Valuing Asset Insurance in the Presence of Poverty Traps

Sarah A. Janzen, Michael R. Carter and Munenobu Ikegami

January 2013

Abstract:

A growing literature on poverty traps advocates that social protection policies which aim to help households manage risk will more effectively alter poverty dynamics if such policies also account for a critical threshold, around which both equilibrium outcomes and optimal behavior bifurcate. In this paper, we account for this type of threshold, and examine whether insurance can achieve the goals of social protection. Unlike traditional publicly-provided social protection, such as cash transfers or food aid, insurance is a market-based risk management tool that protects households only if they self-select into purchasing an insurance contract. Stochastic dynamic programming methods reveal low demand for asset-protection insurance is optimal for vulnerable households whose assets are near a critical threshold, because the opportunity cost of insurance at the threshold is especially high. Paradoxically, these same households have the most to gain from protection of this kind. Despite low demand, an insurance-induced behavioral response and the ability to protect assets in the future reduces vulnerability for these same households. We consider this impact on poverty dynamics in a typical setting by calibrating the model to the northern Kenyan rangelands, where evidence of a poverty trap exists and pastoralists have the opportunity to insure livestock against drought losses. (JEL D91, G22, H24, O16).

Sarah Janzen is a Ph.D. candidate in the Department of Agricultural and Resource Economics at the University of California, Davis. Michael Carter is a Professor in the Department of Agricultural and Resource Economics at the University of California, Davis. Munenobu Ikegami is a post-doctoral scientist at the International Livestock Research Institute in Nairobi, Kenya. We thank the BASIS Research Program on Poverty, Inequality and Development and UKaid (Department for International Development) for financial support. We also thank seminar participants at the 2012 NEUDC Conference, the 2012 AAEA Annual Meeting, the Pacific Development Conference 2012, the 7th International Microinsurance Conference and the I4 Technical Meeting 2011 for helpful comments. All errors are our own.

Social protection policies and programs have been widely heralded as important for addressing observed persistent poverty. The aim of social protection is to enhance the capacity of poor and vulnerable persons to manage economic and social risks. In developing countries, this protection often takes the form of food aid or cash transfers. In this paper, we focus on a particularly vulnerable subset of the population, and ask whether a market-based mechanism, insurance, can achieve the same goals as publicly-provided social protection.

In order to be most effective, social protection must address poverty dynamics and the full range of factors that keep people in poverty (Barrientos, Hulme, and Moore, 2006). This requires a clear understanding of the structural foundations behind persistent poverty. The growing literature on poverty traps suggests that in some environments there exists a critical asset threshold, sometimes referred to as the Micawber[1] threshold, at which both equilibrium outcomes and optimal behavior bifurcate. In other words, two stable equilibria exist, a high (good) equilibrium, and a low (poor) equilibrium. These equilibria are separated by a third unstable equilibrium: the Micawber threshold. In this type of environment, uninsured risk and vulnerability play a key role because shocks can have permanent consequences. For example, if a shock causes a household's assets to fall below the threshold, they move toward a permanent low equilibrium and find themselves "trapped" in poverty. For this reason, households holding assets near the threshold can be considered the most "vulnerable."

Barrett, Carter, and Ikegami (2013) account for this structural foundation of persistent poverty by modeling social protection provision in a setting of poverty traps, in which they explicitly model a dynamic asset threshold. They compare two strategies of providing social protection: one which targets the poorest households, and one which targets the Micawber threshold. They find, perhaps counterintuitively, that the welfare of the poorest will be

[1]The label 'Micawber' stems from Charles Dickens' character Wilkens Micawber (in *David Copperfield*), who extolled the virtues of savings with his statement, "Annual income twenty pounds, annual expenditure nineteen nineteen and six, result happiness. Annual income twenty pounds, annual expenditure twenty pounds ought and six, result misery." Lipton (1993) first used the label to distinguish those who are wealthy enough to engage in virtuous cycles of savings and accumulation from those who are not. Zimmerman and Carter (2003) went on to apply to the label to describe the dynamic asset threshold for the type of poverty trap model we analyze here. Thus, the Micawber threshold divides those able to engage in a virtuous cycle of savings and accumulation, from those who cannot.

higher in the long run under the policy which prioritizes the vulnerable poor (those near the Micawber threshold) if aid budgets are limited. This result stems from limiting unnecessary deprivation. These findings suggest potentially large returns to targeting social protection assistance at a critical asset thresholds. Although theoretically insightful, the main policy recommendations are practically and politically infeasible. First, it is difficult to justify using limited aid budgets on a policy which temporarily favors the vulnerable over those suffering from life-threatening food security, regardless of predicted dynamic welfare improvements. Second, critical asset thresholds are difficult to pinpoint, may vary across time and space, and may even depend on unobservable factors at the household level. Such imperfect information about thresholds means that distinguishing target populations remains a substantial hurdle.

In this paper we recognize that publicly providing threshold-targeted social protection is largely infeasible. Instead, we examine whether threshold-targeted protection can be achieved through a market-based risk management mechanism, insurance. Unlike publicly-provided protection, insurance requires that households self-select into purchasing a contract. One might hypothesize that insurance should be most attractive to vulnerable households if it prevents them from falling below the threshold in the event of a shock. This provides a means of self-targeting. Thus, our primary research question becomes: will vulnerable households situated at the threshold self-select into a well-designed insurance program? If yes, then insurance can achieve the goals of publicly-provided threshold-targeted social protection for vulnerable households at zero cost to the public. Meanwhile, limited aid budgets can still be used to assist the least well off through traditional social protection policies. In what follows, we disprove this commonly expressed hypothesis.

To answer this question, we begin in Section 1 by reviewing some of the key literature regarding poverty traps, social protection and insurance. In Section 2, we develop a dynamic model of investment, consumption and asset insurance in the presence of a structural poverty trap. The theoretical model provides the initial intuition for understanding optimal behavior by vulnerable households: that the optimal insurance decision depends jointly on the opportunity cost of future assets and the benefit-cost ratio of insurance. We then numerically solve a dynamic stochastic model to determine whether vulnerable households will self-select into a pure market-based insurance contract. The model is calibrated to reflect an actual asset insurance contract available in northern Kenya, where pastoralists can choose to insure their livestock against drought losses (Chantarat et al., 2007, 2012; Mude et al., 2009). This case study is a particularly relevant application because previous analyses of the livestock-dependent economy in this region have provided strong evidence of a poverty trap (Lybbert et al., 2004; Santos and Barrett, 2011; Barrett et al., 2006; McPeak and Barrett, 2001)

In Section 3 we present the optimal insurance policy function. Our main contribution stems from this counterintuitive result: the benefit of insurance is highest for the most vulnerable households in the Micawber region, but it's not optimal for them to insure (in the current period). This is because vulnerable households face a high opportunity cost of liquidity. At first glance, this result suggests that insurance cannot operate as threshold-targeted social protection, because vulnerable households will not self-select into an insurance contract. However, in Section 4 we explore the impacts of insurance secured through changes in future expectations. These altered beliefs provoke an important behavioral response through which we show that vulnerable households, and even semi-vulnerable households, are dynamically better off in an environment with insurance even if they don't insure in the current period. We develop these findings further in Section 4.3 by looking at household asset dynamics for a population under various social protection programs. We show that insurance will substantially improve poverty dynamics with subsidies offering only marginal improvements. Section 5 closes with some concluding remarks.

