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SHOCK WAVES: MANAGING THE IMPACTS OF CLIMATE CHANGE ON POVERTY

Background Paper

Social Protection in the Face of Climate Change

Principles and Financing Mechanisms

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Abstract

Climate risk is an important driver of long-term poverty dynamics, especially in rural regions. This paper builds a dynamic, multi-generation household model of consumption, accumulation, and risk management to draw out the full consequences of exposure to climate risk. The model incorporates the long-term impacts of consumption shortfalls, induced by the optimal "asset smoothing" coping behavior of the vulnerable, on the human capital and long-term wellbeing of families. The analysis shows that the long-term level and depth of poverty can be improved by incorporating elements of "vulnerability-targeted social protection" into a conventional system of social protection. The paper also explores the degree to which vulnerability-targeted social protection can be implemented through a subsidized insurance mechanism. The analysis shows that insurance-based vulnerability-targeted social protection dominates (in economic growth and poverty reduction measures) both in-kind transfer mechanisms and vulnerability-targeted protection paid for using a public budget. The relative gains brought about by this scheme of insurance-augmented social protection increase—at least for a while—under climate change scenarios. However, if climate change becomes too severe, then even this novel form of social protection loses its ability to stabilize the extent and depth of poverty.

Social Protection in the Face of Climate Change: Targeting Principles and Financing Mechanisms

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(JEL I32, H50, Q54, G22)

Key words: social protection, poverty, climate change, insurance

1   Introduction

Climate shocks, which reduce incomes and destroy productive assets, can drive rural households into poverty. Climate change, which increases the frequency and intensity of these shocks, threatens to make climate risk an ever more important contributor to poverty dynamics. Against this backdrop, we ask two questions concerning the design of social protection programs intending to reduce poverty and facilitate the upward mobility of poor and vulnerable households:

1. How should a given social protection budget be targeted or prioritized between the already destitute and those who are vulnerable to becoming destitute?

2. Can public budget constraints be relaxed – and poverty impacts improved – through targeting social protection at the vulnerable with partial financing provided by beneficiaries' own private 'premium' contributions?

To gain purchase on these questions, we develop a theoretical, dynamic programming model of multi-generation families or 'dynasties' that in the face of risk allocate scarce resources between consumption and asset accumulation to maximize long-term family well-being. Loosely calibrated on the pastoral regions of East Africa where climatic shocks already loom large and drive poverty, each dynasty in the model begins with initial levels of physical assets and human capabilities or capital. Over time, shocks can not only drive vulnerable households into long-term poverty, they may also induce households to cut consumption and preserve physical assets as they seek to avoid chronic poverty.

One novelty of the model developed here is that we allow consumption shortfalls (or undernutrition) to feedback and probabilistically reduce the human and economic capabilities of the dynasty's next generation. This feedback further increases the impact of vulnerability on long-term poverty dynamics, raising the stakes for addressing poverty and vulnerability through carefully designed social protection programs.

Using this model, we explore the effectiveness of different schemes of social protection, ranging from conventional in-kind transfers, means-tested and targeted at the already destitute, as well as novel schemes where a fraction of a fixed social protection budget is spent as contingent transfers that protect the vulnerable. Our key findings are as follows: Gauged by standard poverty metrics, targeting some of the fixed social protection budget at the vulnerable can reduce both the extent and depth of poverty over time relative to a conventional in-kind transfer strategy. However, given budget constraints, targeting the vulnerable induces a tradeoff between the short-term and the long-term well-being of the poor. This tradeoff can be

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partially mitigated if a fixed social protection budget is stretched by having the vulnerable privately fund a portion of the premium load for an insurance that functions as contingent social protection.

The ability of households to adapt to increasing climate risks will depend largely on poverty dynamics of local settings. As climate change increases risk and vulnerability, social protection will become increasingly important. This analysis suggests that targeting vulnerable households - in addition to the already destitute - will protect households against heightened risk and minimize unnecessary poverty in future generations. Targeted social protection policies that carefully consider the poverty dynamics of local settings will result in greater resiliency.

The remainder of this paper is organized as follows. Section 2 develops the dynamic model of dynastic decisionmaking, illustrating how coping strategies interact with the evolution of human capital to alter the mapping between initial endowments and long-term poverty. Section 3 then explores alternative schemes of social protection, including in-kind transfers, vulnerability-targeted social protection and insurance models with mixed public and private financing of social protection. Section 4 summarizes the impact of increased risk on the design of social protection. Finally, Section 5 concludes with thoughts on furthering the social protection conversation in an era of climate change-fueled increases in the number and intensity of shocks.

