Valuing Asset Insurance in the Presence of Poverty Traps

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October 2012

Abstract:

A growing literature of poverty traps advocates that social protection can be more effective in addressing poverty dynamics if it accounts for a critical threshold, around which both equilibrium outcomes and optimal behavior bifurcate. In this paper, we account for this type of threshold, and ask whether insurance can achieve the goals of social protection. Unlike traditional publicly-provided social protection, insurance is a market-based risk management tool that protects households only if they self-select into purchasing an insurance contract. To answer our question, we use stochastic dynamic programming methods to show that market-valued insurance uptake by vulnerable households holding assets near a critical threshold will be low, because the opportunity cost of insurance to them is particularly high. Paradoxically, these same households have the most to gain from protection of this kind. Because of the potential gains from insurance to vulnerable households, we analyze the benefits that can result from crowding-in additional insurance purchases by subsidizing insurance. We consider what these benefits mean for poverty dynamics in a typical setting by calibrating the model to the northern Kenyan rangelands, where evidence of a poverty trap exists and an existing insurance contract provides pastoralists the opportunity to insure livestock against drought losses. We find that providing insurance subsidies may be a more cost-effective way of altering poverty dynamics than traditional social protection policies. Our findings suggest that a public-private partnership between governments and insurance companies may be a useful avenue of social protection provision (JEL D91, G22, H24, O16).

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Social protection has been widely heralded as an important policy tool to address persistent poverty. The aim of social protection is to enhance the capacity of poor and vulnerable persons to manage economic and social risks. Most often, this protection 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 certain 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 (forthcoming) 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 around the Micawber threshold. Their results suggest potentially large returns to targeting social protection assistance based on knowledge about critical asset thresholds. Although theoretically insightful, the main policy recommendations are practically and politically infeasible. For example, even if prioritizing the vulnerable poor (those near the Micawber threshold) offers dynamic benefits to the poorest as Barrett, Carter and Ikegami argue, it is difficult to justify using limited aid budgets on a policy which favors the vulnerable over those suffering from life-threatening food security. Moreover, 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 practically and politically 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 pur-

[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 (2001) 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.

chasing a contract. 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 Micawber 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.

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 Micawber households: that the optimal insurance decision depends mutually 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 Micawber 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 now insure their livestock against drought losses (Chantarat et al. 2007, Chantarat et al. 2011, 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 2011).

In Section 3 we present the optimal insurance policy function. Our results suggest that market-valued insurance is not threshold-targeting. Instead, Micawber households do not purchase insurance when faced with the market price. This presents a dilemma of privately provided social protection: The benefit of insurance is highest for the most vulnerable households in the Micawber region, but the opportunity cost of insurance is also highest for these same Micawber households. Only when the market price is reduced to below market value will such households begin to insure. For this reason, in Section 4 we consider the impact of providing insurance subsidies, and demonstrate that demand for insurance is highly elastic around the threshold. We also show that increasing insurance demand through subsidies not only impacts a household's ability to cope with shocks ex post, but influences ex ante coping behavior. One of our unique contributions stems from recognizing the importance of this ex ante behavioral change in altering poverty dynamics. We develop these findings further in Section 4.3 by looking at household asset dynamics for a population under various social protection policies.

Since pure public provision of social protection often fails to account for poverty dynamics, and pure market-based insurance fails to target those who might gain the most from a safety net, our findings suggest that there may be substantial gains from establishing a public-private partnership to provide social protection through subsidized insurance. In Section 5 we compare the costs and benefits of various modes of social protection provision. Our findings suggest that subsidizing insurance may be a cost effective form of providing lasting social protection that also addresses the structural foundations of poverty. Section 6 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 2004). 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, forthcoming).

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.

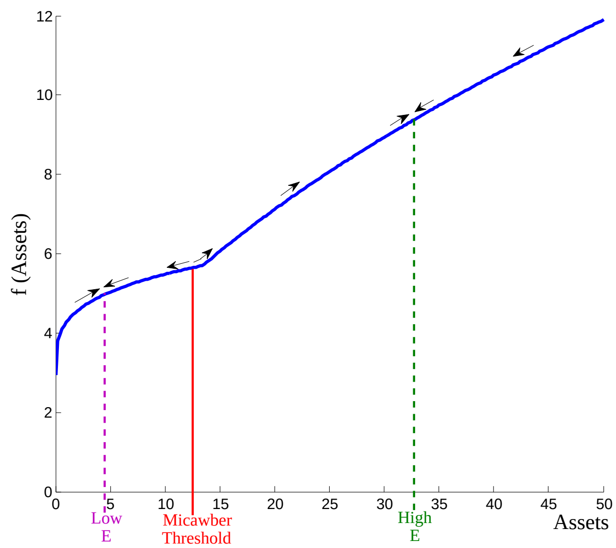
For example, consider two households with similar asset levels near the asset threshold. Such seemingly similar households may end up on divergent paths if they begin on opposite sides of the dynamic asset threshold. Moreover, in a risky setting a single asset shock can have permanent consequences if 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 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 and Lybbert and Barrett 2010) and empirical evidence (Carter and Lybbert forthcoming, and Santos and Barrett 2011, Hoddinott 2006) suggest, then ex ante coping strategies can actually influence the locations of the relevant dynamic asset threshold. In this way, the dynamic asset threshold that matters is based on optimal behavior. It is obvious then that the behaviorally-based Micawber asset threshold depends on the choices available to the consumer. In addition, the threshold can actually shift as the environment around it changes.

A multiple equilibrium poverty trap, such as the one just described, is often modeled as a choice between two discrete production technologies which creates a non-convexity in the income-generating process. This non-convexity can generate a bifurcation in both behavior and equilibrium outcomes. Figure 1 graphically depicts this process. In the next section we follow this oft-used basic model of a poverty trap.

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 (forthcoming) 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

Figure 1: Modeling a Poverty Trap as a Non-convexity in the Income-Generating Process



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 with the initially vulnerable non-poor for transfers. 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 under the threshold-targeted scheme. In essence, the model shows that threshold-targeted policies can work by eliminating unnecessary deprivation.