1 Poverty Traps, Social Protection and Insurance

Economists typically define poverty traps as "any self-reinforcing mechanism which causes poverty to persist" (Azariadis and Stachurski, 2005). The study of poverty traps therefore focuses on the structural foundations of chronic poverty by attempting to identify and explain the existence of low well-being "basins of attraction" within an economy (Barrett and Carter, 2013).

Many types of poverty traps are thought to exist. In this paper we focus on a multiple equilibrium poverty trap in which at least one equilibrium is associated with low levels of welfare, and another is associated with high welfare. The existence of multiple stable steady states implies also the existence of at least one "threshold" or "tipping point" at the boundaries between the two regions. Most recent studies of poverty traps use an asset-based approach building on Carter and Barrett (2006), who suggest that the relevant threshold can be viewed in asset space. Furthermore, identification of a dynamic asset poverty threshold allows researchers to distinguish between persistent and transitory poverty by understanding the underlying patterns of asset dynamics.

For example, consider two households with similar asset levels near the asset threshold. Such seemingly similar households may end up on divergent paths if they begin on opposite sides of the dynamic asset threshold. Moreover, in a risky setting a single asset shock can have permanent consequences if it shifts households onto an alternative path. In particular, a shock which drops a household to a level of assets below the dynamic asset threshold inevitably sends them into a poverty trap, destined for the low-welfare steady state equilibrium.

This ex post effect of shocks is not the only way that risk affects poverty dynamics when a poverty trap exists. Evidence exists to suggest that ex ante vulnerability may cause households to limit their exposure to risk by choosing lower risk activities at the cost of higher expected returns. If perceptions of asset thresholds induce a risk response, as both theoretical (Lybbert and Barrett, 2007, 2011) and empirical evidence (Carter and Lybbert, 2012; Santos and Barrett, 2011; Hoddinott, 2006) suggest, then ex ante coping strategies can actually influence the location of the relevant dynamic asset threshold. In this way, the dynamic asset threshold that matters is based on the choices available to the consumer and her optimal behavior. In addition, the threshold can actually shift as the environment around it changes.

Although much analytical and empirical work supports the existence and importance of poverty traps, seldom has the knowledge of poverty traps and dynamic asset thresholds guided the design and development of policy tools. Barrett, Carter, and Ikegami (2013) are an exception. They use a numerical dynamic programming simulation to compare needs-based social protection with a budget-neutral "threshold-targeted" policy. The details of the model can be found in their paper, but we summarize here an important inter-temporal paradox which stems from their analysis. While a purely needs-based distribution of aid is initially favorable to the poorest, over time they must compete for transfers with the previously vulnerable non-poor who have since fallen into the ranks of the poor. If the aid budget remains constant, then individual transfers shrink as more people collapse into poverty, unable to graduate from poverty without larger transfers. Over time the initially poorest would have fared better if at least some aid had been devoted to a threshold-targeted scheme. In essence, the model shows that threshold-targeted policies can achieve the major aims of social protection by eliminating unnecessary deprivation.

Obviously, the Barrett, Carter, and Ikegami (2013) model depends on large assumptions of perfect information and targeting. Moreover, the policy paradox they present - that everyone is eventually better off if limited funds are allocated first to those marginally better off rather than the poorest of the poor - represents a conundrum for those who truly seek to help those suffering from devastating poverty. In this paper we want to see if we can generate the benefits of threshold-targeted social protection policies using a risk transfer contract, insurance, for which beneficiaries pay a market, or near-market price.

Microinsurance has experienced a boom in the development community in the past decade. Index insurance, in particular, has been used in a variety of contexts in an attempt to circumvent some of the fundamental problems that have hampered the development of insurance contracts in the past. Such issues include high transaction costs, adverse selection and moral hazard. Index insurance differs from traditional insurance in that the indemnity payments are based on an indicator which is outside the influence of the insured. A growing literature has been devoted to studying the benefits of insurance, and especially index insurance, for poor households in low income countries (Alderman and Haque, 2007; Barrett et al., 2007; Barnett, Barrett, and Skees, 2008; Chantarat et al., 2007; de Nicola, 2011; Skees and Collier, 2008; Smith and Watts, 2009).

Two papers in particular have theoretically analyzed the benefits of insurance in the presence of poverty traps. Chantarat et al. (2010) and Kovacevic and Pflug (2011) both consider whether an active insurance market can work as a safety net for vulnerable households. In their analysis, Chantarat et al. present the primary dilemma faced by threshold households. Suppose a household situated precariously above the Micawber threshold makes a payment which drops them below the threshold. If the weather turns sour, such that an indemnity payout is received, then decumulation is averted. The households welfare is improved, and they are on a positive herd growth trajectory toward a high level equilibrium. However, if nature provides good weather then no indemnity payment is received, but because the premium was too costly, the household is now on a path of decumulation toward the low level equilibrium. These findings are similar to a more mathematical treatment of the same question by Kovacevic and Pflug (2011). Their ruin theoretic approach shows that for households with capital above but near the critical asset threshold, the probability of collapse to a low level equilibrium increases with the introduction of insurance since the premium payments reduce the ability to create growth.

A critical limitation of these studies is that they both restrict behavioral choice, focusing instead on a state variable which follows a stochastic, albeit deterministic path to determine each household's future welfare. In doing so, the models ignore the endogenous ex ante effect of the risk reduction brought about by insurance as well as the household's optimal insurance choice. Our paper builds on the intuition established in both of the papers mentioned, and then takes each analysis one critical step further by allowing greater flexibility of behavioral choice. Specifically, our model allows us to see whether we should expect households at the threshold to actually choose to purchase insurance, and how the presence of an insurance market will influence other behaviors as part of their risk management strategy.

2 A Dynamic Model of Asset Insurance

In this section we present a dynamic household model of consumption, investment and asset insurance in the presence of risk and a structural poverty trap. To build intuition we first consider the autarkic problem, where households do not have access to an insurance market, before adding the complexities of insurance.

2.1 Poverty Dynamics in the Absence of Insurance

Consider the following dynamic household model. Each household has an initial endowment of assets, A_0, where the subscript denotes time. Households maximize intertemporal utility by choosing consumption (c_t) in every period. The problem can be written as follows:

$$\max_{c_t} \quad \mathbb{E}_{\theta,\varepsilon} \sum_{t=0}^{\infty} u(c_t)$$

subject to:

$$\begin{aligned} &A_{t+1} = f(A_t) - c_t + (1 - \theta_{t+1} - \varepsilon_{t+1})A_t \\ &f(A_t) = \max[F^h(A_t), F^l(A_t)] \\ &c_t \leq A_t + f(A_t) \\ &A_t \geq 0 \end{aligned} \tag{1}$$

The first constraint is the equation of motion for asset dynamics. It can also be thought of as an intertemporal budget constraint, with liquidity expressed in asset units. The model assumes that assets are productive ($f(A_t)$), decrease with consumption (c_t), and are subject to stochastic depreciation, where θ_{t+1} is a covariate shock and ε_{t+1} is an idiosyncratic shock. The covariate shock θ_{t+1} is the same for all households in a given period, but idiosyncratic shock ε_{t+1} is specific to the household. Both shocks are exogenous, and realized for all households after decision-making in the current period (t), and before decision-making in the next period ($t+1$) occurs.