2   A Dynamic Model of Risk, Vulnerability and Long-term Poverty Dynamics

We begin with our core theoretical model of household intertemporal decision making and analyze it first under the simplifying assumption that human capital is an endowment that is fixed over time and is not influenced by a dynasty's history of consumption and undernutrition. While this assumption is patently unrealistic over the longer term, it provides the opportunity to fix key concepts and ideas concerning risk, vulnerability and asset smoothing.

We then generalize the model and incorporate a feedback loop between consumption, nutrition and the evolution of human capabilities or capital. This feedback loop increases the probability that vulnerable households will collapse into long-term destitution. Section 3 will then explore the implications of this feedback loop for the design of social protection programs.

2.1 Poverty Dynamics with Exogenous Human Capital

We model an infinitely lived household dynasty d, which is comprised of a sequence of generations $g = 0, 1, 2, \ldots$. Each generation lasts for 25 years ($t = 1 - 25$) and considers only the welfare of the current generation (but does not know when the generation will conclude). Each dynasty enjoys initial endowments of physical assets, A_{d0} and human capital, H_{d0}. We will initially assume that the dynasty's human capital is fixed once and for all. We will later relax this assumption and allow the next generation's human capital to evolve, in part in response to that generation's 'early childhood' nutritional experience as reflected in the consumption levels of the prior generation.

We assume that the household dynasty manages its resources to solve the following problem:

$$\max_{\overrightarrow{c}_{dgt}} \quad E_\theta \left[\sum_{g=1}^{\infty} \sum_{t=1}^{25} u(c_{dgt}) \right]$$

$$subject\ to :$$

$$
\begin{aligned}
& c_{dgt} \leq A_{dgt} + f(A_{dgt}, H_{dgt}) \\
& f(A_{dgt}, H_{dgt}) = H_{dgt} \max[A_{dgt}^{\gamma^h} - F, A_{dgt}^{\gamma^l}] \\
& A_{dgt+1} = [f(A_{dgt}, H_{dgt}) + (1 - \theta_{dgt+1})A_{dgt}] - c_{dgt} \\
& H_{dgt+1} = H_{d0} \\
& A_{dgt} \geq 0
\end{aligned}
$$

$$(1)$$

The first constraint restricts current consumption to cash on hand (the value of current physical assets plus income). As shown in the second constraint, dynasties have access to both a high and a low productivity technology ($\gamma^h > \gamma^\ell$). Fixed costs, F, associated with the high technology make it the preferred technology only for households above a minimal asset threshold, denoted $\tilde{A}$. Thus, households with assets greater than $\tilde{A}$ choose the high technology, and households below $\tilde{A}$ choose the low productivity technology. Note that human capital, H_{dgt}, augments the total factor productivity of both production technologies.

The third constraint is the equation of motion for physical assets. Assets are subject to stochastic shocks (or depreciation), $\theta_{it+1} \geq 0$. The shock is independent and identically distributed, and realized for the households after decision-making in the current period (t), and before decision-making in the next period ($t+1$) occurs. Period t cash on hand that is not consumed by the household is carried forward as period $t+1$ assets.

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As shown by the fourth constraint, we assume for now that the dynasties' human capital is exogenously fixed at its initial level. Finally, the non-negativity restriction on assets reflects the assumption that households cannot borrow. This assumption implies that consumption cannot be greater than current production and assets, but it does not preclude saving for the future.

As has been analyzed by others in similar models (*e.g.*, Buera, 2009 and Carter and Ikegami, 2009), the non-convexity in the production set can, but need not, generate a bifurcation in optimal consumption and investment strategies (or what Barrett and Carter, 2013 call a multiple equilibrium poverty trap). This bifurcation happens if steady states exist both below and above $\tilde{A}$. If they do, there will exist a critical asset threshold where dynamically optimal behavior bifurcates, with those below the threshold deaccumulating assets and moving towards the low steady state, and those above it investing in an effort to reach the high steady state. The former group are often said to be caught in a poverty trap. Following Zimmerman and Carter (2003), we label the critical asset level where behavior bifurcates as the Micawber threshold, and denote it as A_M.

Using the parameter values given in the Appendix, numerical dynamic programming analysis of the household problem 1 shows that multiple equilibria exist for a range of human capital levels. The solid blue line in Figure 1 graphs the probability that a dynasty with a fixed intermediate level of human capital will end up in the low-level, poverty trap equilibrium as a function of its initial level of physical assets, A_{d0}. As can be seen, for a fixed level of H_{d0}, an asset level of about 14 units marks the Micawber threshold as dynasties with initial assets below that level will, with probability one, end up at the low level equilibrium.