Obviously, the Barrett, Carter and Ikegami 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 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 forthcoming, Skees and Collier 2008, Smith and Watts forthcoming).

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 (2010) 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 (2010). 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 market-based 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:

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

subject to:

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

The model assumes that assets are productive, but subject to stochastic shocks θ and ϵ. These shocks can be thought of as stochastic depreciation, where the losses incurred can be quite large. Covariate shock θ is the same for all households in each period, but idiosyncratic shock ϵ is specific to the household. Both shocks are exogenous, and realized for all households after decision-making in the current period, and before decision-making in the next period occurs.

As is common in the literature on poverty traps, the model assumes households have access to a high and low productivity technology. 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 non-convexity can generate (but does not guarantee) a bifurcation in both optimal behavioral strategies and equilibrium outcomes, indicative of a poverty trap.

The poverty trap mechanism could not be complete without the third constraint which assumes a lack of available credit markets. This assumption implies that consumption must not be greater than current production and assets. 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.[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:

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

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

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

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.

For this type of model, the asset level where optimal dynamic behavior bifurcates, A^{MT}, is what Zimmerman and Carter (2003) label the Micawber Threshold.[3] At the 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 through

[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. While this may more closely reflect reality, doing so only clouds our understanding of the mechanisms at work in this particular problem.

[3] Notice that A^{MT} is not necessarily equal to $\tilde{A}$, because households may strive to reach $\tilde{A}$ by changing other behaviors at A^{MT} prior to reaching $\tilde{A}$. See Figure 1 for a graphical depiction.

consumption or by nature of an unfortunate shock 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}.

2.2 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 $((i(\theta_t) - \theta_t) + \epsilon_t))$. 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:

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

subject to:

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

This too can be expressed as the Bellman equation:

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

There are now two first order conditions:

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

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

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.[4] If it is, then we would expect optimal consumption and investment to vary with the introduction of an insurance market. Highlighting the importance of these altered ex ante risk coping strategies is one of the unique contributions we seek to make in this paper.

The second constraint is more readily interpreted if we break it 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. In essence, the benefit of insurance occurs whenever the net payout, $\delta - p$, is positive. This benefit is largely captured by the right hand side of the equation below:

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

The real cost of insurance (the left hand side of Equation 8) is incurred whenever households 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:

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

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 $V_I'(A_{t+1})$, and therefore 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).

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

2.3 Numerical Implementation

It is not immediately clear from the theoretical model whether Micawber households will self-select into a pure market-based insurance contract. 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 Micawber 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 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.

The solution to Problem 4 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]

We have seen from the first order conditions that the derivative of the expected value function matters crucially for optimal decisions. One benefit of the numerical example is that we can actually plot this derivative, interpreted as the opportunity cost of future assets (or liquidity) at the optimum. We do so in Figure 2, which demonstrates that Micawber households (loosely speaking with between 11 and 20 initial assets) have a high opportunity cost of liquidity. In fact, it can be shown that the opportunity cost of liquidity attains a maximum precisely at the Micawber threshold (A^{MT}). The reason is intuitive. A small change in assets around the Micawber threshold 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 high in the region of the Micawber threshold. This feature underscores a critical insight which

[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 livestock mortality (depreciation) and insurance payout.

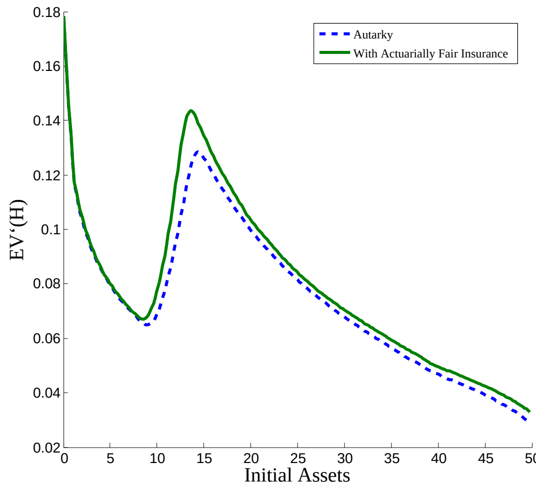
2. Households observe exogenous shocks θ_{t+1} and ϵ_{t+1} which determine livestock mortality (depreciation) and insurance payout $\delta(\theta_{t+1})$.

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 2: Opportunity Cost of Assets



leads to a dilemma of privately provided social protection. The insight comes from realizing that because $V_I'(A_{t+1})$ is large for Micawber 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 social protection of this kind, because protection offers dynamic path-altering benefits. But the opportunity cost of insurance is also (potentially prohibitively) highest for these same Micawber households who are faced with a binding liquidity constraint. If the costs outweigh the benefits, then optimizing households will not self select into privately provided protection in the form of insurance, 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 an impressively high cost.

Moreover, the deductible s matters crucially to Micawber 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]

Besides the swelling of $V_I'(A_{t+1})$ around the Micawber threshold, Figure 2 demonstrates

[6] Basis risk adds to the complexity, and the cost. If the covariate shock alone doesn't push the household over 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.

two additional key points from which we can develop some intuition for optimal behavior. First, the opportunity cost of future assets under actuarially fair insurance, $V_I'(A_{t+1})$, increases relative to the autarkic opportunity cost, $V_A'(A_{t+1})$, especially around the Micawber threshold. This increase in the opportunity cost of future liquidity stems from the improved ability of households to protect against becoming trapped in poverty in the future. Since the expected outlook is better, the marginal benefit of future assets increases.

The final insight to be gleaned from Figure 2 is to understand that $V_I'(A_{t+1})$ is not only high for Micawber households, but the slope of $V_I'(A_{t+1})$ around the threshold is relatively steep. This implies that behavior in this region will be highly sensitive to the economic environment just described. In particular, Micawber households should exhibit extreme price sensitivity to the design of the insurance contract and its expected benefit-cost ratio. This offers at least one potential solution to our dilemma of privately provided social protection if households don't choose to purchase insurance at the market price: subsidized insurance offered through a public-private partnership between government and insurance companies. If the cost of obtaining insurance can be reduced for the most vulnerable households, then the benefit-cost ratio increases, and the most vulnerable households will find it optimal to insure.

