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ABSTRACT

To cope with shocks, poor households with inadequate access to financial markets can sell assets to smooth consumption and, or reduce consumption to protect assets. Both coping strategies can be economically costly and contribute to the intergenerational transmission of poverty, yet limited evidence exists regarding the effectiveness of insurance to mitigate these costs in risk-prone developing economies. Utilizing data from an RCT in Kenya, this paper estimates that on average an innovative microinsurance scheme reduces both forms of costly coping. Threshold econometrics grounded in theory reveal a more complex pattern: (i) wealthier households primarily cope by selling assets, and insurance makes them 96 percentage points less likely to sell assets following a shock; (ii) poorer households cope primarily by cutting food consumption, and insurance reduces by 49 percentage points their reliance on this strategy.

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1 Introduction

Poor households in developing rural economies are highly vulnerable, exposed to climatic and other shocks that can slash incomes and destroy productive assets. For many, binding credit constraints and missing insurance markets limit coping options to the sale of remaining assets or to deep cuts in basic family consumption, both of which can have serious long-term economic repercussions. In this paper we assess the effectiveness of a novel satellite-based microinsurance contract at mitigating these costly coping strategies.

The pastoral regions of northern Kenya and southern Ethiopia are archetypes of this kind of vulnerability. When extreme drought strikes, the effects are devastating. Livestock, the primary asset and source of livelihood, weaken and die. Distressed sales of livestock flood the market, causing downward pressure on livestock prices (Barrett et al. 2003; Kerven 1992). The combination of livestock loss and pro-cyclical price swings debilitates households' main productive resource, making recovery after the drought more challenging for households choosing to sell assets to smooth and maintain consumption standards. Alternatively, in an effort to maintain assets, households may instead choose to cut back on meals and other consumption. Yet by reducing consumption, households undercut critical investments in human capital, inhibiting both current and future productivity. In these ways, a single negative shock can lead to chronic poverty by restricting the ability of multiple generations to generate current and future income.

Microinsurance has been heralded over the past decade as a market-based risk transfer mechanism with the potential to act as a safety net, preventing catastrophic collapse. Although a number of microinsurance pilot projects have appeared in the last few years, relatively little is known about their impacts. There is a modest body of evidence showing that microinsurance can influence households' *ex ante* resource allocation by encouraging them to take on riskier, but higher returning activities. However, almost nothing is known about the effectiveness of insurance after a shock is realized for the simple reason that these impacts are observable only after an insured population receives a shock.

This analysis offers one of the first empirical assessments of the impact of a market-based index insurance contract on a household's ability to cope with shocks *ex post*. This examination is critical, since *ex post* protection is generally thought to be the primary goal of insurance. Other papers simply take as given that insurance will reduce the likelihood of drops in consumption while simultaneously protecting assets. We test this conjecture explicitly. We report impacts of an index-based livestock insurance (IBLI) pilot in Marsabit district of northern Kenya. Since 2010, pastoralists in northern Kenya have had the opportunity to purchase an index-based insurance contract to protect against livestock mortality due to drought. A harsh drought swept the Horn of Africa in 2011 activating IBLI payouts. We use households' reported coping strategies at the time of the payout to empirically study the impact of insurance on consumption smoothing and asset protection. Because the IBLI pilot was rolled out as part of a large-scale randomized controlled trial, we are able to utilize randomly distributed price discount treatments to cleanly identify the impacts of insurance on coping behavior.

We first consider the average impact of insurance on household coping strategies. Our results reveal that insurance leads households on average to radically reduce their dependence on two costly coping strategies that are likely to impair their future productivity. With insurance, households are *on average*: (i) 61 percentage points less likely to anticipate selling livestock in the wake of the 2011 drought, improving their ability to generate income after drought. (ii) 12 percentage points less likely to reduce meals. Only the former estimated impact is statistically significant.

There are a number of reasons to expect that these averages obscure a more complex pattern of heterogeneous impacts. Growing evidence suggests that unique households will employ heterogeneous coping strategies. Both standard and poverty trap models of the accumulation of productive assets predict that asset poor households will actually forfeit consumption (rather than smooth consumption as is often assumed) in times of crisis in order to protect their limited productive assets and subsequent future income-generating capacity. While we might expect asset rich households to modestly reduce consumption in response to a shock that reduces their permanent income, they should in theory be more willing to sell assets in order to smooth consumption in the wake of a shock.

Motivated by this expectation of bifurcated coping behavior, we employ the Caner and Hansen (2004) threshold estimation method to provide evidence of a behavioral threshold in wealth in this setting: consumption smoothing is more common above an estimated threshold, and asset smoothing is more common below an estimated threshold. This finding, interesting in and of itself, implies that simply estimating the average effect of insurance may be misleading. The results of our threshold-based impact analysis show that:

1. Households holding assets above the estimated threshold, who are most likely to sell assets, are (a statistically significant) 96 percentage points less likely to anticipate doing so when an insurance payout is available. Insurance has no significant impact on meal reductions by these predominantly consumption smoothing households.

2. Households holding assets below the estimated critical threshold, who are prone to destabilizing consumption, are (a statistically significant) 49 percentage points less likely to anticipate doing so with insurance. Relative to wealthier households, insurance has a dampened (54 percentage points), yet still significant, impact on asset sales by these asset smoothing households.

Together, these results suggest that insurance can help households to protect assets during crises, without having a deleterious effect on human capital investments.

The rest of the paper is organized as follows. Section 2 briefly reviews both theoretical and empirical literature to explain the coexistence of asset smoothing and consumption smoothing strategies within poor communities. A technical appendix puts forward a stochastic model of intertemporal asset management to clarify when and why some households smooth consumption in the face of shocks, while others smooth assets. Section 3 then provides an overview of the literature studying how insurance might help households to cope with uninsured risk and vulnerability, particularly in developing countries. Following Section 4's background on the research setting and available data, Section 5 outlines our identification and estimation strategies and presents our main findings on the impact of insurance on asset and consumption smoothing strategies. Section 6 concludes.

2 The Coexistence of Consumption and Asset Smoothing

As a prelude to considering the potential impacts of insurance, this section briefly reviews household coping strategies in the absence of insurance and borrowing options. Absent these options, households in the wake of a shock can choose to draw down assets to defend their consumption standard (consumption smooth),[1] or they can preserve assets and destabilize their consumption (asset smooth). While consumption smoothing is sometimes discussed as if it were the primary goal of households' intertemporal savings decisions, there is a modest but growing body of evidence that some, especially lower wealth, households choose to asset smooth instead.

In earlier empirical work on coping strategies, both Townsend (1994) and Jalan and Ravallion (1999) note that poor households less effectively smooth consumption than do wealthier neighbors. In later work, Hoddinott (2006) provides evidence that in the wake of the 1994-1995 drought in Zimbabwe, richer households sold livestock in order to maintain consumption. In contrast, poor households with one or two oxen or cows were much less likely to sell livestock, massively destabilizing consumption instead. In Ethiopia, Carter et

[1] Classic studies of consumption smoothing include (Deaton, 1991; Paxson, 1992; Rosenzweig and Wolpin, 1993; Morduch, 1995; Townsend, 1995; Fafchamps et al., 1998; Gertler and Gruber, 2002)

al. (2007) also find evidence of asset smoothing by the poor, as households coping with a drought attempted to hold onto their livestock at the cost of consumption. Building on Kazianga and Udry's (2006) empirical finding that poor and wealthy households manage their savings and assets differently in the face of shocks, Carter and Lybbert (2012) propose a structural approach to this problem. They empirically estimate an asset threshold, and show that households above an estimated asset threshold almost completely insulate their consumption from weather shocks by drawing down assets, whereas households below the threshold do not, despite having the assets to do so.

These empirical findings on asset smoothing are consistent with a number of theoretical perspectives. While sometimes overlooked, a standard model of the inter-temporal accumulation of productive assets can imply that lower wealth households (those with post-shock asset holdings well short of their desired steady-state levels) will exhibit asset smoothing behavior, whereas wealthier households will not. Multiple equilibrium poverty trap models (*e.g.*, see discussion in Barrett and Carter (2013)), in which accumulation behavior bifurcates around a critical minimum asset threshold, amplify this asset smoothing logic. Specifically, for households in the vicinity of this threshold, assets have a strong dynamic value that incentivizes asset smoothing. Both standard and poverty trap models indicate that we should expect consumption and asset smoothing behavior to coexist in a population with strictly positive, but heterogenous, levels of assets. The technical appendix goes into greater detail on these points using a model of intertemporal choice that spans Deaton's (1991) canonical consumption smoothing model as well as models of productive assets and poverty trap mechanisms.