As is common in the literature on poverty traps, the second constraint assumes households have access to a high and low productivity technology, $F^h(A_t)$ and $F^l(A_t)$, respectively. The technological choice is endogenized such that fixed costs associated with the high technology make it the preferred technology only for households above a minimal asset threshold, $\tilde{A}$. Thus, households with assets greater than $\tilde{A}$ choose the high technology, and households below $\tilde{A}$ choose the low productivity technology. This creates a non-convexity in the income-generating process, which can generate (but does not guarantee) a bifurcation in optimal consumption and investment strategies. This bifurcation happens if a steady state exists both below and above the kink, such that some households holding assets below $\tilde{A}$ but above a critical asset threshold A^{MT} strive to reach $\tilde{A}$ by dramatically changing optimal strategies in the vicinity of A^{MT}. This asset level where optimal dynamic behavior bifurcates, A^{MT}, is what Zimmerman and Carter (2003) label the Micawber Threshold. In the absence of a negative shock, households holding assets greater than A^{MT} move toward the high equilibrium, whereas households holding assets below A^{MT} move toward the low welfare equilibrium. The latter households are considered "trapped."

The poverty trap mechanism is not complete without the third constraint which assumes a lack of available credit markets. This assumption implies that consumption cannot be greater than current production and assets, but it does not preclude saving for the future. In addition, asset levels are assumed to be non-negative.

It is informative to express the household's optimization problem in terms of the Bellman Equation. We consider the simple case where the shocks are distributed i.i.d., so that the most recent shock, either covariate or idiosyncratic, does not give any information about the next period's shock. In this case, there is only one state variable, A_t.[2] We include an A subscript on the value function to distinguish the autarky problem from the insurance problem presented in the next section. Under these assumptions, the Bellman Equation is:

$$V_A(A_t) = \max_{c_t} \quad u(c_t) + \beta\, \mathbb{E}_{\theta,\varepsilon}[V_A(A_{t+1}|c_t, A_t)] \tag{2}$$

The intertemporal tradeoff between consumption and investment faced by the consumer is captured clearly by the first order condition:

$$u'(c_t) = \beta\, \mathbb{E}_{\theta,\varepsilon}[V_A'(A_{t+1})] \tag{3}$$

A household will consume until the marginal benefit of consumption today is equal to the discounted expected value of assets carried forward to the future.

At the Micawber threshold A^{MT}, incremental assets are strategically important. In a model similar to this one, Carter and Lybbert (2012) point out that the future value of assets can swell around the Micawber threshold, because it represents a tipping point between dynamic movement toward the stable high or low equilibrium. Investing in assets can have the benefit of moving the household over the tipping point toward the high equilibrium, whereas a decrease in assets forces such households toward the low equilibrium. As Carter and Lybbert demonstrate numerically, this increased value of future assets can be reflected in a swollen $V_A'(A_{t+1})$ when $A_{t+1} = A^{MT}$. For this reason, one may expect to observe asset smoothing (at the cost of current consumption) around A^{MT}.

[2] If instead the shocks are serially correlated, the agent would use the most recent shock to forecast future asset levels. The state space would then include current and maybe past realizations of θ and ε in addition to A_t. This extension is considered in the absence of a poverty trap in Ikegami, Barrett, and Chantarat (2012).

2.2 Poverty Trap Model with Asset Insurance

Let us now suppose households are given the opportunity to insure their assets. With insurance, a household has the ability to protect assets which are then carried forward to the future. Formally, if the household wants insurance, it must pay a premium equal to the price of insurance (p) times the number of assets insured (I_t). We assume the number of assets insured cannot exceed the number of current assets.

Because of the rapid expansion and development of index insurance contracts in developing countries over the past decade, we consider index insurance rather than traditional insurance. The basic index insurance contract specifies that a payout will be made if the aggregate index ($i(\theta)$), which depends on the the aggregate shock (θ) but not the household-specific shock (ε), exceeds a certain strike point (s). In our specification, s can be likened to a deductible, the maximum covariate loss incurred by an insured household. Payment (δ) then covers all predicted aggregate losses over and above s. In this way, the insurance payout for each unit of insurance purchased at time t is simply $\delta = \max((i(\theta_{t+1}) - s),\ 0)$.

A notable feature of index insurance is that the insurance contract and payments are based on an aggregate index, rather than individual outcomes, a feature made clear by the definition of δ. In this case, both realized losses and the index depend on the covariate shock. While they are positively correlated, they need not be perfectly correlated because households are also subject to idiosyncratic losses (ε). The difference between individual losses and the index represents basis risk. Hence, risk enters the problem in three related ways: the covariate shock (θ_t), the idiosyncratic shock (ε_t), and basis risk $((i(\theta_t) - \theta_t) + \varepsilon_t)$. To simplify the problem we assume the index perfectly predicts the covariate shock, so that $i(\theta_t) = \theta_t$, and basis risk is simply captured by ε.

The household dynamic optimization problem with a market for insurance is now to choose consumption and a level of insurance which maximizes intertemporal utility. This can be written as follows:

$$\max_{c_t,\, 0\leq I_t\leq A_t} \qquad \mathbb{E}_{\theta,\varepsilon}\sum_{t=0}^{\infty} u(c_t)$$

subject to:

$$\begin{aligned}
&A_{t+1} = f(A_t) - c_t + (1-\theta_{t+1}-\varepsilon_{t+1})A_t + (\delta(\theta_{t+1}) - p)I_t \\
&f(A_t) = \max[F^h(A_t), F^l(A_t)] \\
&c_t + pI_t \leq A_t + f(A_t) \\
&A_t \geq 0 \\
&\delta(\theta_{t+1}) = max\ ((\theta_{t+1} - s),\ 0)
\end{aligned} \tag{4}$$

This can also be expressed as a Bellman equation:

$$V_I(A_t) = \max_{c_t,\, 0\leq I_t\leq A_t} \; u(c_t) + \beta\, \mathbb{E}_{\theta,\varepsilon}[V_I(A_{t+1}|c_t, I_t, A_t)] \tag{5}$$

There are now two first order conditions:

$$u'(c_t) = \beta\, \mathbb{E}_{\theta,\varepsilon}[V_I'(A_{t+1})] \tag{6}$$

$$\mathbb{E}_{\theta,\varepsilon}[V_I'(A_{t+1})(\delta - p)] = 0 \tag{7}$$

The first constraint looks the same as Equation 3 except that insurance may actually change the expectation of future asset holdings and therefore future well-being, so that the term on the right hand side can be altered by the presence of an insurance market.[3] If it is, then we would expect optimal consumption and investment to change when an insurance market is introduced. Highlighting the importance of these altered ex ante risk coping strategies is one contribution of this paper.

[3] That is, $\mathbb{E}_{\theta,\varepsilon}[V_A'(A_{t+1})]$ is not necessarily equal to $\mathbb{E}_{\theta,\varepsilon}[V_I'(A_{t+1})]$.