3 Optimal Insurance Decision

The primary question we seek to address is whether Micawber households will choose to purchase pure market-based insurance. 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.

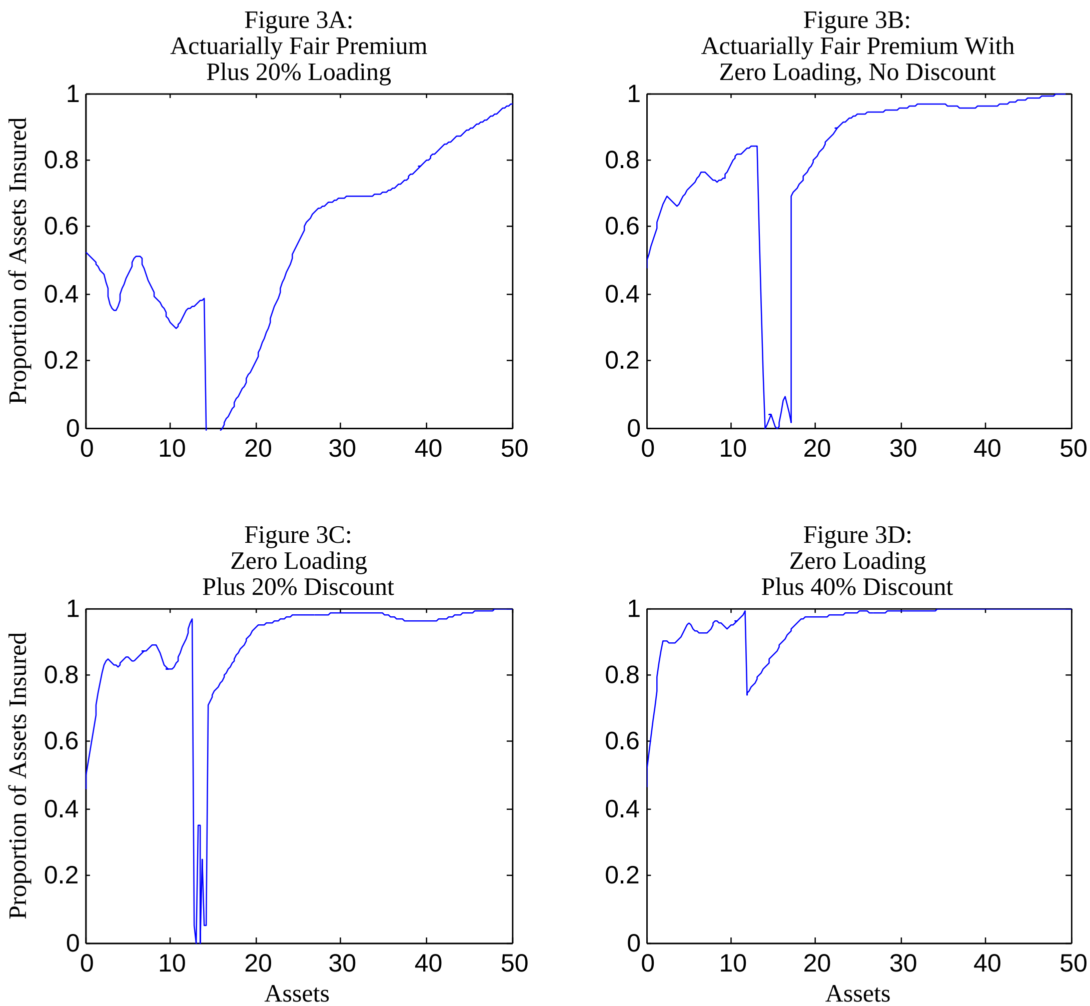
Figure 3A plots the insurance policy function using 20% loading. This figure demonstrates a distinct bifurcation in behavior at approximately 14 assets, the Micawber threshold. The policy function for Micawber households dictates zero insurance, with the optimal proportion of assets insured increasing as initial asset levels move away from the threshold. This demonstrates that the opportunity cost of market-valued insurance is too high for Micawber households. The dilemma of privately provided social protection has revealed itself. Even though they have much to gain from protecting current assets, the cost of acquiring that protection is too high for these liquidity-constrained households.

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 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.[7]

In this way, we see that pure market provision of social protection through insurance may not succeed, at least not if we seek to target protection for the most vulnerable households

[7] This is perhaps less surprising if we consider the experiences of the U.S. agricultural insurance program. In order to encourage participation, farmers in the U.S. do not pay any of the administrative costs of the program (the loading term is zero), and U.S. farmers pay on average only about 40% of the actuarially fair premium (Shields 2010, Smith and Watts forthcoming). The remaining costs are covered by subsidies.

Figure 3: Insurance Policy Function Under Various Prices



at the Micawber threshold. However, if our primary goal is social protection, and traditional needs-based social protection fails to address poverty dynamics, there may still be cause for subsidizing insurance in a setting of poverty traps. If subsidies crowd-in insurance purchases by the most vulnerable households, then insurance can protect those households against falling into a poverty trap. In this way the cost of social protection is shared by households and the government through a market-based mechanism. Moreover, the cost of such social protection could be substantially lower than the cost of lifting the same households out of a poverty trap after collapse. If that's the case, then public-private provision of insurance may be a cost-effective avenue of providing social protection, especially if subsidies can be targeted.

Subsidies will be most efficient at crowding-in insurance if demand for insurance is elastic. The steepness of $V_I'(A_{t+1})$ around the Micawber threshold demonstrated in Figure 2 suggests that optimal behavior in this region will be sensitive to the economic environment in which a household finds itself. Hence, small changes to the contract design, and especially to the price of insurance can result in dramatically altered behavior.