The "chronic poverty map" shown in Figure 2a graphs across the full endowment space of initial physical and human capital assets the probability that a dynasty will end up at the low level equilibrium. The light region across the northeast corner of the figure shows those asset combinations for which this probability is zero, whereas the dark region across the southwest corner of the figure shows those combinations with probability one of the low level equilibrium. As can be seen, in this model, dynasties with initial human capital above 1.35 units will always escape the poverty trap, whereas those with human capital below 1.05 never will, irrespective of their initial level of physical assets. We refer to this latter group as the chronically poor or *Destitute*.

Between those two critical human capital levels, dynasties are subject to multiple equilibria, and their probability of ending up poor depends on their initial endowment of physical assets. We label dynasties in the intermediate multi-color band as the *Vulnerable* - households that face a probability between zero and one of ending up

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Figure 1: Probability of Chronic Poverty (low level equilibrium)

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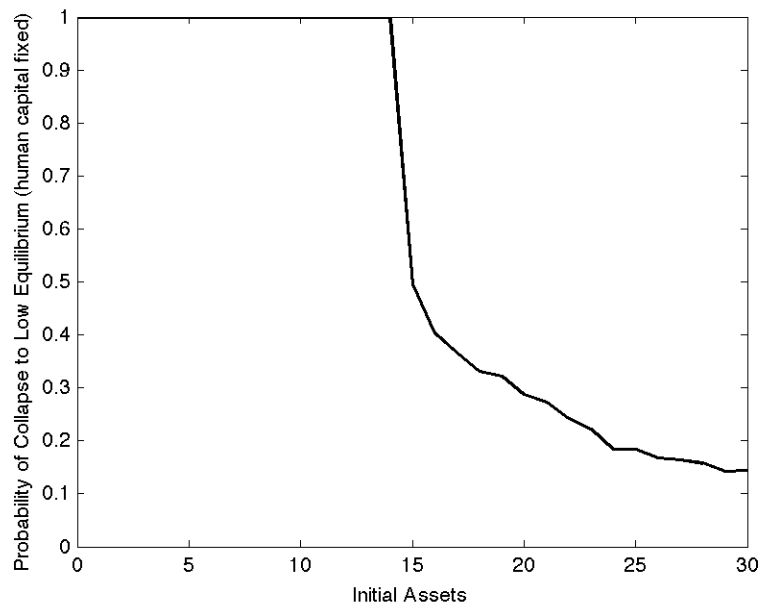
in the poverty trap.

As analyzed further by Janzen, Carter, and Ikegami (2015), a key implication of this model is that incremental physical assets carry an extremely high shadow value for these vulnerable households.[1] Incremental assets not only create an income flow, they also give the option of advancing to the high equilibrium in the long-run, or, conversely, avoiding falling into a poverty trap. As discussed by these authors and by Carter and Lybbert (2012), it is this jump in the shadow value of assets that leads households in this asset neighborhood to smooth assets, and destabilize consumption when hit with a shock.

While highly stylized, this model has rich implications concerning the impact of shocks:

- *Shocks Can Have Irreversible Consequences for the Vulnerable*
  A shock that pushes a household below the critical asset level, A_M, has irreversible consequences as the household becomes mired in chronic poverty. Vulnerability, as defined in Figure 1 thus matters as those who fall below A_M become candidates for conventionally conceived schemes of social protection.

- *Shocks Can Induce Asset Smoothing by the Vulnerable*
  While households near either steady state will tend to smooth consumption in the spirit of the Deaton (1991) model, highly vulnerable households in the neighborhood of A_M will asset smooth when hit with a shock. These households drastically cut consumption in an effort to preserve capital and avoid the collapse into chronic poverty. While this coping behavior is understandable, it potentially has deleterious long-term consequences as consumption doubles as investment into future human capital. We will later explore the implications of this behavior for long-term poverty dynamics.

In addition, as we will explore later in Section 4, climate change that increases the severity or probability of shocks will redraw the poverty map, increasing both destitution and vulnerability. However, before turning to the analysis of climate change, we need to further probe the logic of asset smoothing and vulnerability.

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[1]Janzen, Carter, and Ikegami (2015) show the shadow value of assets is non-monotonic with respect to assets, and, for a typical level of human capital, swells around approximately 14 asset units.