Asset smoothing behavior lends particular importance to insurance and other risk management interventions. As Hoddinott (2006) points out, even though asset smoothing is an attempt to preserve assets, consumption is an input into the formation and maintenance of human capital. Hoddinott pointedly argues that, "The true distinction lies in households' choices regarding what type of capital - physical, financial, social or human (and which human) - that they should draw down given an income shock." While asset smoothing strategies may be instrumentally rational, they likely come at the cost of immediately reduced consumption, with potentially irreversible losses in child health and nutrition (Carter et al., 2007).

The outcomes of undernutrition and malnutrition are well known. In children, these conditions can lead to muscle wastage, stunting, increased susceptibility to illness, lower motor and cognitive skills, slowed behavioral development, and increased morbidity and mortality (Martorell, 1999). Those that do survive suffer functional disadvantages as adults, including diminished intellectual performance, work capacity and strength. For example, Alderman et al. (2006) show persistent effects of drought shocks in Zimbabwe that caused lower height-for-age scores and lower educational outcomes, presumably due to lower consumption. In women, undernourishment during childhood can be the cause of lower adult body mass, which means increased risk of delivery complications and lower birthweights for the next generation (Martorell, 1999). These outcomes set the stage for a pernicious intergenerational cycle of undernutrition and its destructive effects. Even during adulthood, severe consumption cutbacks diminish muscular strength and increases susceptibility to disease. Such undernourishment in adults can also lead to a nutrition-based poverty trap if it decreases the capacity to do productive work (Dasgupta and Ray, 1986).

Table 1 previews the coexistence of consumption and asset smoothing in the northern Kenya study area. The data (described more fully in Section 4.2) show the percent of surveyed households that reported reducing daily meals and selling livestock during the third (Q3) and fourth (Q4) quarters of the 2011 drought year. Rangeland conditions had begun to deteriorate in late 2010, and livestock mortality and other losses peaked in the third and fourth quarters of 2011. As can be seen in the first column of the table, on average, 60 to 70% of households reduced their daily meals, while less than 30% reported selling livestock in a given quarter to cope with the drought. In considering these figures that signal imperfect consumption smoothing, it is important to note that 95% of all surveyed households had

Table 1: Consumption and Asset Smoothing in Northern Kenya

Variable	Average Response	By Livestock Wealth: Lowest Quartile	Highest Quartile	Difference in Means	By Insurance Purchase: Insured	Uninsured	Difference in Means
Consumption Smoothing							
Q3 Probability Reduce Meals (%)	72	82	61	21***	64	75	10.9***
(prior to payout)	(1.7)	(3.0)	(3.8)	(4.9)	(3.8)	(1.9)	(4.0)
Q4 Probability Reduce Meals (%)	62	72	51	21***	33	71	37.9***
(after receiving payout)	(1.8)	(3.5)	(4.0)	(5.3)	(3.7)	(2.0)	(4.1)
Asset Smoothing							
Q3 Probability Sell Livestock (%)	29	12	44	32***	34	28	-.053
(prior to payout)	(1.7)	(2.6)	(3.9)	(2.5)	(3.7)	(1.9)	(4.1)
Q4 Probability Sell Livestock (%)	27	12	42	30***	11	32	20.7***
(after receiving payout)	(1.7)	(2.6)	(3.9)	(4.7)	(2.5)	(2.0)	(3.9)
Observations	675	163	161		161	514	

Standard errors, including the standard errors of the difference in means, are reported in parentheses.
For the difference in means tests: *** p<0.01, ** p<0.05, * p<0.1.

some livestock that they could in principle have sold had they wished. In other words, despite holding assets that could be used to smooth consumption, these households were not smoothing consumption (as would be expected from the perspective of the classic Deaton model reviewed in the appendix).

While Table 1 shows that asset and consumption smoothing coexist, it also shows that the relative deployment of these strategies varies by household wealth. Columns 2 and 3 of the table display the coping strategy employed by households in the lowest and highest quartiles of the livestock wealth distribution. Lower wealth households are roughly 32 percentage points less likely to sell assets than higher wealth households. While substantial numbers of higher wealth households report some reliance on meal reduction as a coping strategy (61% in Q3),[2] more than 80% of poorer households rely on this coping strategy. These differences in means are statistically significant by a standard t-test.

[2] Given that households lost on average 35% of their productive wealth in the 2011 drought, it is perhaps not surprising to see consumption cut-backs by even wealthier households who must have experienced some drop in their permanent income due to the shock.

In this context, insurance that indemnifies against large losses would seem to provide protection for consumption smoothing households against losing productive assets, while affording asset smoothing households a coping strategy that does not impair the human capital of current and future generations. The last three columns of Table 1 report the difference between insured and uninsured households' ability to smooth consumption and assets before and after receipt of an insurance payout. As can be seen, with the exception of Q3 (pre-payout) livestock sales, insured and uninsured households behave quite differently. The differences are particularly pronounced for Q4 meal reductions (33% of insured households report cutting meals, whereas 71% of uninsured households report an intention to rely on that strategy), and Q4 animal sales (11% versus 32%). While these differences are statistically significant, the key question of course is whether they represent a causal impact, or simply a spurious correlation induced by the fact that different types of households chose to purchase insurance. The rest of this paper is dedicated to correctly identifying the causal relationship between insurance and these costly coping strategies.

3 Prior Evidence on the Impacts of Microinsurance

Insurance is a market-based product that has the potential to act as a safety net (Barrett et al., 2007; Skees and Collier, 2008). It offers an alternative means of coping with negative shocks, allowing the potential smoothing of consumption and nutrition, as well as avoidance of costly asset depletion (Dercon et al., 2008). A growing literature has been devoted to studying the benefits of insurance for poor households in low income countries. This type of insurance (targeted to poor households, and available at low cost) has become known as microinsurance. Barnett et al. (2008), Dercon et al. (2008), Miranda and Farrin (2012) and Cole et al. (2012) provide summaries of the literature. The literature highlights two primary avenues through which insurance might bring about positive impacts. These avenues reflect the fact that households make both *ex ante* risk management decisions and *ex post* risk coping decisions.

Section 2 suggests that poor households are limited in their ability to cope with risk *ex post*. Often such households are forced to choose between destabilizing critical consumption and depleting productive asset stocks, and either decision can result in permanent consequences. In the absence of insurance, there are several potential avenues for *ex ante* risk management, though all similarly involve tradeoffs (Morduch, 1995; Dercon, 2002; Dercon et al., 2008). One option is to simply allocate resources toward activities with lower risk. However, these lower-risk activities generally produce a lower return (Rosenzweig and Binswanger, 1993). Another option is to build up precautionary savings, but such savings must come at the cost of (often critical) investment or consumption today (Deaton, 1991). Households may also choose to reduce their risk exposure by diversifying crop choice, assets or other entrepreneurial activities, but such diversification is not always possible, and is only beneficial when the risk involved is not perfectly correlated across the various activities. Households may instead rely on informal insurance mechanisms, but such mechanisms often offer limited protection, especially against common shocks (Morduch, 1999).

Insurance provides an alternative risk management tool that may reduce the use of these and other *ex ante* risk management strategies. By altering the ability of households to cope with risk *ex post*, insurance may also change optimal behavior before a shock is actually observed. To demonstrate this effect, de Nicola (2015) estimates a dynamic stochastic model of weather-based agricultural insurance. The model predicts that insurance will increase the adoption of riskier but more productive seeds, while simultaneously stimulating decreased investment, as households shift towards higher levels of consumption. This may reflect the idea that investment is a form of precautionary savings in the model. Janzen et al. (2015) use similar methods but allow a non-convexity in the production set, in the spirit of the poverty trap variant of the model outlined in the appendix. The Janzen et al. model generates an endogenous asset threshold around which optimal behavior and equilibrium outcomes bifurcate. It shows that households above the threshold follow de Nicola's prescription: decreased investment and increased consumption as households move away from holding assets as precautionary savings. However, increased investment occurs around the threshold as households assume greater risk in order to attain higher productivity and a higher equilibrium.

