0.178**	**-0.182**	**-0.173**	**-0.142**	**-0.126**
	(0.130)	**(0.155)**	**(0.153)**	**(0.144)**	**(0.142)**	**(0.144)**
(Drought # insurance) $_{\mathbf{s-1}}$	**0.192**	**-0.140**	**-0.150**	**-0.218**	**-0.0429**	**-0.0757**
	(0.201)	**(0.216)**	**(0.215)**	**(0.207)**	**(0.266)**	**(0.262)**
Female Headed HH (indicator)	-0.252**	-0.351***	-0.344***	-0.112	0.625	0.625
	(0.111)	(0.0977)	(0.0978)	(0.404)	(0.583)	(0.573)
Girl (indicator)	-0.0484	-0.0874	-0.0942			
	(0.0906)	(0.0834)	(0.0833)			
Dependency Ratio	-0.0712***	-0.0239	-0.0242	0.0438	-0.0171	-0.0216
	(0.0271)	(0.0282)	(0.0278)	(0.0467)	(0.0546)	(0.0547)
Education of head in yrs	0.0707***	0.0442***	0.0452***	0.0232	0.0491	0.0451
	(0.0180)	(0.0139)	(0.0141)	(0.0469)	(0.0545)	(0.0530)
Settled HH (indicator)	0.215**	0.0922	0.0878	0.102	-0.0451	-0.0459
	(0.0925)	(0.0916)	(0.0918)	(0.0922)	(0.106)	(0.106)
Milk Production at Base	-0.00864	-0.00865	-0.00835	0.0146	-0.0594**	-0.0568**
	(0.0153)	(0.0153)	(0.0151)	(0.0240)	(0.0248)	(0.0250)
Milk Production at Satellite Camp	-0.0120	-0.00360	-0.00244	-0.00447	-0.00657	-0.00476
	(0.0123)	(0.0134)	(0.0134)	(0.0170)	(0.0165)	(0.0167)
Ln(consumption)	0.115**	0.0250	0.0273	-0.0305	0.0361	0.0373
	(0.0497)	(0.0634)	(0.0629)	(0.0674)	(0.0565)	(0.0557)
HH TLU holdings	-0.000407	0.00108	0.000864	0.000792	-0.00446	-0.00478

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[29] Probability weights in the fixed effects equations are average child-level probability weights.

	(0.00192)	(0.00163)	(0.00162)	(0.00356)	(0.00535)	(0.00523)
# Insured TLU_s	0.00239	0.0153***	0.0150***	0.00457***	-0.0116	-0.0113
	(0.00155)	(0.00537)	(0.00529)	(0.000845)	(0.0278)	(0.0289)
Child FE	N	N	N	Y	Y	Y
Constant	12.83***	28.48*	146.1	13.44***	-14.52	194.4
	(0.438)	(17.14)	(103.6)	(0.597)	(26.00)	(125.9)
Observations	1,882	1,257	1,257	1,882	1,257	1,257
Adjusted R^2	0.112	0.246	0.247	0.132	0.250	0.257
Number of children				941	730	730
Correlation Coefficient[30]	**0.3672**	**-0.1244**	**-0.1245**	**0.4122**	**0.7049**	**0.7109**

Clustered (child) standard errors in parentheses. Round fixed effects included in all specifications.

*** $p<0.01$, ** $p<0.05$, * $p<0.10$

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[30] The correlation coefficient is the pairwise correlation coefficient between the regression residual and the lagged value of the regression residual. Higher correlations indicate serial correlation.

Table B3: Binomial[31] MLE of TLU resilience – marginal effects at representative values of the PLM index