Figure 2: Chronic Poverty Maps–Probability of Chronic Poverty

(a) Fixed Human Capital

(b) Endogenous Human Capital
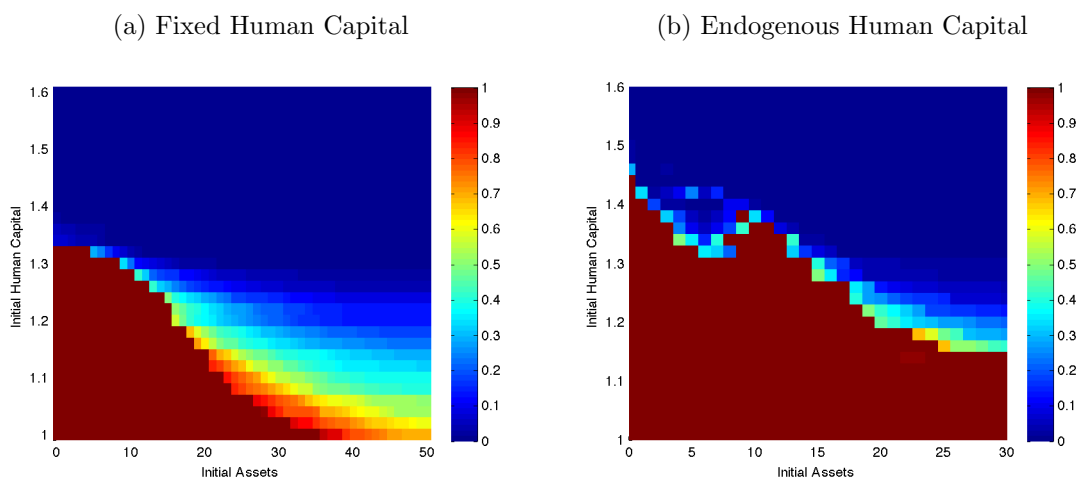
2.2 Asset Smoothing by the Vulnerable as Intergenerational Asset Shifting

Consistent with our theoretical model, there is an emerging body of evidence that poorer households tend to hold on to their (modest) assets and smooth consumption less effectively than they might, and certainly less effectively than wealthier households do. Townsend (1994), Jalan and Ravallion (1999) and Kazianga and Udry (2006) note that poor households less effectively smooth consumption than do wealthier neighbors. In later work, Hoddinott (2006) provides evidence that in the wake of the 1994-1995 drought in Zimbabwe, richer households sold livestock in order to maintain consumption, while poorer households did not, destabilizing consumption instead. Similar evidence is found by Carter et al. (2007) (for Ethiopia) and Carter and Lybbert (2012) (in Burkina Faso). Exploiting a randomized controlled trial in Kenya, Janzen and Carter (2013) find evidence not only of differential asset smoothing by the poor, but also evidence that insurance allows the poor to improve consumption smoothing, while the impacts for the wealthier allow them to hold on to assets that they would otherwise sell to smooth consumption.

While asset smoothing by the vulnerable thus has both theoretical and empirical foundations, the full welfare consequences of asset smoothing are less explored. Hoddinott (2006) points out, even though asset smoothing is an attempt to preserve assets, consumption itself is an input into the formation and maintenance of human capital, and hence "the true distinction lies in households' choices regarding what

type of capital–physical, financial, social or human (and which human)–that they should draw down given an income shock." With this tradeoff in mind, Jacoby and Skoufias (1997) present evidence that households in rural India cope with shocks by reducing child school attendance - another way of drawing down human capital in the wake of a shock. While asset smoothing strategies may be rational, when they come at the cost of immediately reduced consumption, such strategies are likley to result in irreversible losses in child health, nutrition and long term well being.[2]

In short, while the logic of asset smoothing is unassailable, it sets the stage for the intergenerational transmission of poverty. The implications for poverty dynamics, and ultimately the design of social protection–especially in the face of climate change–warrant attention.

While asset smoothing protects the dynasty from immediate danger of permanent economic collapse, it may also impinge on future capabilities and human capital of the family. To explore the longer-term implications of asset smoothing by the vulnerable, we modify the equation of motion for human capital for inter-temporal choice model 1 as follows:

$$H_{dgt} = \begin{cases} H_{dgt-1} \forall t \neq 1 \\ \left\{ wH_{d(g-1),25} + (1-w)\tilde{H} \right\} - \left\{ \lambda \sum_{t=1}^{5} 1(z > c_{d(g-1)t}) \left(\frac{(z-c_{d(g-1)t})}{z} \right)^2 \right\} \ if \ t = 1 \end{cases}$$

(2)

This somewhat tortuous notation indicates that human capital within a generation is fixed at its starting value for that generation. However, when the generation changes (and when the children of the prior generation take over as dynasty leaders), human capital resets based on the realized capabilities of this next generation.