Cole et al. (2012) conduct a systematic review of the effectiveness of microinsurance, and specifically index-based insurance, in helping smallholders manage weather-related risks. Their review identifies a substantial evidence gap in the literature on the impact of index-based microinsurance. Several papers have attempted to bridge this gap empirically, but all papers known to the authors focus on the impact of insurance on household's *ex ante* risk management strategies. These papers all show that insurance encourages investment in higher risk activities with higher expected profits. Mobarak and Rosenzweig (2012) provide evidence that farmers in India with access to insurance shift into riskier, but higher-yielding rice production. Cai et al. (2015a) find that insurance for sows significantly increases farmers' tendency to raise sows in southwestern China, where sow production is considered a risky production activity with potentially large returns. Karlan et al. (2013) show that farmers who purchase rainfall index insurance in Ghana increase agricultural investment. Elabed et al. (2014) find that cooperatives with access to area-yield index insurance for cotton increased risky cotton production (and subsequent cotton inputs) in Mali. Cai (forthcoming) demonstrates that tobacco insurance increases the land tobacco farmers devoted to risky tobacco production by 20% in China, suggesting reduced diversification among tobacco farmers. The same paper also finds that insurance causes households to decrease savings by more than 30%, suggesting that households were building up extra savings in order to better smooth consumption in the case of a shock. Hill and Viceisza (2010) use experimental methods to show that in a game setting, insurance induces farmers in rural Ethiopia to take greater, yet profitable risks, by increasing (theoretical) purchase of fertilizer.

While the impacts of insurance on *ex ante* risk management decisions are important, none of these papers are able to assess how an insurance payout directly influences the ability of poor households to recover after a shock.

4 Research Setting and Data

This impact evaluation utilizes data from the index-based livestock insurance (IBLI) pilot project in northern Kenya's arid and semi-arid lands (ASALs). This section provides background information about the research setting, the insurance pilot, and summary statistics from the available data.

4.1 Drought Risk and the IBLI Insurance Pilot in Northern Kenya

More than 3 million pastoralist households live in remote northern Kenya's ASALs. Although broad-based empirical evidence of poverty traps globally has been mixed (Subramanian and Deaton, 1996; Kraay and McKenzie, 2014), in a recent review, Kraay and McKenzie (2014) conclude that the strongest evidence for poverty traps comes from rural remote regions like the ASALs of northern Kenya. Indeed, the single asset livestock-based economy of this region, with its limited available production technologies (a result of both remoteness and a harsh climate), renders growth challenging. Lybbert et al. (2004) and Barrett et al. (2006) use different data and methods to demonstrate nonlinear asset dynamics in the ASALs, such that when livestock herds fall below a critical threshold, recovery becomes difficult, and herds tend to move toward a low level equilibrium. Santos and Barrett (2011) show that access to informal credit in this region is uneven across households and follows a pattern that would be expected in a world of poverty traps. Toth (2015) argues that these nonlinear asset dynamics stem from a critical herd size necessary to support mobility. Small herds are restricted to town centers, where rangeland is regularly degraded, limiting herd productivity and growth. This problem is compounded by an absence of (or uneven access to) formal credit markets: households can't take out a loan to reach the dynamic asset threshold, thereby moving onto a higher welfare path.

Irrespective of whether poverty traps strictly exist in this environment, the evidence does suggest that asset losses in this environment have severe and long-lasting consequences. When drought hits this region, households confront large livestock losses, as well as decreases in current (and future) income flows and consumable by-products (such as milk) generated by livestock (McPeak, 2004). According to the data used for this paper, in the drought that devastated the Horn of Africa in 2011, families lost on average more than one third of their animals. As we have already highlighted, during and after a drought, cash-strapped food-insecure households often have limited options for coping with the harsh effects of drought, and the options available often undercut future productivity.

In January 2010 the index-based livestock insurance (IBLI) pilot project was launched in Marsabit District of northern Kenya in an effort to help pastoralists manage drought risk. IBLI provides payouts to insured households whenever the IBLI index, predicted average livestock mortality, exceeds 15%. This index was established using longitudinal observations of household-level herd mortality fit to satellite-based normalized difference vegetation index (NDVI) measures of available vegetative cover within a particular region. The IBLI index has been shown to be highly correlated with actual livestock mortality losses experienced by pastoralists in the region so that basis risk is perceived to be minimal (see Chantarat et al., 2010, 2012 for details regarding the design and performance of the index). Households choose the number of livestock (goats, sheep, cattle, and camels)[3] they wish to insure, and the premium depends on the risk associated with the geographic region in which they live (for example, Upper Marsabit is more susceptible to extreme drought than Lower Marsabit, so households insuring in Upper Marsabit pay a higher premium). Insured households receive a payout at the end of each dry season (i.e. at the beginning of October and/or early March) if the predicted average livestock mortality rate reaches the minimum payout level (15%),

[3] The IBLI contract is expressed in tropical livestock units (TLUs). A goat or sheep is equal to .1 TLU, cattle are equal to a single TLU, and a camel is equal to 1.4 TLU.

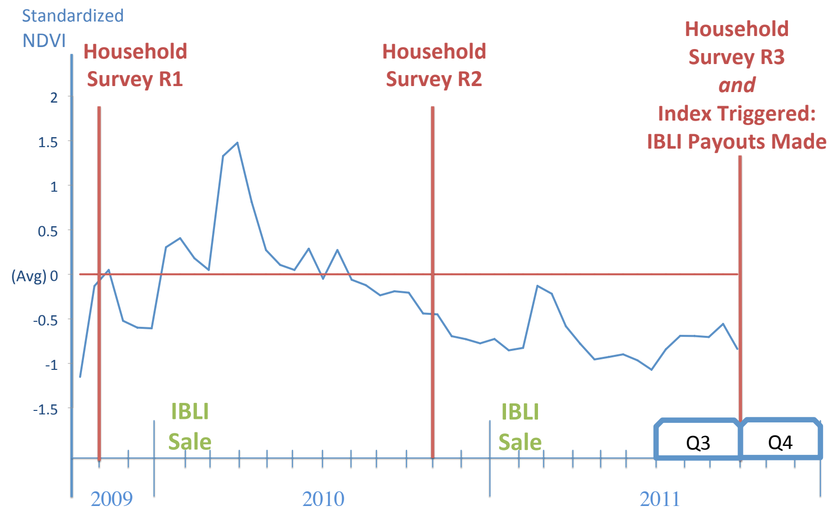
with the payout equal to the value of all predicted losses greater than 15%.

In order to study the impact of this insurance, IBLI was rolled out only in randomly selected districts within Kenya's arid and semi-arid lands. Within these treatment areas, households were randomly selected for both information and price discounts meant to encourage purchase of the insurance. As part of this encouragement design, in each sales period 60% of surveyed households were randomly selected to receive coupons offering a 10-60% discount on the first 15 TLU insured. In addition, some households were randomly selected to participate in experimental games, which were used as a means of communicating the complex concepts of index insurance. The games were designed to demonstrate the intertemporal benefits of insurance by simulating herd dynamics over multiple seasons. They demonstrated that insurance would have to be purchased before the normal rainy season began, and for each subsequent year that coverage was desired. In addition, the games conveyed that indemnity payments were triggered by droughts, that IBLI would not cover non-drought-induced losses, and that if a drought did not trigger payments, the premium would not be returned (see McPeak et al., 2010 for details). Non-participants heard about IBLI from other participants, through village assemblies, by word of mouth or through local village insurance promoters. For the purposes of this analysis, we will focus only on data from the treatment area,[4] using the identification strategy detailed below.

Figure 4.1 depicts fortnightly NDVI averaged across the insured areas of Marsabit district over the 2010-2011 period in which the drought occurred. The measures are normalized by their long-term seasonal averages, so that if conditions had been statistically normal, the NDVI curve would appear in the graph as a horizontal line at zero. As can be seen, rangeland conditions began to deteriorate in late 2010 with the failure of the "long rains." Figure 4.1 shows how the situation deteriorated throughout much of 2011 as a harsh drought swept

[4] Data from control areas was collected by a different research organization on a different calendar which made it impossible to collect the information needed for this analysis in the control areas.

Figure 4.1: Timeline of IBLI Sales, Surveys, Payouts and Standardized NDVI



across the Horn of Africa. The cumulative effect of these below average conditions triggered the first IBLI payouts in October-November 2011, as the predicted livestock mortality rose above the 15% deductible in all five insurance zones. These payouts were made to households who had purchased insurance earlier in the year. Households in our study received an average payout of about 10,000 Kenyan Shillings, or roughly $120. With a median family annual cash income of only $260 in the study area, these payments were a substantial boost to families' cash on hand.

4.2 Data and Descriptive Statistics

The data available includes household-level information collected annually (beginning in 2009) for 673 randomly selected households living in various sub-locations across Marsabit district, all with access to IBLI. In each round of the survey, households were asked to answer questions about health, education, livestock holdings, herd migration, livelihood activities, income, consumption, assets, and access to credit. Each household also participated in an experiment to elicit their risk preferences. In the surveys following the baseline, households were also asked questions about insurance purchases, access to information about insurance, and tested on their level of insurance understanding.