The second constraint is more readily interpreted once broken into two components. Since insurance only provides a payout when a large aggregate shock occurs, we know that δ will be zero whenever θ is less than or equal to s. Thus, households benefit from insurance whenever the net payout, $\delta - p$, is positive. This benefit is largely captured by the right hand side of the equation below:[4]

$$\Pr(\theta \leq s)\, \mathbb{E}[V_I'(A_{t+1})(-p)|\, \theta \leq s, \varepsilon] = \Pr(\theta > s)\, \mathbb{E}[V_I'(A_{t+1})(\delta - p)|\, \theta > s, \varepsilon] \tag{8}$$

Households insure the cost of insurance (the left hand side of Equation 8) whenever they don't experience a large covariate shock, but have already forgone the cost of protection through insurance. An interior solution requires that the benefit of at least some small amount of insurance exceeds the costs. If instead the opportunity cost exceeds the benefits, a corner solution results and no insurance will be purchased in a given period.

The first order conditions (Equations 6 and 7) can alternatively be consolidated into the following decision-making rule:

$$u'(c_t) = \beta\, \mathbb{E}_{\theta,\varepsilon}[V_I'(A_{t+1})] = \beta\, \mathbb{E}_{\theta,\varepsilon}\left[V_I'(A_{t+1})\frac{\delta(\theta)}{p}\right] \tag{9}$$

This statement says that the marginal benefit of consumption today must be equal to the expected discounted value of carrying an additional asset forward to the future, which also must be equal to the expected discounted benefit of insuring an additional unit.

Equation 9 highlights the mutual importance of the opportunity cost of future assets, $V_I'(A_{t+1})$, and the benefit-cost ratio of insurance. A change in either feature will influence behavior. The first feature reflects a binding liquidity constraint. Relaxing the liquidity constraint by way of either credit or a cash/asset transfer reduces $V_I'(A_{t+1})$ as long as it

[4] To perfectly capture the benefits, the right hand side must be broken into two additional parts, one in which $\delta - p$ is positive, and one in which the premium exceeds the payout (even though δ is positive) so that $\delta - p$ is negative. This second term should then be brought to the left hand side, as it is counted as a part of the cost of insurance. Since this is a small case we ignore it to keep the math simpler, and more intuitive.

moves households away from the Micawber threshold, and therefore it also decreases the opportunity cost of insurance. The second feature reflects sensitivity to the design of the insurance contract and the importance of the different insurance contract parameters: p, s and the expected performance of the index (basis risk).

2.3 Numerical Implementation

It is not immediately clear from the theoretical model whether vulnerable households will self-select into purchasing asset insurance at the market price. Their optimal choice depends largely on the insurance contract they are presented with, and the opportunity cost of assets. To answer the question of whether market-based social protection can reach vulnerable households, we use numerical methods to solve a dynamic stochastic model. The model presented in Sections 2.1 and 2.2 is calibrated to the northern Kenyan rangelands, where a representative insurance contract provides pastoralists the opportunity to insure their primary asset, livestock, against drought losses. The pastoralist livestock economy in this arid and semi-arid region of Kenya has often been characterized as an ideal example of a poverty trap. Details regarding the numerical implementation and calibration procedures are outlined in the appendix. Most importantly, the parameters used ensure the existence of two stable equilibria and one critical threshold so that the assumption of a poverty trap is established.

The solution to the problem described by the system of equations (4) presented in Section 2.2 finds the optimal consumption, investment and insurance decisions in each period. We use dynamic programming techniques to find a policy function for each behavior as it depends on herd size (asset levels). Specifically, we use value function iteration, by which it follows that the Bellman equation has a unique fixed point as long as Blackwell's Sufficient Conditions (monotonicity and discounting) are satisfied.[5]

[5]To solve the problem numerically, we assume the following timeline of events:

1. In period t households choose optimal c_t, I_t and (implicitly) i_t (where i_t denotes investment) based on state variable H_t (herd size, same as A_t in the theoretical model) and the expectation of future

3 Optimal Insurance Decision

Using the results obtained from numerical methods, we are now able test the hypothesis that insurance will be most attractive to vulnerable households if it prevents them from falling below the threshold in the event of a shock. That is, we are able to answer the question, will vulnerable households choose to purchase insurance at the market price? The market price is the actuarially fair price of insurance plus a loading term. Loading is the amount added by an insurance company to cover the expense of securing and maintaining business. A typical loading amount is at least 20%. The answer to our main inquiry can thus be found by looking at the optimal policy function for insurance under 20% loading, a typical loading amount.

Figure 1A plots the insurance policy function using 20% loading. The figure demonstrates a distinct bifurcation in behavior at approximately 14 assets, which corresponds to the Micawber threshold (A^{MT}). However, the policy function for vulnerable households situated near A^{MT} dictates zero insurance, with the optimal proportion of assets insured increasing as initial asset levels move away from the threshold. This seems to contradict the original hypothesis that vulnerable households have the most to gain from insurance. Rather, insurance seems to be least attractive to the most vulnerable households.

The explanation for this counterintuitive result lies in the first order conditions discussed in Section 2.2. Equation 9 shows that the derivative of the expected value function matters crucially for optimal decisions. One benefit of the numerical example is that we can actually

livestock mortality (depreciation) and insurance payout.

2. Households observe exogenous shocks θ_{t+1} and ε_{t+1} which determine livestock mortality (depreciation) and insurance payout $\delta(\theta_{t+1})$.
3. These shocks, together with the optimal choices from period t determine H_{t+1} through the equation of motion for herd (asset) dynamics.
4. In the next period steps 1-3 are repeated based on the newly updated state variable H_{t+1} and the expectation of future livestock mortality and indemnity payment.

The primary timing assumption is that the shocks happen post-decision and determine H_{t+1} given the household's choices of c_{t+1}, I_{t+1} and i_{t+1}, and then once again all the information needed to make the next period's optimal decision is contained in H_{t+1}.