As shown by Equation 2, two forces shape this human capital update. The first term in curly brackets is the next generation's genetic potential expressed as a weighted average of the parent generation's human capital endowment and a random draw, $\tilde{H}$, from the overall population capabilities distribution. Numerically, $\tilde{H}$ is distributed with expected value of 1.35. Note that this term will generate a regression to mean genetic potential.

The second term in curly brackets is a penalty that pushes an individual below genetic potential if she or he suffered consumption shortfalls ($c_{dgt} < z$, where z is the nutritional poverty line) in the first critical five years of life. This specification

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[2]The outcomes of undernutrition and malnutrition are well known. In children, these conditions can lead to muscle wastage, stunting, increased susceptibility to illness, lower motor and cognitive skills, slowed behavioral development, and increased morbidity and mortality (Martorell, 1999). Those that do survive suffer functional disadvantages as adults, including diminished intellectual performance, work capacity and strength (Alderman, Hoddinott, and Kinsey (2006)).

is meant to capture the idea that undernutrition *en utero* and in the first 4 years of life can have irreversible damage on the physical and cognitive development of the child. Note that a dynasty that avoids nutritional penalties will regress towards mean human capital potential, $E[\tilde{H}]$.

After replacing the fixed human capital specification in model 1 with the new human capital equation of motion 2, we used the same parameter values to reanalyze the implications of the dynasty intertemporal problem for long-term poverty dynamics.[3] For this analysis, we assume that households ignore these long-term feedbacks into its long-term human capital. While this assumption helps keep the problem mathematically tractable, it is consistent with a broad range of evidence that families often overlook the long-term consequences of nutritional shortfall on long-term economic capacity of children. The strength of this evidence is reflected in the routine practice that interventions intended to boost family income must include an element of nutrition behavior change communication to be sure that income gains translate into improved child food intake.[4] Simple discounting will also lead current decision makers to largely, but not completely, ignore impacts that occur in the distant future. We leave it to future work to incorporate nutritional awareness in this model. Note also that for the asset smoothers, choice even with full knowledge of its long-term consequences, may be no different than that which modeled when this human capital feedback is ignored. For these households, failure to consumption smooth would mean an immediate dissent into chronic poverty as opposed to putting it off for a generation.

Figure 2b displays the modified frontier that evolves across the generations when human capital is nutritionally sensitive. The color contours again mark the probability of chronic poverty as a function of the dynasty's initial human capital and asset endowments. The results are quite striking. Comparing Figures 2a and 2b, we see that the Micawber Frontier has moved to the northeast. Initial endowment positions in the lower right of the diagram, which used to have some probability of escape from long-term poverty have seen those prospects drop to zero. Moreover, vulnerability has increased for a broad range of dynasties that used to be able to rely on rapid accumulation and asset smoothing to ensure a near certain escape from poverty.

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[3]The Appendix also reports the parameters needed for equation 2.

[4]Underlying this practice is work such as Kolsteren, Lefèvre, and Paule (1997) who find that parents in Nepal have inadequate knowledge about the links between food intake and chronic malnutrition. Colecraft et al. (2006) suggest that knowledge is even weaker about the importance of micronutritients for long-term child development. Other factors that militate against parents taking long-term consequences into consideration are "middle-age bias" (prioritizing the food needs of working adults to the detriment of children as in Sauerborn, Berman, and Nougtara, 1996) and present bias (overweighing short-terms needs relative to long-term needs, as in Dupas, 2011).

Interestingly, households with approximately 5 physical assets appear better off than those with somewhat higher assets, holding A fixed. This reflects our assumption that households ignore the intergenerational consequences of nutritional choices. A first generation household with 5 physical assets will smooth consumption, and the human capital of the next generation will not be penalized. A household with a slightly higher physical asset endowment will attempt to smooth assets instead, hoping to reach the high welfare equilibrium. Unknowingly, in the following generation, this household will be penalized as a result of their lower consumption in the first 5 periods and the intergenerational transmission of poverty ensues. This directly highlights the tradeoff between asset smoothing today and the welfare of future generations.

3   Social Protection Tradeoffs: Targeting the Destitute or the Vulnerable

As analyzed in the prior section, undernutrition worsens the poverty map by deepening the intergenerational transmission of poverty as the children and grandchildren of initially poor and vulnerable households tend to suffer a long term deterioration in their realized levels of human capital. This result is strikingly illustrated in Figure 2b where we see that after 4 generations, initially disadvantaged dynasties fall short of their potential human capabilities, whereas initially better off dynasties oscillate around the population potential level (set at 1.35 in our simulations).