The third round of the panel survey coincided with the October-November 2011 IBLI payout. At that time, every household was asked about the ways in which they had been coping with the drought over the three months prior to the survey (Q3 of 2011, as shown in Figure 4.1), and how they anticipated coping with the drought over the 3 months following the survey (Q4). Specifically, households were asked about reliance each period on common coping behaviors, including selling livestock, reducing meals and relying on food aid. Insured households were asked about anticipated fourth quarter coping behavior after the enumerator told them exactly how much they would receive as an insurance payment. In a few cases, households had already received the payment prior to the interview. Most received the payment a week or two after the survey.

Ideally, data on actual behavior would have been collected 3 months after the payout was received. Given the remoteness of the area, this was deemed cost prohibitive. The usefulness of responses to hypothetical questions for predicting actual behavior has been the source of much debate. The most widely-used application in economics is contingent valuation (CV) with some arguing that any CV surveys are misleading and their use misguided (Diamond and Hausman, 1994), while others have argued that CV can sometimes be a reliable source, and often the only source, of important information (Hanemann, 1994; Carson et al., 2001). In social psychology, the widely cited theory of planned behavior suggests that behavioral intentions do indeed result in actual behavior (Ajzen, 1991). Three meta-analyses of empirical evidence (Albarracin et al., 2001; Sheeran, 2002; Webb and Sheeran, 2006) support the importance of stated intentions for predicting actual behavior. These studies and others acknowledge the limitations of using intentions, as do we, but we agree with them that such intentions are not completely irrelevant for understanding actual behavior.

Another reason we might be interested in these results is precisely because they are based on a household's expectations for improved or degrading circumstances. The most important question is arguably, "Does insurance protect households in the *midst* of a shock (i.e. as conditions continue to deteriorate)?" If households expect the situation to worsen, then their response should reflect that. The data suggests this to be the case - 86% of households anticipated observing some goat/sheep mortality within the herd in the near future, with an average of 22% mortality anticipated. Similarly, 78% of households anticipated some cattle mortality, and 67% expected to observe camel mortality despite the perceived resilience of camels. In reality, predicted livestock mortality (as measured by the IBLI index) across the region decreased shortly after the payout as the drought lessened and the vegetative conditions improved. On one hand, this may mean the actual impacts are smaller than our results reflect. But if our results reflect the impact if the conditions had actually continued to deteriorate, then they are still relevant from a policy perspective.

Table 2 reports summary statistics on key variables disaggregated by whether a household was insured during the 2011 drought. All households had the opportunity to insure, but only 24% had actually purchased insurance. The table provides no evidence that wealthier individuals (as measured by livestock wealth and a non-livestock asset index[5]) are more likely to purchase insurace, although uninsured households are likely to have a higher dependency ratio (the ratio of children less than 15 years, adults greater than 55 years, disabled or chronically ill household members) and be recipients of a cash transfer targeted to the poorest households in the region. Education levels, risk attitudes, credit constraints and savings also vary little between the groups, as do both realized and expected livestock losses. Insured households are more likely to participate in social groups, which could mean they are more

[5] A non-livestock asset index was constructed from the first principle component using factor analysis. Variables used to generate the asset index include housing characteristics (such as materials used in the wall or for flooring in the house), cooking appliances, access to water, and possession of large assets such as a motorbike, boat, sewing machine, grinding mill or television.

Table 2: General Summary Statistics

Variable	By Insurance Purchase: Insured	Uninsured	Difference in Means	By Discount Coupon: Received Coupon	No Coupon	Difference in Means
Permanently Settled	.50	.48	-.025	.50	.46	-.042
(dummy=1 if true)	(.04)	(.02)	(.045)	(.02)	(.03)	(.040)
Livestock Owner	.95	.95	-.001	.94	.96	.016
(owns at least some livestock)	(.02)	(.01)	(.020)	(.01)	(.01)	(.017)
Number of TLU Owned	16.22	18.86	2.64	18.07	18.49	.420
(Oct. 2010)	(1.40)	(1.29)	(2.42)	(1.32)	(1.69)	(2.15)
TLU Owned per capita	2.70	3.54	.85*	3.19	3.59	.404
(Oct. 2010)	(.24)	(.25)	(.457)	(.22)	(.37)	(.407)
Number of TLU Lost	7.67	7.53	-0.137	7.66	7.40	-.265
(between Oct. 2010-2011)	(.49)	(.90)	(1.00)	(.54)	(.69)	(.884)
Expected TLU Losses	6.99	7.43	.442	7.71	6.68	-1.03
(between Oct. 2011-2012)	(.61)	(.36)	(.73)	(.39)	(.51)	(.645)
Farmer	.25	.21	-.041	.21	.25	.034
(farms any agricultural land)	(.03)	(.02)	(.038)	(.02)	(.03)	(.033)
Non-livestock Asset Index 2011	.15	.00	-.150	-.02	.14	.161*
(from factor analysis)	(.10)	(.05)	(.098)	(.05)	(.08)	(.086)
Credit Constrained	.42	.37	-.039	.42	.34	-.078**
(difficulty acquiring a loan)	(.04)	(.02)	(.044)	(.02)	(.03)	(.039)
Borrower	.33	.36	.038	.36	.34	-.024
(Borrowed in past year)	(.04)	(.02)	(.043)	(.02)	(.03)	(.038)
Savings	.18	.16	-.017	.14	.21	.072**
(Any current household savings)	(.03)	(.02)	(.034)	(.02)	(.03)	(.030)
Amount of savings	28890	71498	42608	40353	83441	43088
(If any savings)	(11942)	(18337)	(32063)	(9906)	(27600)	(27988)
Lender	.07	.06	-.004	.07	.06	-.008
(Loaned any money)	(.02)	(.01)	(.022)	(.01)	(.01)	(.020)
HSNP	.32	.43	.103**	.42	.37	-.057
(cash transfer recipient)	(.04)	(.02)	(.044)	(.02)	(.03)	(.039)
Dependency Ratio	.50	.54	.047***	.54	.53	-.009
(<15yrs, >55yrs, disabled, chronic ill)	(.01)	(.01)	(.017)	(.01)	(.01)	(.015)
Cell Phone	.45	.51	.058	.48	.53	.045
(uses at least monthly)	(.04)	(.02)	(.045)	(.02)	(.03)	(.040)
Social groups	.86	.70	-.161**	.78	.66	-.121*
(Number of groups participating in)	(.06)	(.04)	(.077)	(.04)	(.05)	(.068)
Muslim	.26	.26	.003	.27	.23	-.040
(dummy=1 if true)	(.04)	(.02)	(.040)	(.02)	(.03)	(.035)
Christian	.30	.42	.117***	.38	.40	.018
(dummy=1 if true)	(.04)	(.02)	(.045)	(.02)	(.03)	(.040)
Literate	.09	.12	.033	.11	.13	.021
(write a simple letter in English)	(.02)	(.01)	(.029)	(.02)	(.02)	(.026)
Years of Education	.76	1.18	.416	1.03	1.16	.131
(household head)	(.21)	(.15)	(.294)	(.15)	(.21)	(.259)
Risk-taking	.24	.29	.049	.28	.28	-.007
(dummy=1 if risk-taking)	(.03)	(.02)	(.041)	(.02)	(.03)	(.037)
Risk-moderate	.50	.45	-.054	.45	.48	.032
(dummy=1 if risk-moderate)	(.04)	(.02)	(.046)	(.02)	(.03)	(.040)
Age	46.22	49.15	2.93**	47.06	50.87	3.803***
(household head)	(1.22)	(.74)	(1.49)	(.75)	(1.14)	(1.313)
Female	.42	.36	-.059	.37	.37	-.001
(household head)	(.04)	(.02)	(.044)	(.02)	(.03)	(.039)
Observations	161	514		426	249	

Standard errors, including the standard errors of the difference in means, are reported in parentheses.
For the difference in means tests: *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Summary Statistics for Potential Instruments

Variable	By Insurance Purchase: Insured	Uninsured	Difference in Means
Participated in 2009 IBLI Game	.27	.24	-.030
(dummy=1 if true)	(.04)	(.02)	(.039)
Received IBLI Discount Coupon	.88	.55	-.321***
(dummy=1 if true)	(.03)	(.02)	(.042)
Value of IBLI Discount Coupon	23.79	16.46	-7.33***
(of: 0, 10, 20, 30, 40, 50, 60)	(1.83)	(.96)	(1.98)
Observations	161	514	

Standard errors, including the standard errors of the difference in means, are reported in parentheses.
For the difference in means tests: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

connected and informed.