Figure 1: Insurance Policy Function Under Various Prices

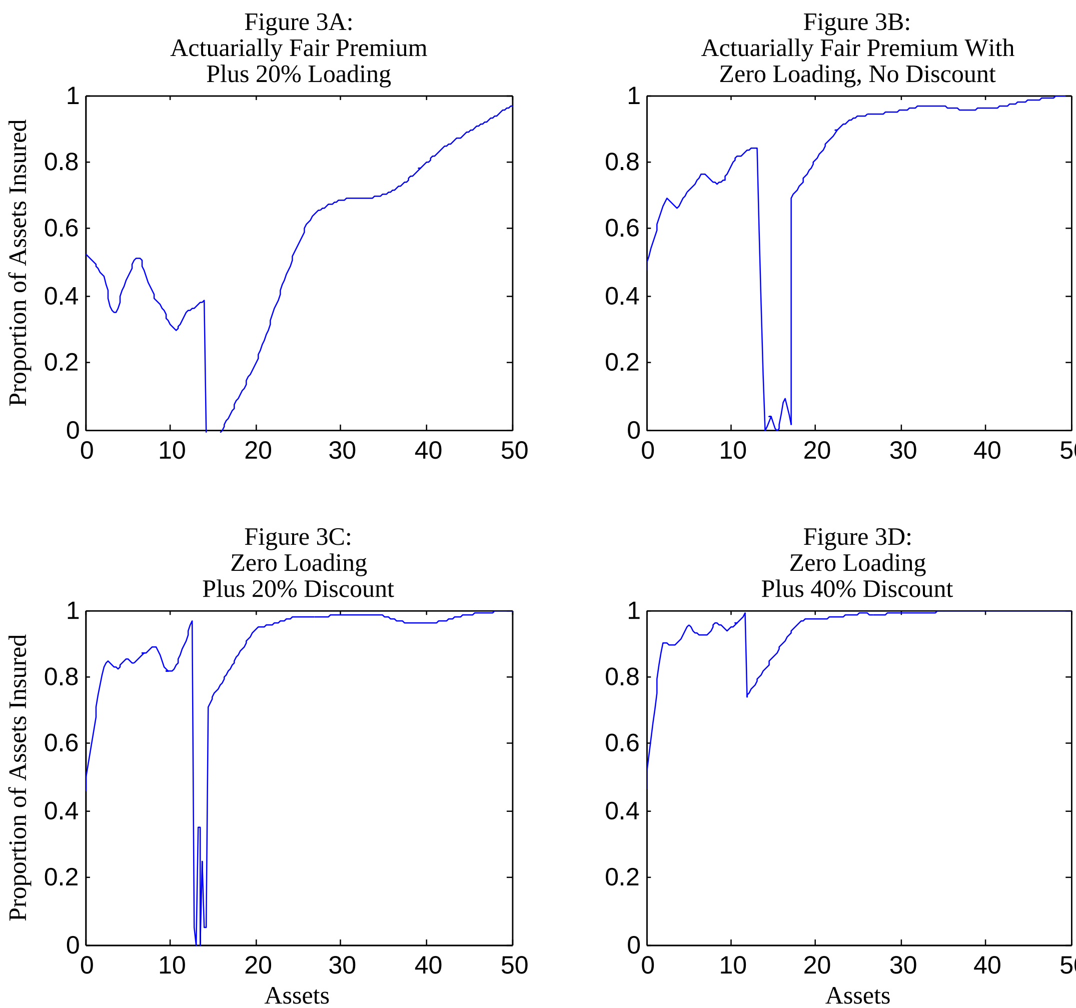
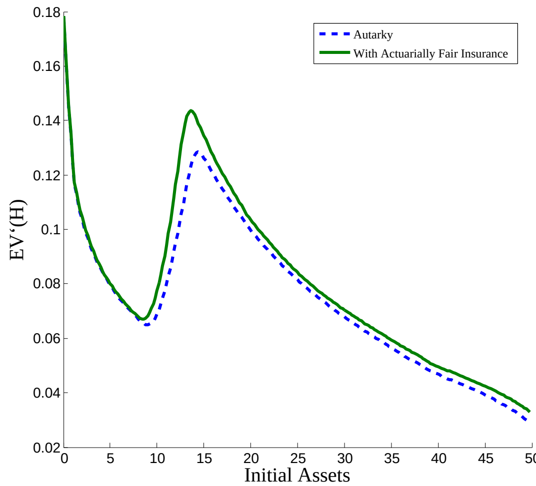


Figure 2: Opportunity Cost of Assets



plot this derivative, interpreted as the opportunity cost of future assets (or liquidity) at the optimum. We do so in Figure 2, which shows that the opportunity cost of liquidity attains a maximum precisely at the Micawber threshold (A^{MT}). In other words, households in the neighborhood of A^{MT} also display the highest opportunity cost of assets. The reason is intuitive. A small change in assets around A^{MT} can have path-altering implications. For example, giving an additional asset to a household just below the threshold allows them to escape the poverty trap, completely altering their dynamic path. On the contrary, taking 1 asset from a household just above the threshold drops the household asset level below the threshold toward ultimate herd collapse.

Equation 8 tells us that both the cost and benefit of insurance depend on the expected opportunity cost of future assets, $V_I'(A_{t+1})$, which we have now demonstrated to be highest in the region of the Micawber threshold. This feature underscores a critical insight which leads to a dilemma of privately provided social protection. The insight comes from realizing that because $V_I'(A_{t+1})$ is large for vulnerable households, both the left and right hand side of Equation 8 are inflated at the Micawber threshold.

The dilemma of privately provided social protection is this: The benefit of insurance is highest for the most vulnerable households in the Micawber region. These households have the most to gain from protection of this kind, because protection offers dynamic path-altering benefits. But the opportunity cost of insurance is also highest for these same vulnerable households who are faced with a binding liquidity constraint. The insurance policy function shows that the costs outweigh the benefits for vulnerable households, such that optimizing households will not self select into an insurance contract, even though they have the most to gain from such protection.

What matters for insurance is where the household ends up after the shocks and subsequent payout (if there is one). If a household is precariously situated on the very cusp of the Micawber threshold, then the opportunity cost of future assets, $V_I'(A_{t+1})$, is at its highest. That means the scenario where a household pays the premium but loses no assets (receiving no payout) is heavily weighted. If paying the premium (in lieu of investment) drops them below the threshold, then insurance comes at a high cost. Moreover, the deductible s matters crucially to vulnerable households. Even if there is an insurance payout, the household must cover the loss of the deductible. But for some households this may put them over the threshold. In this case the costs are too high. This leads to a corner solution such that households on the brink of the threshold will not insure their assets.[6]

In fact, the opportunity cost may be too high for most households to fully insure. The only households who choose full or nearly full insurance at the market price are households that are situated near or above the high asset equilibrium, where the marginal benefit of an additional asset is minimal. All other households choose moderate levels of insurance.

Thus far, we have only considered optimal behavior when households face the market price. It may also be informative to analyze the elasticity of insurance demand. That is, how does the insurance policy function change when the cost of insurance is reduced? Figures 1B, 1C, and 1D display the optimal insurance policy function under three different

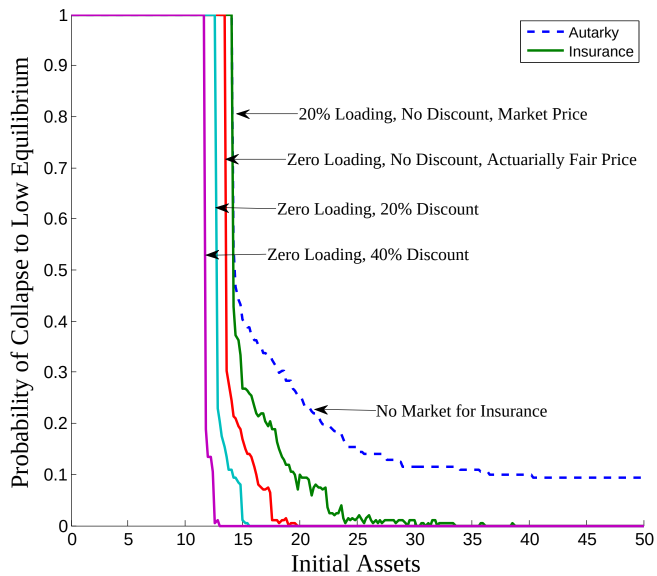
[6] Basis risk adds to the complexity, and the cost. If the covariate shock alone doesn't push the household below the threshold, and it doesn't trigger a payout, but the combination of the idiosyncratic and covariate shocks do push the household over the threshold, then the cost of basis risk is high. Similarly, basis risk comes with a high price tag if payment of the premium only pushes the household over the threshold when they also experience an idiosyncratic shock.

price schemes: 20%, 40% and 60% discounts. As the price of insurance falls, households choose to insure a higher proportion of their assets. A 20% subsidy is essentially a subsidy of the loading term, so that households face approximately the actuarially fair price. Figure 1B shows that this crowds in additional purchases for all but those households just above the Micawber threshold. The opportunity cost of insurance is still too high for these households, so the optimal strategy remains a corner solution: no insurance. An additional 20% subsidy (Figure 1C) nudges some of these households into purchasing insurance, and increases the level of insurance for all other households. For a few households on the brink of the Micawber threshold though, the preference is to hold on to valuable assets, rather than forgo the cost of insurance. Only when the subsidy is increased to 60% of the market price (Figure 1D) are insurance purchases high across the asset spectrum.