This concern that long-term poverty sometimes deepens and perpetuates itself by diminishing the human capital of the next generation motivated the outpouring of both in-kind and cash transfer programs that have been largely focused on helping poor families invest in the nutrition, health and education of their children. In order to achieve these goals in-kind transfers often limit consumer choice by providing food or education stipends directly. Cash transfer programs similarly often come with "conditions" attached that require investments to be made in nutrition, health and/or education. Note that at least in principle, cash or in-kind transfers could help avoid the deterioration of human capital and thereby alter poverty dynamics.

The goal of this section is to explore the impact of a stylized, means-tested, in-kind transfer program on long-term poverty dynamics in a world with risk and poverty traps. This type of program can be thought of as food aid, but it is also similar to a conditional cash transfer program that encouragees investments in education and nutrition (the human capital of future generations) rather than physical capital

accumulation.[5]

After exploring the efficacy of such a program in terms of its impacts on the evolution of both the poverty headcount and the poverty gap, we consider the tradeoffs (in terms of the core poverty measures) that are induced if a proportion of a given social protection budget is targeted at the vulnerable rather than the destitute.

To explore these social protection tradeoffs we analyze a stylized economy comprised of D dynasties that are uniformly distributed across the domain of the endowment space shown in the preceding poverty maps. This distributional assumption is meant to illustrate the workings of the model from the full range of possible original positions. Over time, as dynasties move to the stochastic steady states associated with this model, certain portions of the endowment space will of course become less densely populated. Subsequent dynamic simulation results are then best considered as illustrations of the underlying economic mechanisms, and not as a prediction of impacts on any actually existing economy (found in mid-history).

3.1 Poverty Dynamics with In-Kind Transfers

We begin by considering a stylized social protection program that offers in-kind transfers τ_{dgt} with the following characteristics:

- *Means Tested*
  Eligible households are those for whom $c_{dgt} < z$, where z is the consumption poverty line.

- *Contingent Transfers*
  Subject to budget constraints, each household receives the transfer needed to completely close the poverty gap – *i.e.*, $\tau_{dgt} = z - c_{dgt}$. Note that under this specification, transfers are contingent in the sense that a dynasty that experiences asset losses and hence lower consumption, will receive a larger transfer from an otherwise identical dynasty. We assume that all transfers are channeled directly into consumption and that they are not anticipated and hence do not influence the decision to accumulation physical capital.[6]

- *Government Budget Constraint*
  We assume that the government has a fixed social protection budget, B, that is

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[5]Some in-kind transfers, like livestock transfer programs, are an example of in-kind transfers that encourage capital accumulation over current consumption. This type of in-kind transfer is not what we study here.

[6]Using a similar model, Barrett, Carter, and Ikegami (2013) analyze what happens if transfers are anticipated.

initially just large enough to close the poverty gap for all destitute households. At any point in time in which the budget becomes insufficient, then we assume that transfers are adjusted so that all destitute dynasties receive transfers that close an equal fraction of their poverty gap.

More specifically, define the total social protection need at each point in time as:

$$\tilde{B}_{gt} = \sum_{d=1}^{D}(z - c_{dgt})1(z > c_{dgt})$$

and define the available budget adequacy as:

$$\lambda_{gt} = \frac{B}{\tilde{B}_{gt}}.$$

If a defines administrative costs, then individual transfers are given by:

$$\tau_{dgt=}\begin{cases} (1 - a_t)(z - c_{dgt}) \; if \; \lambda_{gt} \geq 1 \\ \lambda_{gt}(1 - a_t)(z - c_{dgt}), \; otherwise \end{cases}.$$

While there is some (very) modest empirical evidence that cash or in-kind transfers spill over into investment and increase potential earnings, in our simulation, we assume the transfer goes directly to consumption. Figure 3 displays the chronic poverty map for the case of perfectly targeted in-kind transfers (i.e. $a = 0$). For ease of comparison with the case without transfers, panel 3a duplicates Figure 2b. We see that in-kind transfers have some impact on poverty dynamics as the area of certain chronic poverty in the southeast corner of the map shrinks modestly. Vulnerability, however, remains high in certain portions of the endowment space.