While it is perhaps surprising that there are not stronger differences in observable characteristics between those who did and did not purchase insurance, these two groups may still differ along unobserved dimensions. Table 3 reports values for the information and discount coupon treatments that were randomly offered across the entire population. These descriptive statistics show no correlation between insurance purchase and receipt of an invitation to play the insurance information treatment. However, discount coupons were effective in boosting up-take. Fully 88% of insurance purchasers received a coupon, whereas only 55% of non-purchasers received a coupon. The value of the coupon received also differs sharply between the two groups. As will be discussed in the section that follows, this encouragement design provides useful instruments for our endogenous regressor (insurance), being highly correlated with the decision to insure yet uncorrelated with the outcomes of interest except through purchase of insurance.

5 Estimation Strategy and Results

While the descriptive statistics signal a statistically significant correlation between insurance coverage and third and fourth quarter coping strategies, these differences cannot be given a causal interpretation because the decision to purchase insurance was endogenous and perhaps correlated with factors expected to independently influence coping strategies. The goal of this section is to identify the causal impact of insurance by econometrically exploiting a set of randomly distributed encouragements designed to boost insurance uptake. After explaining the basic identification strategy based on these instruments, section 5.1 presents the average treatment effect of insurance on household coping strategies. Section 5.2 next lays out a threshold-based method of testing for the presence of consumption and asset smoothers, and for the differential impacts of insurance on the behavior of these two groups. We first presents the results utilizing a threshold that has been identified in the empirical literature. We then employ the Caner and Hansen (2004) GMM threshold estimator to identify the existence and location of the asset-based threshold.

5.1 Estimating the Average Impact of Insurance on Coping Strategies

The analysis of the impacts of insurance would be simplest if we could compare a cohort of households randomly assigned to an insurance "treatment" with a control group denied access to insurance. Although IBLI was implemented with a randomized spatial rollout, the data needed for the analysis here are available only within the treatment area (see Section 4.1 above). For this analysis we are thus limited only to a population in which all households had the opportunity to insure their livestock, though not all households chose to do so. Since households must self-select into purchasing insurance, we must account for selection into the insurance treatment.

In the absence of a simple randomized treatment assignment, a variety of techniques exist to control for selection bias. These methods vary according to the underlying assumptions that must be made to use them. Because the endogenous decision to insure is likely to depend on unobservables, our preferred estimates are based on an instrumental variables (IV) approach.

The encouragement design implemented with IBLI (as described in Section 4.2) provides three potentially suitable instruments: participation in an insurance game, receipt of an insurance coupon and the value of the discount coupon received. All are the result of randomization, so none should be correlated with coping strategies, but we expect all to be correlated with insurance uptake. The descriptive statistics reported in Table 3 suggest that the coupon (both its receipt and value) is indeed highly correlated with the decision to insure, and thus constitutes a good instrument. Participation in the insurance game is not as highly correlated with insurance uptake as we might expect, and turns out to be a weak instrument. The right hand columns of Table 2 also checks the balance of the covariates, to ensure that the receipt of the coupon was indeed random. As would be expected, few statistically significant differences are observed. Coupon recipients are three years younger on average and are more likely to have participated in social groups. They are also more likely to report difficulty in acquiring a loan, but equally as likely to have actually taken out a loan. Less than a quarter of households have any savings, and coupon recipients are less likely to save. But if they do save, the amount of savings is not significantly different from non-coupon recipients. As measured by the non-livestock asset index, they do appear to be slightly less wealthy, but herd size is equivalent across the two populations, and wealth is often kept as livestock in this region. In the estimation that follows, we will control for all characteristics of observable imbalance in our vector of controls X_{ij}.

Using IV we obtain the local average treatment effect of insurance on coping strategies. To obtain this effect, we estimate the following first stage regression equation, where I_{ij} is an indicator variable equal to 1 if household i in location j purchased insurance, Z_{ij} is a vector of instrumental variables (including receipt and value of coupon), X_{ij} is a vector of covariates that influence a household's drought-coping behavior, and γ_j represents a location[6] fixed effect:

$$I_{ij} = Z_{ij}\,\delta + X_{ij}\,\theta + \gamma_j + v_{ij} \tag{5.1}$$

We then estimate the impact of insurance (β) on y_{Si}, a binary indicator of household i's use of a particular coping strategy S in the post-insurance payout period, using the following second stage regression:

$$y_{Sij} = \beta_S \widehat{I}_{ij} + X_{ij}\phi_S + \gamma_j + \varepsilon_{ij} \quad , \tag{5.2}$$

where predicted insurance uptake ($\widehat{I}_{ij}$) is obtained from the first stage estimation 5.1.

As with any encouragement design, there may be some concern that the encouragement itself induces an artificial selection into the program, with, for example, households expecting less benefit from the insurance purchasing it only because of the discount coupon. As we will show, the variation in price affects demand much less than the coupon itself, regardless of value. In this context (using a longer time series), Jensen et al. (2014) estimate relatively inelastic demand (-.43). Other research has shown that barriers to the uptake of index insurance in similar contexts are often non-price factors including trust and understanding of the contract, risk aversion, wealth and financial liquidity, and access to informal risk sharing networks, rather than heterogeneous willingness to pay for insurance (Gine et al., 2008; Patt et al., 2010; Mobarak and Rosenzweig, 2012; Cole et al., 2013; McIntosh et al.,

[6] Because households in different geographic locations face different risks and hold their wealth in different species–*e.g.*, more camels in the more arid locations–location fixed effects have a potentially important role to play.

2013; Dercon et al., 2014; Cai et al., 2015b). In this circumstance, encouragement coupons are likely to substantially reduce the mean square error of impact estimates as analyzed in detail by Mullally (2012).

Because the assumptions necessary for IV are minimal given the available data, this is our preferred approach. However, several alternatives to IV exist. Although we do not discuss or present alternative methods in this paper, we obtain very similar results using both matching and Heckman selection methods (see footnotes 7 and 8 below).

Table 4 presents the first stage regression used to obtain the IV estimates. Column (1) includes location fixed effects to control for location-specific rangeland conditions. This approach is used in almost all specifications. Column (2) presents the same first stage without location fixed effects for reasons described later. The first stage results demonstrate a strong correlation between receiving a coupon and insurance uptake. It also demonstrates a minimal (if any) price effect.

Table 5 presents our main impact estimates. We focus on the impact of an insurance payout on two primary outcomes of interest: anticipated fourth quarter livestock sales and anticipated reduction in the number of daily meals consumed in quarter 4. Selling livestock reflects a willingness to destabilize asset holdings, and meal reduction suggests an inability to smooth consumption. In the first column of each table we present population average impacts for each outcome of interest using IV as described above. In the following sections we describe our approach for analyzing threshold-disaggregated impacts; these results are presented in columns (2)-(6) in each table.

Considering first the impact of insurance on curbing the sale of productive assets, the results presented in the bottom panel of Table 5 suggest that an insurance payout substantially reduces the probability that a household intends to sell livestock. The average impact results presented in Column (1) of Table 5 imply a large 61 percentage point reduction in the number of households who anticipated selling livestock in the short run in order to cope

Table 4: Demand for Insurance: First Stage Linear Probability Model Selection Regression

	(1)	(2)
Received IBLI discount coupon	0.29***	0.30***
	(0.061)	(0.053)
Value of IBLI discount coupon	-0.0011	-0.0012
	(0.0013)	(0.0012)
Years of education (head)	-0.016**	-0.019**
	(0.0063)	(0.0067)
Risk-taking	0.0021	-0.023
	(0.037)	(0.034)
Risk-moderate	0.015	0.017
	(0.023)	(0.028)
Non-livestock asset index	0.059*	0.050
	(0.028)	(0.029)
TLU Owned	-0.0011	-0.0011**
	(0.00064)	(0.00040)
TLU losses in past year	0.0025*	0.0019
	(0.0014)	(0.0017)
Expected TLU losses	-0.0012	-0.0017
	(0.0017)	(0.0021)
Credit Constrained	0.025	0.033
	(0.035)	(0.044)
Household currently has savings	0.038	0.017
	(0.039)	(0.044)
Age (head)	-0.0016*	-0.0023**
	(0.00080)	(0.00084)
Number of group memberships	0.0048	0.034
	(0.013)	(0.025)
Constant	0.0068	0.18***
	(0.055)	(0.057)
Location fixed effects	yes	no
Observations	627	627
R^2	0.245	0.125

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

with the 2011 drought.[7] As discussed earlier, when poor households endeavor to maintain scarce productive assets during a shock, it often imposes a high cost on consumption. The top panel of Table 5 reports the estimated impact of insurance on meal reduction as a coping strategy. Focusing first on the local average treatment effect in Column (1), an insurance payout results in a 12 percentage point drop in the number of households that anticipate decreasing the number of meals eaten each day when under stress from a drought.[8] Although the average result for meal reduction is not statistically significant, we show in the next section that the average results may be masking a heterogenous response, as predicted by theory. We turn to that analysis now.