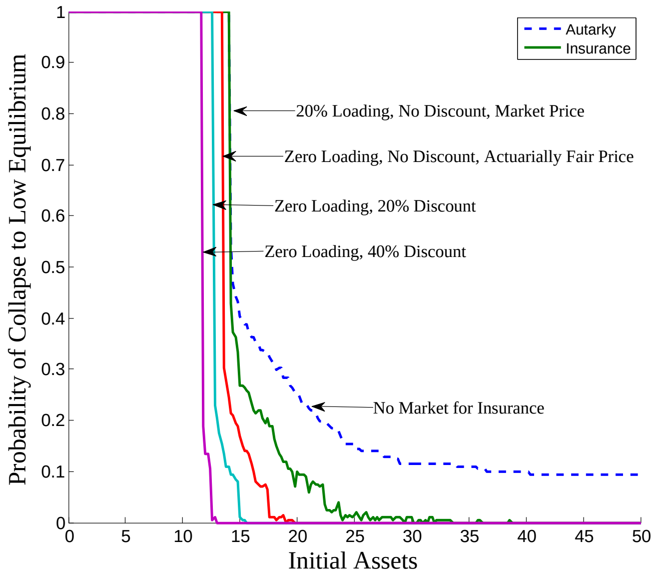
Figures 3B, 3C, and 3D plot the optimal insurance policy function under three different price schemes: actuarially fair, 20% off the premium, and 40% off the premium. In each of these scenarios, we assume the government subsidizes the loading term. In 3C and 3D the government provides an additional subsidy of 20% and 40% of the actuarially fair premium, respectively.

As the price of insurance falls, households choose to insure a higher proportion of their assets. Subsidizing the loading term so that households face the actuarially fair price (Figure 3B) 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 off the actuarially fair premium (Figure 3C) 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 40% of the actuarially fair premium (Figure 3D) are insurance purchases high across the asset spectrum.

4 Benefits of Crowding-in Insurance

Crowding-in insurance at the threshold through subsidies is only valuable if the expected benefits of targeted social protection can be achieved. The theoretical model suggests that Micawber households have much to gain from insurance, but since it may come at a cost to both households and taxpayers, a thorough analysis of the benefits and costs are required. This section looks at the benefits that are brought about from insurance. While the obvious impacts stem from the enhanced ability of a household to cope with shocks ex post, we also demonstrate how some of the benefits of insurance arise from ex ante behavioral changes. In Section 4.3 we consider what these combined effects mean for poverty dynamics beyond the household level.

Figure 4: Probability of Collapse to a Low Level Equilibrium



4.1 Ex Post Effects at the Household Level

In an economy characterized by a poverty trap large shocks can have permanent consequences. One way to assess vulnerability to path-altering shocks is to consider the probability of becoming trapped in poverty. We run a large number of simulations using the policy functions derived in Section 3 to obtain the probability that a household ends up at the low equilibrium in the long run. The results are depicted in Figure 4. In the absence of insurance (autarky), all households can be identified as vulnerable, bearing a positive probability of becoming trapped in poverty. Those closest to the Micawber threshold, who also exhibit the highest probability of collapse (other than 1), are considered the most vulnerable.

All households below the Micawber threshold end up at the low equilibrium with 100% probability. They are, in essence, trapped from the beginning. But, for households above the Micawber threshold, insurance changes the probability of a poverty trap. Consider the expected outcome of three households with three different initial asset endowments: 30, 20 and 15 assets. The first household, with 30 assets, can expect to end up at the low equilibrium in the absence of insurance 17% of the time. When an insurance market is introduced, this household will insure about 70% of their assets, so that the chance of falling into a poverty trap falls to just 1%. Subsidizing insurance adds to the proportion of assets insured, and removes that chance altogether. However, most of the benefits of insurance are felt by this household with or without a subsidy.

Compare that household's experience to the expected outcome of a household with an initial endowment of 20 assets. In the absence of insurance this household faces a 26% chance of becoming trapped in poverty. Given the opportunity, this household chooses to insure approximately 20% of assets at the market price which reduces its probability of collapse to only 9%. A subsidy covering the loading term nudges this household to insure 4 times more, thereby reducing the chance of experiencing a poverty trap to practically zero (0.5%). For this household, the benefit of additional subsidies is minimal, but the impact of insurance and a small basic subsidy is large.

Finally, compare the previous household to the anticipated outcome of a household endowed with 15 assets, just above the Micawber threshold. The opportunity cost of insurance is high for this household, so high that the household initially doesn't insure any assets unless insurance is heavily subsidized. Nonetheless, the household lies above the Micawber threshold which means that the ability to purchase insurance in subsequent periods can influence the household's expectations. That's why insurance changes the probability of a poverty trap even without purchasing insurance today. This household experiences a 45% probability of poverty trap in autarky, 26% with market-priced insurance, 9% with a subsidy on the insurance loading, 1% with a 20% premium subsidy, and 0% with a 40% subsidy. Insurance, and insurance subsidies, dramatically alter the expected equilibrium outcome for this household.

Insurance improves the ability of households to cope with large negative shocks ex post, dramatically altering the probability that such households end up trapped in poverty. But insurance also alters the economic landscape households find themselves in, and can change the way households cope with risk ex ante (before the shock actually hits). The experience just described of the 15 asset household hints at this ex ante effect, given the widely varied outcomes under the various scenarios despite negligible insurance purchases. The effects of ex ante impacts are discussed in the following section.