A sharper way to engage the effectiveness of different social protection schemes is to define a set of standard poverty measures, whose evolution over time can be traced under different policies. Specifically, we consider headcount and poverty gap measures using realized consumption (optimal consumption plus an in-kind transfer when appropriate) defined as follows:

$$P_{gt} = \sum_{d=1}^{D}\frac{1(z > c_{dgt})}{D}$$

$$G_{gt} = \frac{1}{DH_{gt}}\sum_{d=1}^{D}(z - c_{dgt})1(z > c_{cgt})$$

Figure 3: Chronic Poverty Map with and without in-kind transfers

(a) Without In-Kind Transfers   (b) With In-Kind Transfers
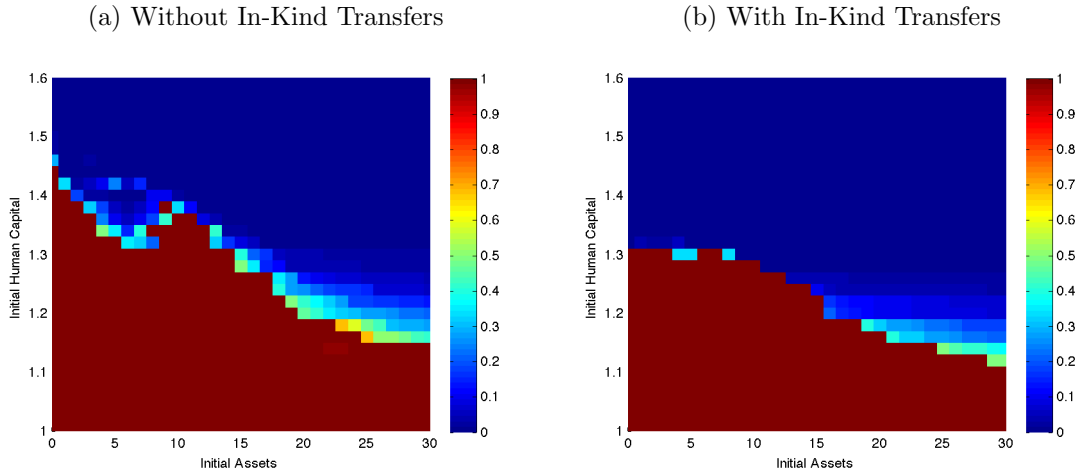
Note that the poverty gap measure, G_{gt}, measures the average depth of poverty across poor dynasties. For both measures we present the average across a large number of simulations.

In addition to these headcount and gap measures based on realized consumption, we can also define variants of these measures based on a dynasties' potential earning given its current holdings of physical and human assets.[7] These potential earnings measures will of course be smoother than those based on realized consumption. Notice that since we assume the transfer goes directly to consumption, an in-kind transfer does not increase production in a given period. The potential earnings measures also allow us to see how potential earnings and economic capacity evolves under any particular policy regime.

Figure 4 traces the evolution of the headcount and poverty gap measures in the short run (within the first generation at 5 years, 10 years, and 25 years) and in the long run (at the end of each of four generations at 25 years, 50 years, 75 years, and 100 years[8]) and allows us to see the aggregate impact of these changes in the poverty map for the stylized population with a uniform distribution of initial endowments of physical and human assets. The top two figures display poverty measures based on realized consumption, whereas the bottom two illustrate the poverty headcount and

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[7]The poverty line for the potential earnings measure is defined as that level of earnings that would, under optimal behavior, yield a consumption level equal to the consumption poverty line, z.

[8]A new generation - when a dynasty's human capital is updated according to equation 2 - begins every 25 years.

gap measures based on potential earnings. In all figures and for each time period, the first (black) bar shows the poverty measures for the autarky case with no social protection, and the second (dark gray) bar tracks these measures for an in-kind transfer program. We will discuss the other two (lighter) bars, which correspond to alternative social protection schemes, momentarily.

As illustrated by the black bar, under autarky, poverty increases markedly upwards over the generations. The second bar in each time period shows the impact of (perfectly) targeted in-kind transfers on this scenario. In-kind transfers eliminate nearly all consumption-based poverty in the short-term[9]. Over the longer term, the extent and depth of poverty drift up over time as those who have collapsed because of shocks become eligible for in-kind transfers, reducing the amount available for other indigent households. Given the fixed budget, this increase in the number of in-kind transfer-eligible households in turn pushes up the average depth of poverty. As can be seen in the lower two graphs in Figure 4, in-kind transfers over the first generation have no impact on the potential earnings of the beneficiary population. This reflects our assumption that in-kind transfer are unanticipated and delivered directly as in-kind additions to consumption.