5.2 Consumption versus Asset Smoothing

As discussed in Section 2, a number of theoretical perspectives suggest that less wealthy households may hold on to (productive) assets in the wake of a shock rather than liquidate them to smooth consumption. Poverty trap theory suggests a particularly sharp discontinuity between conventional consumption smoothers and these asset smoothing households. Table 1 shows that both asset and consumption smoothing behaviors are observed in the data. The key question is whether all households pursue a mixed strategy, or whether there are really two distinctive behavioral regimes, as some earlier work has suggested is likely (*e.g.*, Carter and Lybbert (2012)). In the latter case, estimated average treatment effects (β in equation 5.2) are a data-weighted average of the behavior in the two regimes disguising

[7] Heckman selection methods yield an estimate of a 27% point drop, while matching methods yield an average impact of a 30% point drop. Full results are available from the authors.

[8] Both Heckman and matching methods estimated the average impact of insurance to be a 37% point drop in reliance upon meal reductions as a way to cope with the drought.

Table 5: Insurance Impacts on *ex post* coping strategies

		Pre-established Threshold		Estimated Threshold	
	(1)	(2)	(3)	(4)	(5)
	Average	Low	High	Low	High
Panel A: Meal Reduction					
		<15	>15	<9.3	>9.3
Insured	-0.12	-0.31**	-0.05	-0.49**	0.004
	(0.11)	(0.16)	(0.03)	(0.23)	(0.17)
	-	-	-	[-.91, .03]	[-.36, .30]
Location fixed effects	yes	yes	yes	yes	yes
Observations	627	381	246	303	324
R-squared	0.21	0.26	0.23	-	-
Test equality of coefficients		1.65**		1.72**	
Panel B: Livestock Sales					
		<15	>15	<22.4	>22.4
Insured	-0.61***	-0.41**	-0.71***	-0.54***	-0.96***
	(0.16)	(0.20)	(0.16)	(0.17)	(0.24)
	-	-	-	[-.85, -.11]	[-1.46, -.47]
Location fixed effects	yes	yes	yes	no	no
Observations	627	381	246	459	168
R-squared	0.12	0.13	0.24	-	-
Test equality of coefficients		1.14		1.42*	

Standard errors in parentheses. * p<0.10; ** p<0.05; *** p<0.01.

Columns (1) - (3) report cluster robust standard erros, while columns (4) & (5) report asymptotic standard errors and asymptotically conservative 90% confidence intervals in brackets. All estimations include the following control variables: number of years of education (household head), a dummy variable for risk-taking, a dummy variable for risk-moderate, non-livestock asset index, number of TLU owned, number of TLU losses in the past year, number of expected TLU losses, a dummy variable for credit constrained, a dummy variable for if the household currently has savings, age (head), number of group memberships.

how microinsurance actually impacts a population comprised of both asset and consumption smoothers.

Drawing on the theoretical perspectives summarized in Section 2, we hypothesize that coping behavior will bifurcate as we move along a wealth or asset continuum. Above some critical or threshold wealth level, we expect the relatively asset rich households to largely smooth their consumption by destabilizing their asset stocks during a shock (excepting for consumption adjustments due to decreases in permanent income). We would thus expect that microinsurance will result in a reduction of asset sales for these asset rich households if insurance helps them to better protect their assets. In contrast, asset poor households below the hypothesized threshold would find that the intertemporal value of assets is extremely high, and thus be unwilling to part with their productive assets even at the cost of hunger. We would expect that microinsurance will help these asset poor households to better smooth consumption during a shock, even as they cling to their current asset stocks. In terms of our measures, insurance should lead to fewer meal reductions for these households, reducing current hunger and better protecting the human capital of their children.

While we could potentially devise a specification to test if there is a smooth transition from asset to consumption smoothing, we follow the lead of earlier empirical (e.g., Hoddinott (2006), Carter et al. (2007), and Carter and Lybbert (2012)) and theoretical (Zimmerman and Carter (2003)) work and test for a sharp break in coping behavior along the wealth continuum using the following model:

$$y_{Sij} = \begin{cases} \beta_S^{\ell}\widehat{I}_{ij} + X_{ij}\phi_S^{\ell} + \gamma_j^{l} + \varepsilon_{Si}^{\ell} & \text{if } A_{ij} < A^* \\ \beta_S^{u}\widehat{I}_{ij} + X_{ij}\phi_S^{u} + \gamma_j^{u} + \varepsilon_{Si}^{u} & \text{if } A_{ij} \geq A^* \end{cases} \tag{5.3}$$

where $\widehat{I_{ij}}$ is again the instrumented insured variable,[9] A_{ij} is the wealth variable, A^* is the wealth threshold around which coping strategies split, and superscripts ℓ and u indicate the parameter vectors for the lower and upper wealth regimes respectively. Our primary interest

[9]We do not assume a threshold for the first stage equation.

is in β_S^l and β_S^u, including testing for whether the two parameters are different. In the next sections, we explore two alternative methods for performing this test and identifying the critical wealth threshold. The first draws on the relatively rich empirical literature regarding the northern Kenya livestock system which identifies a relatively precise prior on the value of A^*. The second approach more conservatively employs threshold estimation techniques (based on Caner and Hansen, 2004) to simultaneously estimate both A^* and the parameter vectors of interest.

Threshold based on Prior Knowledge

The livestock-based economic system in the northern Kenyan rangelands, the location of this study, have been the subject of substantial empirical investigation. Three studies stand out as using distinct methods to identify a critical asset threshold where economic behavior changes. Lybbert et al. (2004) use panel data to non-parametrically estimate a threshold around which accumulation strategies bifurcate, with households below the estimated threshold heading to a low-level, poverty trap, equilibrium, and those above heading towards a higher level asset equilibrium. Santos and Barrett (2011) hypothesize that informal credit and insurance transactions will be sensitive to the presence of a poverty trap and test indirectly for the presence of a critical asset threshold by examining data on informal transactions. Finally, Toth (2015) hypothesizes that if a poverty trap exists in this environment, it would be driven by a non-convexity in the production function due to minimum herd size necessary to undertake high return seasonal herd migration. He then examines production data directly to identify the existence of such a minimum scale for seasonal migration.

While distinctive in their approaches, these studies all detect asset thresholds in the neighborhood of approximately 8-12 tropical livestock units.[10] We employ the mid-point of

[10] Santos and Barrett (2011) estimate a threshold of 7-10 tropical livestock units per household. Lybbert et al. (2004) estimate the threshold to be between 10-15 tropical livestock units per household. Toth (2015) finds an estimated threshold of 5 tropical livestock units per adult male, which can be converted to approximately

this range (10) as the tipping point in the dynamic system. Consistent with the theoretical analysis of Ikegami et al. (2016) and Carter and Janzen (2015), we anticipate a conservative asset smoothing strategy as households approach this tipping point. However, given the severity of risk in the system (where single drought events can destroy upwards of 40% of household livestock assets), Ikegami et al. (2016) and Carter and Janzen (2015) predict continued asset smoothing behavior by households just above the tipping point as they seek first to reduce their vulnerability, before later shifting behavior toward less conservative consumption smoothing. Using the empirical and theoretical literature as our guide, we thus propose to test model 5.3 using a value of $A^* = 15$. Sensitivity to the use of this pre-established threshold is addressed through the more conservative threshold estimation approach employed in the following subsection.

Returning to Table 5, columns 2 and 3 display the impact of insurance on quarter 4 consumption smoothing and asset protection for households above and below a threshold value of 15 tropical livestock units. The second panel shows the estimated average insurance impact (61 percentage point reduction) on livestock sales masks a larger impact for wealthier households (a 71 percentage point reduction) and a smaller reduction (41 percentage points) for less wealthy households. Impacts for both groups are statistically significant. As shown in the top panel of Table 5, the differential impact of insurance is even sharper for meal reduction. The average effect of a statistically insignificant 12 percentage point reduction (column 1) is shown to be the result of a statistically significant 31 percentage point reduction for less wealthy households and a near-zero impact for households above the 15 TLU wealth level.[11]

7.5 tropical livestock units per household.