VARIABLES	(1) MLE $\hat{\rho}_{is}^{TLU}, \underline{W} = 14$		(2) MLE $\hat{\rho}_{is}^{TLU}, \underline{W} = 14$	
	(A)	(B)	(A)	(B)
PLM =	**.039**	**0.26**	**.039**	**0.26**
TLU$_{s-1}$	0.0183***	0.0158***	0.0183***	0.0158***
	(0.00129)	(0.000934)	(0.00129)	(0.000948)
PLMindex$_{s-1}$	-0.397***	0.0416***	-0.385***	0.0434***
	(0.0476)	(0.00705)	(0.0472)	(0.00707)
(No drought # insurance) $_{s-1}$	**-0.00321**	**-0.00288**		
	(0.00217)	**(0.00194)**		
(Drought # insurance) $_{s-1}$	**0.00791***	**0.00710***		
	(0.00441)	**(0.00395)**		
(No drought # treatment) $_{s-1}$			**0.00111**	**0.001000**
			(0.00190)	**(0.00171)**
(Drought # treatment) $_{s-1}$			**-0.00227**	**-0.00205**
			(0.00328)	**(0.00296)**
Female Headed HH	-0.00746***	-0.00670***	-0.00768***	-0.00692***
	(0.00190)	(0.00171)	(0.00194)	(0.00175)
Dependency Ratio	-0.00391***	-0.00351***	-0.00392***	-0.00354***
	(0.000655)	(0.000564)	(0.000655)	(0.000567)
Education of head in yrs	0.000477	0.000428	0.000494	0.000445
	(0.000402)	(0.000357)	(0.000399)	(0.000356)
Settled HH (indicator)	-0.0379***	-0.0341***	-0.0379***	-0.0342***
	(0.00288)	(0.00203)	(0.00287)	(0.00205)
Milk Production at Base	0.00534***	0.00480***	0.00535***	0.00482***
	(0.000644)	(0.000533)	(0.000647)	(0.000537)
Milk Pr, Satellite Camp	0.0119***	0.0107***	0.0118***	0.0107***
	(0.00133)	(0.000974)	(0.00133)	(0.000984)
Ln(consumption)	0.00159*	0.00143*	0.00145*	0.00131*
	(0.000850)	(0.000762)	(0.000843)	(0.000758)
Insurance TLU	0.000207	0.000186	0.000207	0.000187
	(0.000127)	(0.000114)	(0.000159)	(0.000143)
Pseudo R^2	0.983		0.983	

Clustered (HH) standard errors in parentheses. Variance standard errors are bootstrapped (reps=400). Season fixed effects included in all specifications. N=6,807.

*** p<0.01, ** p<0.05, * p<0.10.

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[31] $\hat{\rho}_{is}^{TLU}$ is assumed to be distributed binomially and fit using the canonical logit link. This is essentially a fraction response logistic regression.

Table B4: 2SLS and IV Tobit Estimates of TLU resilience

VARIABLES	(1) 2SLS $\hat{\rho}_{is}^{TLU}, \underline{W} = 14$	(2) 2SLS FE $\hat{\rho}_{is}^{TLU}, \underline{W} = 14$	(3) ivtobit [0,1] $\hat{\rho}_{is}^{TLU}, \underline{W} = 14$	(4) ivtobit [0,1] $\hat{\rho}_{is}^{TLU}, \underline{W} = 14$
TLU_{s-1}	0.0371***	0.0429***	0.0371***	0.0403***
	(0.00349)	(0.000914)	(0.00455)	(0.000915)
TLU_{s-1}^{2}	-0.000390**	-0.000521***	-0.000391*	-0.000444***
	(0.000157)	(1.76e-05)	(0.000206)	(2.05e-05)
TLU_{s-1}^{3}	1.51e-06	2.34e-06***	1.52e-06	1.82e-06***
	(1.98e-06)	(1.09e-07)	(2.61e-06)	(1.38e-07)
TLU_{s-1}^{4}	-1.93e-09	-3.32e-09***	-1.94e-09	-2.42e-09***
	(7.10e-09)	(1.86e-10)	(9.29e-09)	(2.44e-10)
PLMindex_{t-1}	-0.515***	-0.597***	-0.502***	-0.468***
	(0.0680)	(0.0687)	(0.0677)	(0.114)
$\text{PLMindex}_{t-1}^{2}$	1.121***	1.314***	1.094***	1.075***
	(0.159)	(0.164)	(0.158)	(0.219)
(No drought # insurance) $_{s-1}$	**-0.00675**	**-0.0253**	**-0.00592**	**-0.0570**
	(0.0446)	**(0.0292)**	**(0.0446)**	**(0.0394)**
(Drought # insurance) $_{s-1}$	**0.00522**	**0.00309**	**0.00779**	**-0.0439**
	(0.0424)	**(0.0267)**	**(0.0429)**	**(0.0488)**
Female Headed HH (indicator)	0.0163**	0.00413	0.0159**	0.00156
	(0.00683)	(0.0143)	(0.00683)	(0.0147)
Dependency Ratio	-0.00183	-0.00274	-0.00184	-0.00496**
	(0.00204)	(0.00187)	(0.00201)	(0.00227)
Education of head in yrs	0.00101	0.000871	0.00101	2.41e-07
	(0.00113)	(0.00287)	(0.00110)	(0.00219)
Settled HH (indicator)	0.00372	-0.0325***	0.00393	-0.0276***
	(0.00636)	(0.00400)	(0.00731)	(0.00526)
Milk Production at Base	-0.000240	0.00777***	-0.000156	0.00682**
	(0.00317)	(0.00173)	(0.00323)	(0.00274)
Milk Production at Satellite Camp	0.0117***	0.0158***	0.0118***	0.0152***
	(0.00193)	(0.00194)	(0.00205)	(0.00196)
Ln(consumption)	0.000680	0.000236	0.000829	-0.000186
	(0.00253)	(0.00158)	(0.00251)	(0.00180)
HH FE	N	Y	N	Y[32]
Constant	-0.0181	-0.0387**	-0.0208	-0.0505
	(0.0243)	(0.0160)	(0.0270)	(0.0907)
Overall R^2	0.90	0.896		
Number of HH		889		
Wald χ^2		471036.22	14152.05	16822.65
		(0.0000)	(0.0000)	(0.0000)