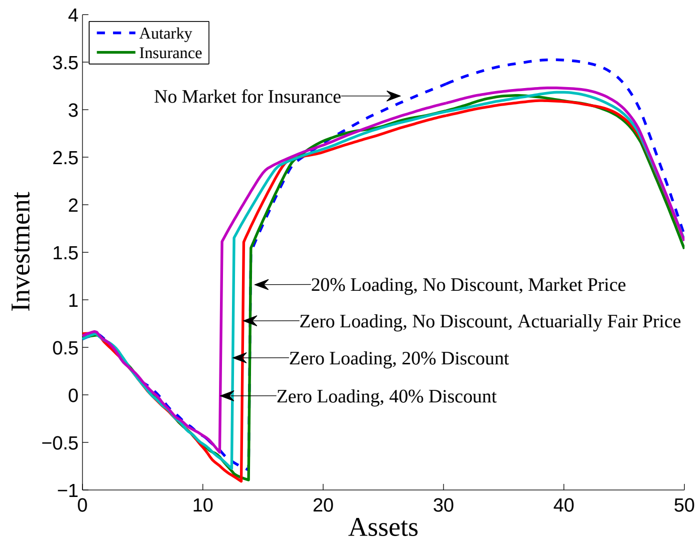
4.2 Ex Ante Effects at the Household Level

The presence of an insurance market changes the expectation a household has regarding its own future. We showed this in Figure 2 which demonstrates how the opportunity cost of assets increases when insurance becomes available. Since both first order conditions in the insurance problem depend on $V_I'(A_{t+1}|c_t, I_t, A_t)$, the presence and nature of an insurance market alters ex ante behavior. Specifically, Equation 9 dictates that as $V_I'(A_{t+1})$ 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 Micawber households for whom insurance is costly. To demonstrate this ex ante behavioral effect, Figure 5 shows the optimal investment policy function with no access to insurance and under the various insurance price subsidies.

The Micawber threshold is by definition the point in asset space where optimal behavior bifurcates. Without insurance this threshold is 14.1 assets. Households on either side of the threshold invest somewhat less when market-priced insurance becomes available than in autarky. This behavioral change suggests that in the absence of an insurance market, most households invest more ex ante, as part of a coping strategy to protect against collapse. When formal insurance becomes available, most households instead choose to use a portion of their liquidity to purchase insurance, forgoing additional investment. This finding supplements findings by Francesca de Nicola (2011) who predicts reduced investment when insurance is introduced (ignoring poverty traps).

The more consequential behavioral change occurs around the Micawber threshold. Even

Figure 5: Investment Policy Function Under Various Prices



though basic subsidies fail to crowd-in insurance purchases at the threshold, Figure 5 shows that subsidies dramatically alter behavior around the threshold by crowding-in investment. The promise of a safety net which prevents against future collapse actually incentivizes investment for 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.[8]

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 Micawber household.

In fact, this ex ante behavioral effect of insurance is of critical importance for households situated at the threshold. Figure 4 also depicts a shift in the Micawber threshold, and testifies to the dynamic implications for a Micawber household. In the previous section we described in detail the expected outcome of households endowed with 30, 20 and 15 assets. Now 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 so that investment can be 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

[8]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.

escaping the poverty trap from zero to 82% with a 20% premium subsidy (and zero loading). Increasing the subsidy to 40% 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.

Up to this point, we have demonstrated how the improved ability to cope with shocks, both ex ante and ex post, offered through insurance alters the probability of arriving at a particular equilibrium. Ex ante behavioral changes are particularly effective for Micawber households at altering the probability of becoming trapped in poverty. We may also be interested in knowing how many households we might expect to benefit from this shifting threshold effect. For this task, we use household survey data collected in 2011 which includes information on household herd sizes in Marsabit district of northern Kenya. From the data we can approximate the fraction of the population which lies in the region where a threshold shift matters. The observational data suggests that approximately 1% of Marsabit households (otherwise destined for the low equilibrium) would attempt to escape the poverty trap through ex ante behavioral changes when the loading costs of insurance are subsidized. If the premium is also subsidized at 20%, the number of households who shift out of a poverty trap (in probability) increases to 2%. Increasing the subsidy to 40% increases the number of households who change their behavior in order to strive for the high equilibrium to about 3.5% of the population. These numbers reflect only households just below the autarkic threshold, and do not include the number of households initially above the autarkic threshold who are better equipped to cope with shocks.

Our analysis also suggests that an insurance market can positively impact the level of the long-term equilibrium outcome. This final benefit of insurance can be observed by comparing the median outcome reached after 50 years over a large number of simulations for a given asset endowment. Our simulations show that the low equilibrium shifts marginally from 3.8 in autarky to 4.0 under almost all price schemes. On the other hand, an insurance market has a large effect on the high equilibrium. Consider again a household endowed with 30 initial assets. We already showed that this household reaches the high equilibrium with 83% probability in autarky, and 99% probability with market-valued insurance. In addition to the change in these probabilities, the high equilibrium achievable actually increases by 3 assets with market-valued insurance from 35.4 assets in autarky to 38.4. When the insurance is subsidized, the median outcome reached after a large number of simulations improves even more. The median outcome under zero loading is 39.0. That increases by almost 1 asset (to 39.8) when offered an additional 20% premium subsidy. When the premium subsidy is increased to 40%, the equilibrium outcome improves by still another asset (to 40.8).

4.3 Insurance Impact on Poverty Dynamics

Our analysis suggests several benefits arise when insurance is made available at the household level. We also want to know what these benefits mean for poverty dynamics of an entire population. Thus far we have used optimal behavior under various scenarios to simulate household asset dynamics 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 have shown that the gains from insurance to households with large endowments stems primarily from a reduction in vulnerability. For these households, subsidies may elevate the level of equilibrium assets, but the primary impact (reducing vulnerability) and goal of subsidy provision (social protection) can be achieved in the absence of any subsidies. The same is not true for households situated near the Micawber threshold where subsidies have the potential to radically reduce vulnerability. For this reason, we also consider the impacts of a targeted subsidy available only to households with fewer than 25 assets. Although a first-best targeting strategy would be tiered, offering the largest subsidies to households endowed with between 11 and 15 assets, this type of policy cannot be feasibly implemented. Along the same lines as the targeted social protection suggested in Barrett, Carter and Ikegami (forthcoming), the ultra-targeted policy unpopularly benefits the vulnerable poor while excluding the current poor. Moreover, it suffers from imperfect information and fuzzy thresholds. As such, we consider a broader and more inclusive targeting strategy.