[11] Intuitively, the more hypotheses we check, the higher the probability of making a Type I error. The Bonferroni-Holm correction is a conservative approach to address this issue of a familywise error rate. We employ the Bonferroni-Holm correction assuming two hypotheses tests (heterogeneous impacts for low and high wealth households) using the calculated p-values for the threshold-disaggregated insurance impact

These heterogeneous impact results indicate that insurance works differently for households of different wealth levels. For households whose asset levels place them well beyond the poverty trap tipping point identified in the literature, insurance allows them to reduce their reliance on asset sales as a (consumption smoothing) coping mechanism. For households whose asset levels leave them vulnerable to collapse (again, according to best estimates in the literature), insurance has a modest impact on livestock sales and a strong impact on meal reduction as an asset smoothing coping strategy.

Estimated Threshold

While the existing literature provides surprisingly consistent guidance on the location of an asset threshold in the pastoral regions in the Horn of Africa, we can also use our data to directly test for the existence of a threshold. Some earlier empirical literature (Carter et al. (2007) and Carter and Lybbert (2012)) relied on Hansen (2000) to test for the presence of an asset threshold as it relates to differentiated coping strategies. Here, because our key variable (being insured) is instrumented using education and discount coupon treatments from our randomized controlled trial, we rely on the approach of Caner and Hansen (2004) who develop GMM methods to extend Hansen (2000) to the case of an endogenous explanatory variable for which a set of valid instruments exist. As in the Hansen (2000) paper, the Caner and Hansen estimation method tests each possible threshold value $\hat{A}$ (splitting the sample into upper and lower regimes around each $\hat{A}$) and devises a statistic to test whether splitting the sample at $\hat{A}$ is statistically significant as compared to a null hypothesis that no such threshold exists.

Figure 5.1 graphs the relevant test statistic against each possible asset value shown on the horizontal axis. The dashed horizontal line in the figure is the 90% critical value of the

coefficients. Using this method, the estimated heterogeneous impacts remain statistically significant.

test statistic, and for values of the test statistic below that critical level, we can reject the null. The preferred estimate of the threshold is the asset level with the lowest value of the test statistic. When the data indicate a sharp discontinuity, we would expect to see a sharp v-shaped pattern in the test statistic. A less precise discontinuity might yield a flatter, or u-shaped relationship.

As can be seen in Figure 5.1a, the test statistic for reduced consumption reveals a relatively sharp discontinuity, with candidate threshold values ranging from about 8 to 12 tropical livestock units. The best estimate is a threshold of 9.3 TLU, as reported in the top panel of Table 5. While somewhat lower than the pre-established threshold of 15 TLU derived from prior literature, splitting the data at this point reveals a much stronger difference in the impact of insurance between lower and higher wealth households.

Figure 5.1b indicates that the discontinuity in the regression regimes for livestock sales is much less sharply identified. Statistically significant asset threshold values span the range from about 14 to 25 TLU, with a best estimate of 22.4 TLU. The inter-regime insurance impact is again stronger under the estimated threshold (a 42 percentage point difference versus a 30 percentage point difference under the threshold based on prior knowledge).

The standard errors reported in columns 4 and 5 of Tables 5 are the asymptotic standard errors derived by Caner and Hansen. These estimated errors indicate insurance significantly reduces reliance on livestock sales for both lower and upper regime households, but only reduces reliance on meal reduction for lower regime households. While inference based on these standard errors is asymptotically valid (as sample size approaches infinity), Caner and Hansen note the finite sample performance of these standard errors is somewhat poor. Intuitively, they note the asymptotic standard errors do not account for the fact that the threshold is itself a noisy estimate (again, especially in small samples). They thus suggest a statistically conservative approach in which the slope coefficients are calculated for every candidate threshold value whose likelihood ratio statistics indicates rejection of the null at the 80% level. In the case of the meal reduction regression, this procedure involves calculating the confidence interval for every candidate threshold value between approximately 8 to 12 TLU. The suggested conservative confidence interval is the union of the set of confidence intervals (or extreme values) that emerges from this exercise. The third rows in both the top and bottom panels of Table 5 give the 90% interval estimates for the impact of insurance on coping. For the lower wealth group, this confidence interval includes zero, despite a relatively small asymptotic standard error.

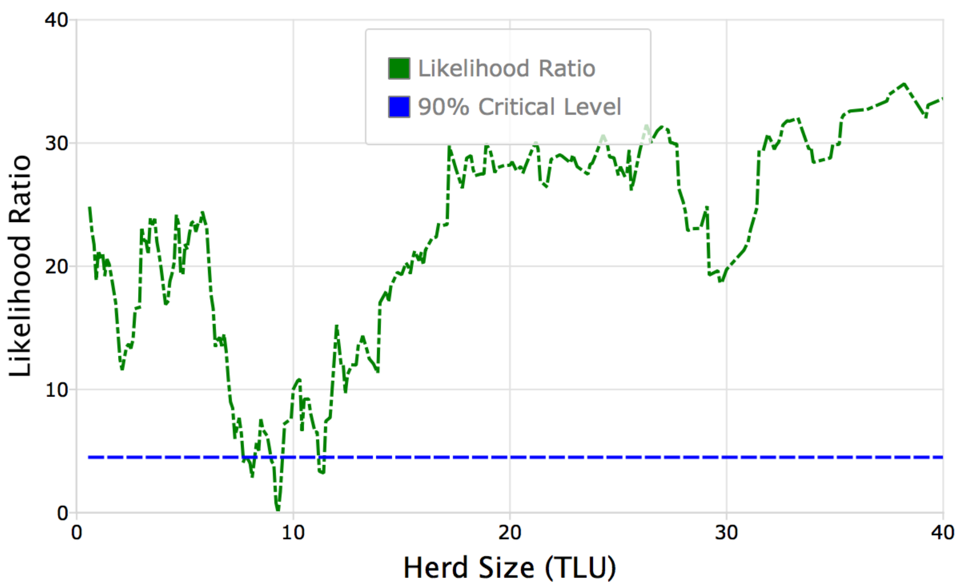
Especially in the case of the livestock sales regression, calculation of these asymptotically conservative confidence intervals requires estimation across a broad domain of candidate threshold values. For some of these values (those at the extreme ends of the domain), the underlying GMM estimation breaks down for reasons of collinearity when location fixed effects are included.[12] While this problem did not emerge for the meal reduction regression with its more precisely estimated threshold, it did prove to be a problem for the livestock sales regression. We thus report results in the bottom panel of Table 5 only for the case of no location fixed effects. While not ideal, we find that inclusion or exclusion of location effects has no noticeable effect on the estimated parameters of the model with the pre-determined threshold. For both low and high wealth groups, the asymptotically conservative confidence intervals exclude zero, indicating statistically significant heterogeneous impacts even after using the more conservative approach.

In summary, these results indicate that receipt of an insurance payment allows households to reduce their reliance on often costly autarkic coping strategies. For modestly better off households, insurance allows households to continue to defend their usual consumption standard without relying on costly livestock sales at depressed prices. For less well-off households, insurance allows them to better smooth consumption while holding on to stocks of

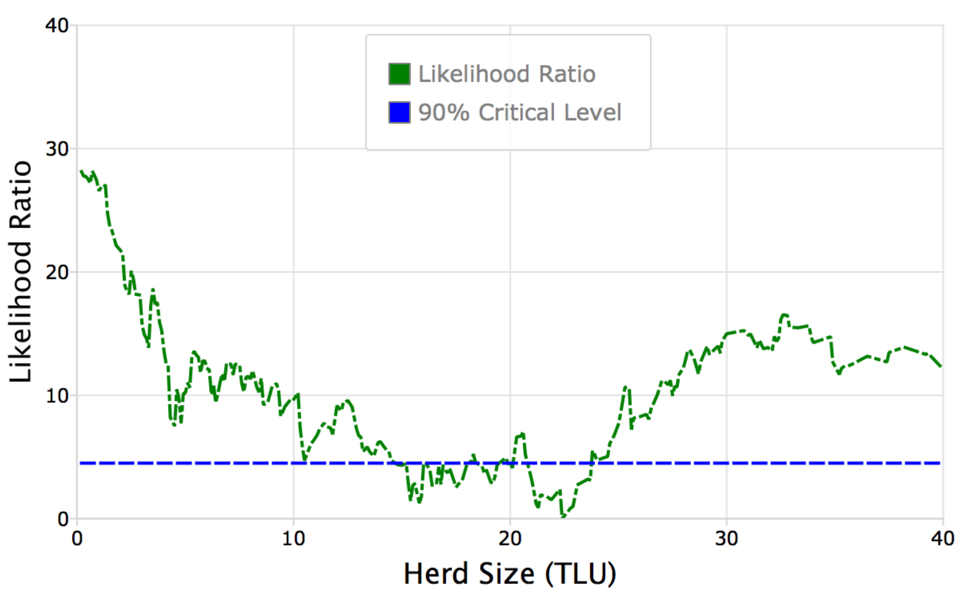
[12] In any given location, there is a minimum and maximum herd size observed in the data. At more extreme threshold values, all observations within a location may fall into a single regime, causing estimation to break down.