Clustered (HH) standard errors in parentheses. (1) & (3) are bootstrapped (reps=400). (2) does not contain survey weights. Season fixed effects included in all specifications. N=6,807.

*** $p<0.01$, ** $p<0.05$, * $p<0.10$

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[32] Fixed effects in column (4) are implemented using household-level means for all covariates.

Table B5: Binomial[33] MLE of MUAC resilience – marginal effects at representative values of the PLM index

VARIABLES	(1) MLE $\rho_{it}^{MUAC}, \underline{W}^{MUAC} = 13.5$		(2) MLE $\rho_{it}^{MUAC}, \underline{W}^{MUAC} = 13.5$	
	(A)	(B)	(A)	(B)
PLM =	**.039**	**0.265**	**.039**	**0.265**
MUAC_{s-2}	0.0892***	0.0565***	0.0903***	0.0551***
	(0.00180)	(0.00118)	(0.00187)	(0.00136)
PLMindex_{s-1}	1.195***	0.324***	1.321***	0.335***
	(0.0426)	(0.0111)	(0.0567)	(0.0113)
(No drought # insurance) $_{s-1}$	**-0.0318*** **	**-0.0201*** **		
	(0.00439)	**(0.00276)**		
(Drought # insurance) $_{s-1}$	**0.0485*** **	**0.0307*** **		
	(0.00879)	(0.00570)		
(No drought # treatment) $_{s-1}$			**-0.00187**	**-0.00114**
			(0.00335)	**(0.00205)**
(Drought # treatment) $_{s-1}$			**0.00906**	**0.00552**
			(0.00759)	**(0.00467)**
Female Headed HH	-0.111***	-0.0703***	-0.111***	-0.0678***
	(0.00307)	(0.00195)	(0.00331)	(0.00216)
Girl	-0.0479***	-0.0303***	-0.0485***	-0.0296***
	(0.00269)	(0.00177)	(0.00296)	(0.00189)
Dependency Ratio	-0.00744***	-0.00471***	-0.00762***	-0.00465***
	(0.000872)	(0.000554)	(0.000920)	(0.000574)
Education of head in yrs	0.0163***	0.0103***	0.0164***	0.0100***
	(0.000815)	(0.000545)	(0.000858)	(0.000552)
Settled HH (indicator)	0.00197	0.00125	-0.000502	-0.000306
	(0.00275)	(0.00174)	(0.00293)	(0.00179)
Milk Production at Base	0.00239**	0.00151**	0.00268**	0.00163**
	(0.00116)	(0.000736)	(0.00119)	(0.000732)
Milk Pr, Satellite Camp	-0.00127**	-0.000801**	-0.00178***	-0.00109***
	(0.000512)	(0.000324)	(0.000531)	(0.000324)
Ln(consumption)	0.00376***	0.00238***	0.00353**	0.00215**
	(0.00141)	(0.000890)	(0.00154)	(0.000939)
TLU	0.000629***	0.000398***	0.000658***	0.000401***
	(6.80e-05)	(4.30e-05)	(7.13e-05)	(4.42e-05)
# Insured TLU $_s$	0.00640***	0.00405***	0.00550***	0.00335***
	(0.000848)	(0.000542)	(0.00108)	(0.000669)
Pseudo R^2	0.967		0.932	

Clustered (child), bootstrapped (reps=400) standard errors in parentheses. Round fixed effects included in all specifications. N=1,257.

*** p<0.01, ** p<0.05, * p<0.10

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[33] $\hat{\rho}_{is}^{MUAC}$ is assumed to be distributed binomially and fit using the canonical logit link. This is essentially a fraction response logistic regression.