4 Impacts of an Insurance Market

The results of the previous section seem to suggest that unless heavily subsidized, the provision of insurance may not achieve the goals of social protection, at least not if we seek to target protection at the Micawber threshold. However, the insurance policy function only represents part of the story. Figure 2 reveals that the opportunity cost of future assets in the presence of an insurance market, $V_I'(A_{t+1})$, increases relative to the autarkic opportunity cost, $V_A'(A_{t+1})$, especially around the Micawber threshold. This shift implies that an asset carried into the future is more valuable if it can also be insured in the future, even if it isn't insured today. The impact is subtle, but important. Households benefit from insurance through an improved expected outcome, because they believe they will be better able to protect against poverty in the future. This increase in the value of future assets also stimulates an important behavioral response. We consider these impacts of an insurance market in the subsections that follow.

Figure 3: Probability of Collapse to a Low Level Equilibrium



4.1 Insurance Changes Expectations

In an economy characterized by a poverty trap, shocks can have permanent consequences. One way to assess vulnerability to path-altering shocks is to consider the probability of becoming trapped in poverty. To do this, we run a large number of simulations using the policy functions presented in Section 3. By classifying terminal asset outcomes, we obtain the probability that a household ends up at the low welfare equilibrium in the long run. These outcomes are compared to simulations using policy functions derived from the autarkic problem. The results are depicted in Figure 3.

In the absence of insurance (autarky), all households can be identified as either trapped or vulnerable. Trapped households begin with an asset endowment less than A^{MT}, and move toward the low welfare equilibrium with 100% probability. Vulnerable households, on the other hand, are those households bearing a positive but not deterministic probability of becoming trapped in poverty. Those closest to the Micawber threshold, who exhibit the highest probability of collapse (other than 1), are considered the most vulnerable.

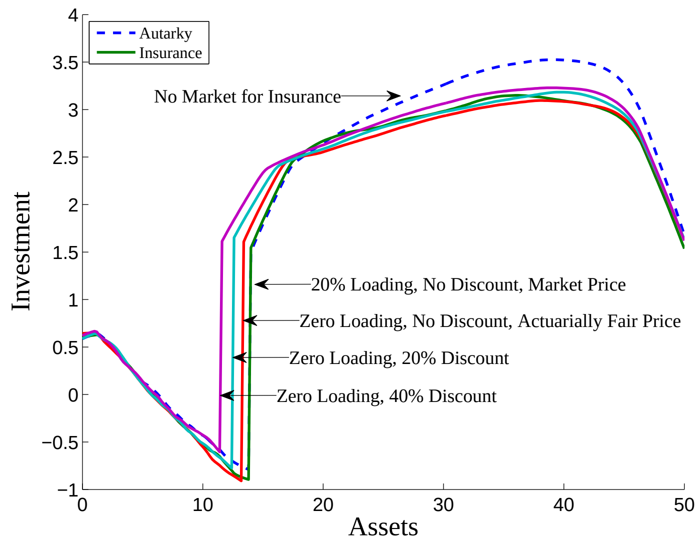
Consider now insurance sold at the market price. Figure 3 shows that for all households with an initial asset endowment greater than A^{MT}, insurance decreases the probability that households end up trapped in poverty. Critically, this is true even for households who do not purchase insurance. Why? Because these households have the opportunity to insure in the future. Although the optimal strategy is to invest today, in order to move away from A^{MT}, if a household succeeds it will begin to insure at least part of their assets. For this reason, household expectations about their future welfare are different when an insurance market is present. This change explains why $V_I'(A_{t+1})$ increases relative to $V_A'(A_{t+1})$, especially around the Micawber threshold.

When insurance is subsidized, households above A^{MT} benefit from an even larger decrease in the probability that they end up at the low welfare equilibrium. In addition, Figure 3 suggests that households with an initial asset endowment just below A^{MT} will dramatically modify expectations about their future outcome. Without subsidized insurance, households see zero possibility of reaching the high welfare equilibrium. With subsidized insurance, they expect to insure in the future if they can make it safely over the asset threshold. For this reason, they expect to escape the poverty trap with positive probability. This suggests a new point of bifurcation in equilibrium outcomes, in part due to a contemporaneous behavioral response which we turn to next.

4.2 Behavioral Response to Insurance

The opportunity to insure either today or in the future changes the expectations a household has regarding its own future. The household optimization problem captures this change as the difference between $\mathbb{E}_{\theta,\varepsilon}[V_I'(A_{t+1})]$ and $\mathbb{E}_{\theta,\varepsilon}[V_A'(A_{t+1})]$. Specifically, Equation 9 dictates that as $\mathbb{E}_{\theta,\varepsilon}[V_I'(A_{t+1})]$ increases, more assets must be brought into the future, either through investment or insuring against negative shocks. As a result, an active insurance market could actually crowd-in additional investment, especially by vulnerable households for whom insurance is costly. To demonstrate this ex ante behavioral effect, Figure 4 shows the optimal

Figure 4: Investment Policy Function Under Various Prices



investment policy function with no access to insurance and under the various insurance price subsidies.

In autarky we observe a clear bifurcation in optimal behavior around 14 assets. This bifurcation defines the Micawber threshold. Households below A^{MT} divest assets, instead enjoying greater consumption today, and move toward the low welfare equilibrium. Alternatively, households at A^{MT} invest substantially, giving up contemporaneous consumption in the hopes of reaching the high welfare equilibrium.

Households on either side of this threshold invest somewhat less when market-priced insurance becomes available than in autarky. This behavioral change is most noticeable among households with large asset endowments, as these households choose to decrease investment in order to insure. This change suggests that in the absence of an insurance market, households with large endowments invest as part of a coping strategy to protect against collapse. When formal insurance becomes available, these households instead choose to use a portion of their liquidity to purchase insurance, forgoing additional investment. This finding supplements findings by de Nicola (2011) who predicts reduced investment when insurance is introduced (ignoring poverty traps).

The more consequential behavioral change occurs around A^{MT}. Even though small subsidies fail to crowd-in insurance purchases at the threshold, Figure 4 shows that subsidies dramatically alter behavior around the threshold by crowding-in investment. The ability to insure in the future actually incentivizes contemporaneous investment by households just below the autarkic Micawber threshold. Remember, the Micawber threshold is, by definition, the point at which optimal behavior bifurcates. In this figure, we see the Micawber threshold actually shift, as previously trapped households now strive to reach the high equilibrium.[7]

It is sometimes argued that subsidizing insurance harmfully induces households to take on more risk than they would in the absence of market intervention. In a poverty trap model, however, inducing risk-taking at the threshold can actually move people onto a better path. Rather than being harmful, crowding-in risk in this way can be largely beneficial to a vulnerable household with an initial endowment near A^{MT}.