It is also useful at this stage to compare the dynamic effects of subsidizing insurance to the dynamic impacts of pure publicly-provided traditional social protection, such as a cash transfer. For this, we simulate the impacts of an unanticipated cash transfer available to poor households. The transfer is modeled after the Hunger Safety Net Programme (HSNP) available in Marsabit. As of June 2012 the value of cash transfer available to HSNP recipient households was KES 3,000 every two months (about $36), or the value of 1.2 assets (that is, 1.2 TLUs) each year. This amount is intended to meet the cost of basic consumption requirements. The program targets the first and second poorest deciles in the district using a fixed budget. Thus, for our simulations we assume an annual transfer worth 1.2 TLU available to the initially poorest 20% of the population.[9]

To evaluate the effectiveness of the various methods of social protection provision on poverty dynamics we consider two common economic indicators: the poverty headcount and poverty gap. Both of these indicators are in the family of Foster-Greer-Thorbecke (FGT) measures, and are calculated as follows:

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

Here, the income poverty line y_p is the standard $1 per day measure, not including income from other forms of aid.[10] Individual j's income y_j is calculated using $f(H_t)$, and γ is the

[9]We do not allow households to anticipate the transfer because doing so requires solving a dynamic programming problem in which households participate in a dynamic game. In the game, households compete to become the poorest 20% in order to receive the transfer. Although arguably more rigorous, solving the dynamic programming problem in this way detracts from the primary research focus. Instead, optimal autarkic behavior is used.

[10]In our model all households can subsist on the equivalent of $1.44 per day without any productive assets or investments. This is captured in $\underline{f}$. We think of this as taking food aid, and so do not count this as part of their earnings in determining whether they are above or below the poverty line. Rather, we consider an additional income above $\underline{f}$ of $1 per day. In livestock terms, $1 per day in earnings is growth of approximately 2 TLU each year. To experience this kind of growth in a given period, households need 4.7 TLU. Consequently, any household possessing fewer than 4.7 assets is considered below the income poverty line because they are unable to generate income averaging $1 per day.

FGT sensitivity parameter. For the poverty headcount, γ is equal to zero, and for the poverty gap γ equals 1.

The predicted evolution of the two FGT measures under the various social protection policies (and in the absence of any social protection) are presented in Figures 6A and 6B. The first thing to notice in either figure is that after the first ten years, the poverty outcomes stabilize. This is a feature of our model, because households tend to stabilize at one equilibrium or the other, and there is very little action crossing the Micawber threshold. Thus, it is the first ten years where we focus our attention.

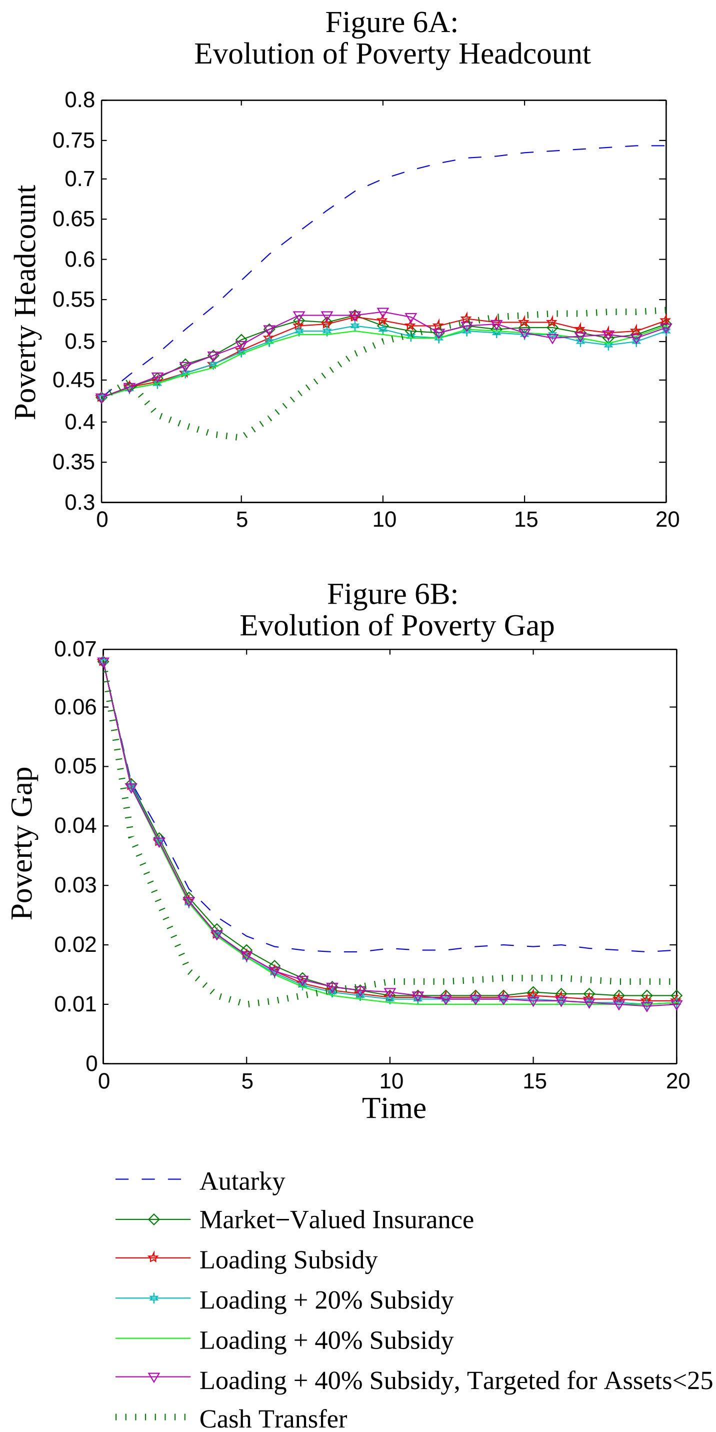
Looking first at the poverty headcount in Figure 6A, we see that the number of households falling below the poverty line steadily increases in the absence of an insurance market. Without a safety net preventing against collapse, more households fall to the low level equilibrium, which lies just below the poverty line. The poverty headcount with insurance (subsidized or not) stabilizes at a level much lower than the autarkic poverty headcount. After 10 years, approximately 20% of the population would be counted as poor without insurance, but are able to stay out of poverty through insurance. This reflects two changes brought about by insurance. First, the shifting threshold effect suggests that some households who would have been destined for the low level equilibrium without insurance, are suddenly able to pull themselves away from ultimate collapse. In addition, households positioned just above the Micawber threshold are no longer susceptible to falling below the poverty line, so that additional households are not added to the ranks of the poor. While the poverty headcount increases during the first few years that households can insure, this initial increase reflects the large number of individuals below the Micawber threshold who are heading toward the low equilibrium with or without insurance (but not initially below the income poverty line).