Figure 5.1: Significance Test for Asset Threshold in Coping Strategies

(a) Coping via Reduced Consumption



(b) Coping via Livestock Sales



productive assets. This latter result is of particular importance as it suggests that these households do not undercut the growth and future potential of children.

6 Conclusion

When adverse shocks strike in developing countries, poor households are often forced to choose between drawing down their physical productive assets or their human capital. Either way, uninsured risk may have long-term consequences if the household's choice undermines its future productivity. In this paper we assess whether insurance can function as a safety net, protecting assets and smoothing consumption, thereby improving the human capital of future generations. Our findings suggest that IBLI insurance payouts in Marsabit district of northern Kenya during the drought of 2011 provided substantial immediate benefits to insured households. On average, insured households who receive a payout are much less likely to sell livestock, improving their chances of recovery. Insured households on average also expect to maintain their current food consumption, rather than reduce meals as their uninsured neighbors do.

We also show that households in our sample behave quite differently depending on their asset holdings. Using the Caner and Hansen threshold estimator, we cannot reject at the 1% level the hypothesis that there are two, quite distinctive behavioral regimes, with distinctive insurance impacts. Livestock-poor households were more likely to smooth assets and destabilize consumption, whereas livestock-rich households were more likely to smooth consumption during the 2011 drought. One reason (although certainly not the only reason) why we might anticipate a threshold disaggregated behavioral response to drought is the presence of a structural poverty trap.

These findings indicate that simply estimating the average effect of insurance masks an interesting heterogeneous impact of insurance. The threshold-disaggregated estimates show that insurance helps stop the households most likely to give up productive assets from reducing their asset base, otherwise harming the household's future income-earning potential. In addition, insurance helps prevent those households most likely to reduce consumption from doing so, thereby protecting vulnerable household members from undernutrition and malnutrition, and improving the human capital of future generations. Considered jointly, these impacts imply that insurance functions as a flexible safety net, allowing smoothing of consumption and nutrition, while preserving productive assets and future livelihoods. In this way, insurance promotes asset smoothing without having the deleterious long term consequences of destabilized consumption.

These results come at a critical time for policymakers. There has recently been a push from development agencies to scale up microinsurance pilots with the goal of reaching a larger number of households. This push has transpired in spite of an incomplete understanding of microinsurance impacts. The results presented here provide some of the first empirical evidence that insurance can improve outcomes when negative strikes occur. We recognize that our main results are based on immediate expectations regarding a specific insurance pilot project, and are therefore not immediately generalizable. Indeed, further impact analyses will help to generalize the results more broadly. However, this research provides an important first step. If the declared intentions of pastoralists in northern Kenya closely follow their true behavior, then the highly anticipated long term positive welfare impacts of IBLI and other similar microinsurance projects are likely to be observed in the near future.

Appendix: Models of Asset and Consumption Smoothing[13]

Deaton's (1991) model of savings and asset management in the presence of liquidity constraints provides a useful starting point for thinking about whether a household will sell or destabilize assets to smooth consumption in the wake of a shock, or whether it will destabilize consumption in order to protect and smooth assets. Deaton's model can be written as:

$$max_{\{c,L\}} E_0 \left\{ \sum \left(\frac{1}{1+\delta} \right)^t u(c_t) \right\} \tag{6.1}$$

$$subject\, to:$$

$$x_t(\theta, L) = \theta_t + rL_t + L_t$$

$$c_t \leq x_t \; \forall t$$

$$L_{t+1} = x_t - c_t$$

$$L_t \geq 0 \; \forall t$$

where the key element is $x_t(\theta_t, L_t)$, time t net wealth or cash-on-hand, which depends on the stock of assets (L_t) and the realized shock (θ_t). Reflecting the existence of borrowing constraints, consumption in any time period (c_t) can never exceed cash on hand and assets must be positive.

Deaton's model imagines that income is generated primarily by a stochastic wage process (θ_t) that is independent of the stock of assets. Assets themselves generate a non-stochastic return, or rate of interest, r. Under these assumptions, Deaton shows that the optimal

[13] This appendix draws on other work and is intended to clarify the theory that underwrites the structure of the empirical testing strategy employed in the paper.

solution to this problem will be characterized by the following behavior:

$$u^{'}(c_t) = max\left\{u^{'}(x_t), \beta E_t[u^{'}(c_{t+1})]\right\} \tag{6.2}$$

where $\beta = \frac{1+r}{1+\delta}$ will be strictly less than 1 if we assume agents are impatient and discount the future at a rate higher than the rate of interest. As long as shocks are i.i.d., this condition implies smooth consumption whenever $u^{'}(x_t) \leq \beta E_t[u(c_{t+1})]$. That is, individuals will consume assets in an effort to stabilize consumption.[14] If $u^{'}(x_t) > \beta E_t[u(c_{t+1})]$, then individuals will stock out and consume all of their cash-on-hand.

While neatly demonstrating the logic of consumption smoothing in the presence of liquidity constraints that define reality for many poor households, the implications of the Deaton model change if assets are productive. A simple way to model this change is to rewrite the cash on hand constraint as

$$x_t(\theta_t, L_t) = f(L_t) + (1-\tau)\theta_t L_t \tag{6.3}$$

where $f(L_t)$ is a production function with the usual properties ($f' > 0, f'' \leq 0$ and $f' \to \infty$ as $L_t \to 0$) and risk is redefined as a shock to the asset stock which depreciates at some rate τ. Under this specification, agents will no longer be impatient as assets approach zero and will optimally destabilize consumption in order to rebuild productive assets. The poorer a shock makes an agent, the more her current consumption will fall in an attempt to protect future consumption.

Furthermore, if we assume the sort of non-convex production structure assumed in some of the poverty trap literature (*e.g.*, Dercon 1998, Buera, 2009), we can rewrite the production

[14] If shocks are not i.i.d., then the underlying probability structure will be conditional on θ_t leading agents to adjust the expectation of $u^{'}(c_{t+1})$ upwards in the wake of a bad shock, thus causing the individual to consume less than she otherwise would were the probability structure independent.

function as

$$f(L_t) = max\left\{f^h(L_t), f^\ell(L_t)\right\} \tag{6.4}$$

where the superior, high technology, f^h always exhibits higher marginal returns to capital but is subject to fixed costs such that $f^\ell > f^h \; \forall \; L_t < \bar{L}$. As analyzed by Carter and Ikegami (2009), for example, this kind of model can result in multiple equilibria, with a behavioral asset threshold dividing asset space into agents attracted to a long-run equilibrium relying on the low technology (the "poverty trap" equilibrium), and those attracted to the high technology. As Carter and Lybbert (2012) illustrate using numerical dynamic programming methods, the future value of assets rises sharply in the vicinity of this behavioral threshold. That is, additional assets next year are valuable not only because their instantaneous returns ($f^{'}$) are high, but also because they reduce the probability that the individual will fall below the threshold and collapse to the long-term poverty trap equilibrium. Given this additional strategic value attached to asset accumulation, households in this model will exhibit a strong tendency to preserve remaining assets and destabilize consumption in the wake of a shock that pushes them back towards this critical behavioral threshold.[15]

In summary, economies, such as the pastoral regions of East Africa in which assets are both productive and subject to periodic shocks, are expected to exhibit multiple behavioral regimes when it comes to coping with shocks. Those households close to a high steady state capital level will approximate conventional consumption smoothing behavior. Poorer households, or households made poorer by large asset losses, will tend to cut consumption in order to defend and rebuild remaining assets. This asset smoothing behavior is likely to be more pronounced in the face of non-convex technologies.

[15] As has been overlooked by some authors, poverty trap theory suggests that there may be a second group of consumption smoothers found in the vicinity of the steady state associated with the low technology.

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