Figure 3 testifies to the dynamic implications of the threshold shift for vulnerable households. Consider a household with an initial endowment of 13 assets, just below the autarkic Micawber threshold. Without insurance this household has only one option: the low equilibrium. The household is trapped in poverty. But if the insurance subsidy is large enough, a dramatic behavioral response is triggered; consumption is cut back and investment is abundantly increased. Even though the opportunity cost of insurance is too high to buy insurance, the household sees how it can protect assets in the future, and therefore invests heavily in an effort to "make it." This behavioral response coupled with the ability to insure at a subsidized rate in future periods improves the household's chances of escaping the poverty trap from zero in autarky to 82% with a 40% subsidy. Increasing the subsidy to 60% completely alters this household's expected outcome: trapped without insurance, the household invests and insures heavily, and as a result moves to the high equilibrium with 100% probability. The threshold shift completely alters the expected path for this household.

[7] The shift in the Micawber threshold is also visible in Figure 3. As the price of insurance falls, the "dip" in the insurance policy also shifts.

4.3 Insurance Impact on Poverty Dynamics

We have shown that the ability to insure improves the chances that a vulnerable household reaches the high equilibrium. This suggests welfare gains for all households with an initial asset endowment greater than A^{MT}. Moreover, if insurance is subsidized such that households face a lower price, A^{MT} may actually shift such that households with an initial endowment less than the original A^{MT}, but greater than the new A^{MT}, appear to benefit from a dramatically improved expected outcome. In this subsection we consider what these welfare gains mean for poverty dynamics of an entire population.

In earlier simulations we used optimal behavior under various scenarios to simulate household asset dynamics for a given initial asset level by drawing a different series of random shocks in each simulation. To extend this to an entire population, we use the empirical distribution of herd sizes in Marsabit district of northern Kenya in 2011 as the initial asset distribution for simulations. This requires aggregating different livestock types in the data into tropical livestock units (TLUs), where a single TLU represents 10 goats, 10 sheep, 1 cattle, or .7 camels.

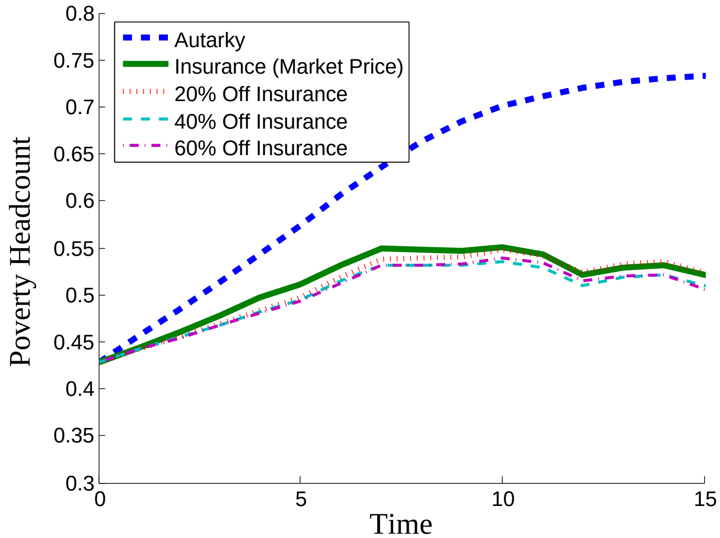
We use the poverty headcount as a measure of poverty. This measure is in the family of Foster-Greer-Thorbecke (FGT) measures, and is calculated as follows:

$$P_\gamma = \frac{1}{n} \sum_{y_j < y_p} \left(\frac{y_p - y_j}{y_p} \right)^\gamma \tag{10}$$

Individual j's income y_j is calculated using $f(A_t)$, and γ is the FGT sensitivity parameter. For the poverty headcount, γ is equal to zero. The income poverty line y_p is set just above the low equilibrium, so that all households at the low equilibrium are counted in the poverty headcount.

Figure 5 shows that the number of households falling below the poverty line steadily increases in the absence of an insurance market. Without a safety net preventing against collapse, households continue to fall below the poverty line. Insurance acts as a safety net, so

Figure 5: Evolution of Poverty Headcount



that far fewer households join the ranks of the poor when insurance is available. For example, after 10 years our simulations suggest insurance offers a 14 percentage point reduction in the poverty headcount in Marsabit. While the poverty headcount increases during the first few years that households can insure, this initial increase reflects the large number of individuals below A^{MT} who are heading toward the low equilibrium with or without insurance (but not initially below the income poverty line) as well as those just above A^{MT} who remain vulnerable to asset collapse.

The provision of insurance subsidies appears to have a nominal effect on poverty dynamics. This is because insurance subsidies only alter the dynamic path of households with an asset endowment near A^{MT}. (This is clear in Figure 3, which shows how households with large asset endowments experience a reduction in vulnerability from insurance sold at the market price, but no additional reduction from subsidies, because they are already fully protected against collapse.) However, a crucial assumption of the poverty trap model is that A^{MT} is an unstable equilibrium. Thus, we expect to observe very few households near A^{MT} in the initial period. Furthermore, the households we do observe in that vulnerable region will quickly move away from A^{MT}, so that subsidies matter little after the first few years.[8]

The lack of subsidy impact on poverty dynamics doesn't mean that subsidies don't matter. Indeed, the discussion in Section 4.2 highlighted how insurance subsidies actually shift the Micawber threshold, thereby providing huge (path-altering) welfare gains to some households. Although the welfare gains are large, we show here that these gains would only benefit a small fraction of the population.

5 Conclusion

A growing literature on poverty traps suggests that we need to think carefully about the ways in which market failures and asset thresholds interact. This literature advocates that social protection can be more effective in addressing poverty dynamics if it accounts for a critical asset threshold, around which both behavior and equilibrium outcomes bifurcate. When such a threshold exists, risk and vulnerability play a key role because shocks can have permanent consequences. One way threshold-targeted policies can work is by limiting risk, and protecting vulnerable households from joining the ranks of the poor. In this paper, we assessed whether the benefits of a threshold-targeted social protection program could be achieved through a market-based mechanism: insurance.

It has previously been posited that insurance will be most valuable to vulnerable households at a critical dynamic asset threshold, and therefore insurance will be self-targeting at the Micawber threshold. Our theoretical model underscores the importance that a high shadow price of liquidity plays in determining how vulnerable households value asset insurance. Because assets are incredibly valuable to these households, the benefit that comes from protecting future assets through insurance is remarkably high. But for the same reason, the steep opportunity cost of insurance presents a formidable tradeoff. This tradeoff leads to a dilemma of privately provided social protection: while vulnerable households have the most

[8] The small impact of subsidies is exacerbated in our model by assuming no positive shocks. Note that the unstable equilibrium will not be repopulated in our simulations whenever insurance protects households from falling, unless we assume positive shocks which allow low welfare households to jump to A^{MT}.

to gain from insurance, they will not self-select into purchasing insurance, at least not when faced with the market price.