The type of subsidy offered matters only marginally in terms of altering aggregate poverty dynamics. This is not surprising given that the larger subsidies alter the likelihood of experiencing poverty for only a small fraction of the population. Although the difference in impact appears small in the figure, it is important to keep in mind that the difference is huge for the few households who benefit most from the subsidies. The larger the subsidy, the better the performance, because it pulls a few more households out of poverty and onto a path toward the high equilibrium. Hence, the 40% subsidy results in the lowest poverty headcount over time: an additional 1.5% of the population is kept out of poverty after 10 years through the 40% subsidy that would otherwise be counted among the poor when faced with market-valued insurance. Notably, the poverty headcount after 10 years under the general 40% subsidy is practically identical to that achieved by offering a targeted 40% subsidy available only to households with fewer than 25 assets. This is notable because the costs associated with a targeted subsidy can be much lower, as we will discuss in the next section.

The cash transfer program more effectively alters poverty dynamics in the short run. Remember, the cash transfer program provides transfers to the poorest 20% of the population. In most cases the transfers are large enough to lift households above the poverty line. That's why the poverty headcount is about 15-20% lower than autarky with the transfer. However, the cash transfer program doesn't address the vulnerability of Micawber households. Some vulnerable households continue to fall into poverty, and the poverty headcount continues to rise.

Even in the short run (after 5 years) insurance achieves half of the reduction in the

Figure 6: Evolution of Poverty Indicators with and without Social Protection



poverty headcount as the cash transfer. After 10 years, the poverty headcount is practically identical with either pure public (cash transfer) or public-private (subsidized insurance) social protection, with both programs performing offering small gains over pure private (market-valued insurance) social protection.

This accentuates the intertemporal tradeoff highlighted in Barrett, Carter and Ikegami (forthcoming). If traditional social protection doesn't address the structural foundations of poverty, then it fails to dynamically alter poverty. By addressing these structural foundations, insurance (subsidized or not) effectively keeps households out of poverty in a way that traditional social protection often fails to achieve. Subsidies work by crowding-in this protection to additional households at the Micawber threshold.

The second economic indicator we consider is the poverty gap, depicted in Figure 6B. In Section 4.2, we described how the equilibrium levels shift slightly when insurance is introduced. Because the low level equilibrium shifts upward with insurance, households are closer to the poverty line, and the gap shrinks. Here again we observe how the cash transfer policy seems to out-perform insurance in the short run. For the poorest households, a cash transfer can bring households close to the poverty line (if not over the poverty line as we saw with the poverty headcount). This may be precisely the treatment poor households need. But over time insurance seems to perform just as well (or better) in terms of changing the poverty gap. As we would expect, subsidized insurance performs better than unsubsidized, with a general 40% discount again achieving similar outcomes as a 40% subsidy available only to households with fewer than 25 assets.

5 Costs of Public-Private Social Protection

The previous section outlined a clear intertemporal tradeoff between providing traditional cash transfers and offering public-private social protection by subsidizing insurance. Insurance functions as a safety net by addressing dynamic vulnerability. For households just below the autarkic threshold, subsidizing insurance can also spur behavioral change, such that those households are able to escape from ultimate collapse. On the contrary, publicly provided cash transfers often do not account for poverty dynamics. Such transfers are allocated to poor households in order to maintain a certain standard of living.

We do not argue that one form of social protection is better than the other. Rather, we suggest that subsidizing insurance should be perceived as an additional tool in any government's social protection toolkit. In this section, we also argue that this form of social protection can be provided at a relatively small cost to governments.

Each of the various economic environments we compare are listed in Table 1. The third column of this table shows the estimated costs per household of each policy. To estimate costs, we consider the average cost of providing each type of subsidy or cash transfer over a large number of simulations using optimal demand for insurance at a given price. Costs are then calculated per household per year averaged over a thirty year period, and reported in US dollars.

Private social protection comes at zero cost to the government as long as private companies are willing to enter the market. We have shown that the benefits associated with pure private social protection (market-valued insurance) are large. Encouraging private insurers

Table 1: Comparing Policy Mechanisms

Protection Category	**Economic Environment**	**Cost**[1]	**Cost**[2] **per 1% Reduction in Poverty Headcount**			**Cost**[2] **per 1% Reduction in Poverty Gap**		
			Year 5	Year 10	Year 20	Year 5	Year 10	Year 20
None	Autarky (No Social Protection)	-	-	-	-	-	-	-
Private	Unsubsidized Insurance available to all households	0.00	-	-	-	-	-	-
Public-Private	Loading Subsidy available to all households	5.96	2.06	1.88	3.50	37.71	43.95	29.67
	Loading + 20% Subsidy available to all households	13.61	4.27	3.92	7.25	78.63	93.39	170.39
	Loading + 40% Subsidy available to all households	23.09	6.93	6.41	11.56	116.69	148.90	254.62
	Targeted Loading + 40% Subsidy for households with <25 assets	6.04	2.93	2.47	3.55	49.28	57.47	78.34
Pure Public	Regular Cash Transfer to poorest 20% of households	44.14	6.50	12.07	24.34	102.99	445.76	921.69

[1] *We consider the average cost per households of providing each policy tool over a large number of simulations using optimal demand for insurance at a given price. Costs are then calculated per household per year averaged over a thirty year period, and reported in US dollars assuming 1 TLU=KES 15,000=USD 178.50 (using an exchange rate of KES 1=USD .0119).*

[2] *We consider the average cumulative costs per household after 5, 10 and 20 years of providing each policy tool over a large number of simulations using optimal demand for insurance at a given price. Costs are calculated in US dollars assuming 1 TLU=KES 15,000=USD 178.50 (using an exchange rate of KES 1=USD .0119).*

to enter the market thus offers large gains in terms of social protection.