Although insurance fails to target households at the threshold in the current time period, insurance may still achieve some of the long-run benefits of a threshold-targeted social protection program. This is because an extra asset in the future is more valuable if it can also be insured in the future, even if it isn't insured today. For this reason, households' optimal behavioral strategies change. This behavioral response, coupled with the ability to protect their assets in the future, results in reduced vulnerability for households around the Micawber threshold.

Our results suggest that over time, insurance protects some (but not all) vulnerable households from joining the ranks of the poor, significantly altering poverty dynamics of a population. This is true despite the lack of early insurance purchases around the Micawber threshold. These results suggest that the value of insurance is inherently a dynamic value function, and a static willingness to pay model will inaccurately reflect the value function it attempts to capture.

These results become important as we think about microinsurance pilot projects being implemented in developing countries worldwide. The findings suggest that static empirical demand analyses may not be enough to capture the dynamic nature of demand. In a similar way, impact analyses will underestimate the impact if they take a short-run approach. Moreover, in the absence of adequate demand, pilots are often short-term. However, our study suggests that insurance is able to target vulnerable households only if they believe insurance will exist in the future, highlighting the importance of long-term commitments to established insurance markets.

As microinsurance markets targeting poor households are introduced worldwide, a better understanding of the dynamic implications of insurance in these contexts is needed. This is particularly true when we consider poverty trap environments. This paper makes a critical step in that direction.

Appendix A: Calibration

Our general calibration method was to evaluate the value of model parameters based on their ability to generate equilibrium stochastic time paths for steady-states (as well as transitions) that are consistent with the stochastic properties of observed data. We use the results of Lybbert et al. 2004 and Santos and Barrett 2011 as our benchmark.

Specifically, we first assume a heterogenous population with identical preferences and uniformly distributed initial asset levels. In Section 4.3 we extend the analysis to consider the dynamic implications our findings hold for the observed empirical distribution of asset levels. In that stage, we use empirical data of the distribution of herd sizes in Marsabit district of northern Kenya, from a dataset that includes a random sample of 924 households in that region in 2011. Livestock are considered the primary, and often the only, asset held by households in this region, (for example, the median household in a 2009 survey reported that 100% of productive assets are held in livestock) so that ignorance of other assets is thought to be acceptable in this setting. This requires aggregating different livestock types in the data into tropical livestock units (TLUs), where a single TLU represents 10 goats, 10 sheep, 1 cattle, or .7 camels.

In order to realistically reflect the risky environment that pastoralists find themselves in, the parameters used for the numerical analysis must also realistically reflect the local setting. In our model, risk primarily takes the form of covariate shocks, since the vast majority of households in this area report drought to be their primary risk. In order to establish a vector of covariate shocks, we roughly discretize the estimated empirical distribution of livestock mortality in northern Kenya reported in Chantarat et al. (2011). Since mortality rates have been shown by the same study to be highly correlated within the geographical clusters upon which the index is based, we assume relatively small idiosyncratic shocks. Using the empirically-derived discretization the assumed mutual shocks allow expected mortality to be 9.2% with the frequency of events exceeding 10% mortality an approximately one in three year event. These two features both reflect observed mortality characteristics in the region.

From the distribution of covariate shocks we calculate the actuarially fair premium using the same strike point as is found in the actual IBLI contract. Parameters for the utility function (ρ and β) are homogenous across the population, and specified using plausible values known from economic theory.

Finally, to obtain parameters for the production technology, we impose equilibrium outcomes based on the findings of Lybbert et al. 2004 and Santos and Barrett 2011 in this particular setting. In this case equilibrium outcomes refers to a single unstable steady state (the Micawber threshold) and two stable steady states (the high and low equilibriums). This identifying restriction allows us to search for numerical values of the production parameters which generate a stable result. While structurally estimating the parameters of the production function based on empirical data would have been preferred, it was deemed not possible at this time.

The specific functional forms and parameters used to solve the dynamic programming problem are reported in the Appendix in Table 1.

Table 1: Functional Forms and Parameters used in Numerical Simulations

Production Technology and Parameters
$F^h(H) = \alpha H_t^{\gamma_L} + \underline{f}$ $F^l(H) = \alpha H_t^{\gamma_H}$ $\gamma_L = 0.28$ $\gamma_H = 0.56$ $\underline{f} = 2.95$ $\alpha = 1.33$
Utility Function and Parameters
$u'(c_t) = \frac{c_t^{1-\rho}-1}{1-\rho}$ $\beta = 0.95$ $\rho = 1.5$
Insurance Contract Parameters
$\textit{Actuarially fair premium} = .0148$ $s = .15$
Random Shocks
$\theta = \{0.0, .05, .10, .15, .20, .25, .30, .35, .40, .45, .50, .55, .60\}$ $\varepsilon = \{0.0, .01, .02, .03, .04\}$ $\Pr(\theta) = \{.3415, .3415, .1494, .0640, .0427, .0213, .0107, .0075, .0043, .0043, .0043, .0043, .0043\}$ $\Pr(\varepsilon) = \{.2000, .2000, .2000, .2000, .2000\}$

Appendix B: Sensitivity Discussion

The specific insurance policy function derived obviously depends on the parameters used in the simulations. Although these parameters are loosely calibrated to fit observed values from northern Kenya, we do not seek to make a direct prescription of household behavior in northern Kenya. Rather, we know that a household's decision will depend on members' time discount rates, personal attitudes toward risk, perceptions regarding drought risk, and their perceived level and understanding of basis risk. In addition, heterogeneous households likely have access to varied production technologies, further complicating the problem.

The work presented here is intended as a theoretical contribution which more broadly contributes to our understanding of insurance in the presence of poverty traps. This type of model, with a kinked production technology, is admittedly sensitive to the specified parameters. However, this assumption of a kinked production technology is grounded in both the theoretical and empirical literature of poverty traps, such that the analysis seems to be of great value, despite its sensitivity to the specified parameters.

That being said, we can make some broad comments regarding the parameters of greatest interest: the time discount rate β, risk attitude ρ, and basis risk $((i(\theta_t) - \theta_t) + \varepsilon_t)$.

1. **Time discount rate β:** Our results suggest that threshold households will not insure today, but will alter other behavior based on adjusted expectations regarding the future. The latter finding relies heavily on the discount rate. As the discount rate falls, households discount their future more heavily, and the impact on current behavior is reduced. More generally, households across the asset spectrum will insure less as the discount rate falls because the marginal benefit of preserving assets for the future declines.

2. **Risk attitude ρ:** The decision to insure obviously depends on personal risk attitudes toward risk. Under the continued assumptions of perfect information and perfect understanding, insurance demand should increase with risk aversion as households seek

to avoid risk. If we focus on the Micawber threshold, our model suggests that the presence of an insurance market induces threshold households to take on more risk than they would in the absence of market intervention, by increasing investment. As households become more risk averse, this behavioral response to insurance is weakened.

3. **Basis risk** $((i(\theta_t) - \theta_t) + \varepsilon_t)$**:** As basis risk increases, demand for insurance across the asset spectrum will subsequently decrease. The cost of basis risk is particularly stark for threshold households. If the covariate shock alone doesn't push the household below the threshold, and it doesn't trigger a payout, but the combination of the idiosyncratic and covariate shocks do push the household over the threshold, then the cost of basis risk is high (because they aren't protected against collapse).

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