Once aggregated, the gains from public-private provision through subsidized insurance are small relative to the initial gain brought about by the existence of an insurance market. But for some households around the Micawber threshold, these gains are path-altering. Moreover, if crowding-in insurance keeps people out of the ranks of the poor, then it can be useful in limiting the cost of future social protection. These future savings are in essence the public return to subsidy provision. Consider the cost of a subsidy to a Micawber household with 15 assets. In autarky, this household has a 45% chance of becoming trapped in poverty, which means there's a 45% chance the household will need traditional social protection in the future. The cost of such social protection, using a local benchmark, is \$216 per year (notice that this is the cost to a receiving household, not the average cost reported in Table 1). With pure market-based social protection the probability of collapsing falls to 26%. If the household is offered a subsidy which covers the loading costs and an additional 40% of the premium, the household increases investment and insures most of its assets. Through these changes, the probability of collapse falls to 0%. The cost of providing the 40% subsidy to this particular household is \$19.06.[11]

Certainly, a \$20 subsidy to keep a household out of poverty is a much better alternative than a 26% or 45% chance of providing social protection through a \$200 cash transfer. This tradeoff carries over to the average costs per household of public-private vs. pure public provision of social protection. The average costs of providing any of the insurance subsidies are markedly lower than the average cost of providing a cash transfer. Even the most expensive subsidy considered can be provided at just over half the average cost of a cash transfer program.

Table 1 also highlights the savings that can be achieved by offering subsidies only to households who are likely to fall into a poverty trap in the future (and therefore likely to need more expensive social protection). Even with a relatively inclusive targeting tool, $\frac{3}{4}$ of the expenses associated with a 40% subsidy can be saved by making the subsidy available only to households with fewer than 25 assets. In the Marsabit sample, this would exclude only the upper 15th percentile while drastically reducing costs.

Perhaps a better way to assess the costs is to consider a cost:benefit ratio. Columns 4-6 of Table 1 show the predicted cumulative cost per person for each 1% reduction in the poverty headcount (relative to autarky) after 5 years, 10 years, and 20 years respectively. Columns 7-9 make the same comparison with regard to the poverty gap. These cost:benefit ratios provide an indicator of cost effectiveness, since they describe for each policy the cost of improving either poverty indicator. Comparing the cost:benefit ratio of the various policy mechanisms offers two primary insights. First, at an aggregated level, the most cost effective policies appear to be the lower cost subsidies (loading plus 0-20%), and the higher value targeted subsidy (loading plus 40% available only to small asset holders). These policies offer large returns at a small cost. Second, as in Figure 6, we observe evidence of an intertemporal tradeoff. In the short run, the large subsidy is slightly less cost effective than the cash transfer. However, over time this changes dramatically, with the cost effectiveness of the large subsidy surpassing that of the cash transfer.

[11] Calculated as $\frac{3}{5}$ of the premium ($\frac{1}{5}$ to cover loading and $\frac{2}{5}$ to cover the 40% premium discount), multiplied by the insurance demand, and then reported in U.S. dollars.

6 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. In this paper, we seek to determine whether the benefits of threshold-targeted social protection policy can be achieved through a market-based mechanism: insurance.

Our theoretical model underscores the importance that a high shadow price of liquidity plays for households situated near the Micawber threshold. 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 means that while Micawber households may have the most to gain from insurance, they may not self-select into purchasing insurance. We call this the dilemma of privately provided social protection. Indeed, our numerical model suggests that we should expect low uptake of market-valued insurance by households in the Micawber region.

Since pure private provision doesn't appear to reach the most vulnerable households, we then consider whether it's possible to crowd-in insurance through a public-private partnership in which governments join insurance companies in offering subsidized insurance. We show that for Micawber households, such subsidies crowd-in both insurance and investment, thereby offering huge path-altering benefits. These benefits take place through both ex ante and ex post behavioral changes. We also show that these benefits can be obtained at a fraction of the cost of pure publicly provided social protection, especially if they can be loosely targeted.

Examples of public-private provision of social protection are abundant in more developed societies. The federal crop insurance program in the United States is an obvious example. Crop insurance policies are sold and completely serviced through private insurance companies. A producer pays a portion of the actuarially fair premium, with the remainder of the premium as well as administrative and operating costs being covered by the federal government. (According to both Shields 2010 and Smith and Watts forthcoming, approximately 60% of the total premium, on average, is paid by the government.) This public-private partnership was designed to encourage the private sector to develop policies, so that America's farmers would be better able to manage risk. In the absence of subsidies, farmer participation in the crop insurance program would likely be substantially lower, although for reasons that are likely to differ from liquidity-constrained Micawber households in Kenya. Nonetheless, this mixed model of offering subsidized insurance may be an effective means of providing social protection to vulnerable populations in risk-prone areas such as the pastoralist population in northern Kenya. As we have shown, for these households the difference in outcomes could be huge.

In this paper we show that insurance subsidies may be a particularly effective social protection policy tool for helping vulnerable, not-yet-trapped households situated in the Micawber region. If critical asset thresholds do indeed exist, then designing optimal social protection policies requires taking the associated dynamics into account. While insurance offers many of the benefits sought after by social protection policies, we show that in the absence of publicly provided subsidies, the opportunity cost of insurance will be too high to induce demand by the most vulnerable households. However, subsidizing insurance provides an intriguing avenue of providing social protection through a public-private partnership.

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Appendix: 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 2.

Table 2: Functional Forms and Parameters used in Numerical Simulations

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