Despite this assumption, we see that at the generational shift points, in-kind transfers do positively impact potential earnings, and therefore reduce the earnings-based poverty measures relative to the autarky case. This improvement of course reflects the intention of in-kind transfers to enhance the human capital of the next generation. Note that the poverty reduction impacts of this improved human capital are relatively modest. This finding in part reflects the fact that in this model, human capital generates income only when employed in conjunction with physical assets. As the poor by definition have few physical assets, the impacts of improved human capital is modest. Adding a second technology in which returns to human capital do not require physical assets would improve the economic impact of in-kind transfers.[10]

For the simulation, the government budget for in-kind transfers is set at the exact amount necessary to bring all poor households in the first year to the consumption-based poverty line. If some fraction of the budget goes toward administrative costs, then the consumption-based headcount is similar to that under autarky - transfers are not large enough, and recipient households are still counted among the poor. Because in-kind transfers do not influence potential earnings- the less efficient in-kind transfer performs similarly to the more efficient one.

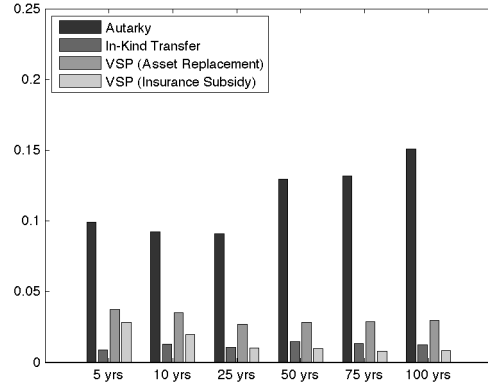[9]By design, the transfers eliminate all poverty in the first year.

[10]For example, the next generation of individuals might exit this economy with prospects of urban wage jobs proportional to their human capital.

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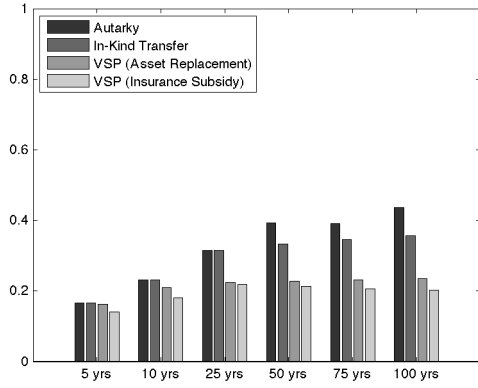Figure 4: Evolution of Poverty Measures under Social Protection

(a) Headcount (realized consumption)
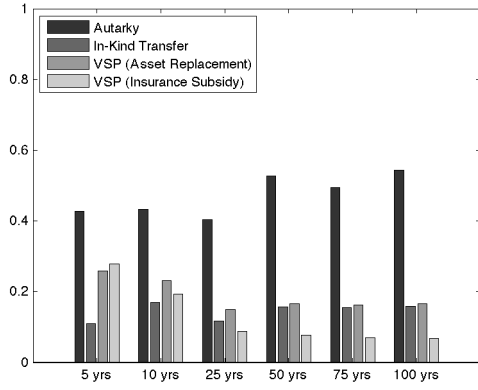
(b) Gap (realized consumption)

(c) Headcount (potential earnings)
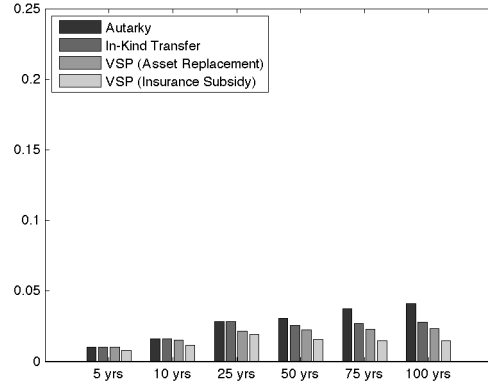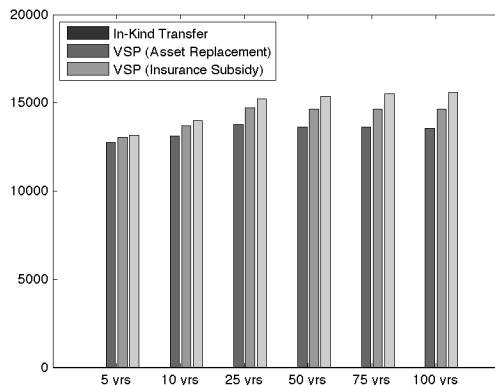

(d) Gap (potential earnings)

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Figure 5: GDP Growth with & without Social Protection

3.2 Poverty Dynamics under Vulnerability-targeted Social Protection

The underlying dynamics of the system, which steadily add individuals to the aid-eligible population, undercuts the efficacy of in-kind transfers scheme analyzed in Section 3.1. The pernicious effects of the underlying system dynamics raise the question as to whether there can be a more effective deployment of the given social protection budget.

In this section, we consider adding vulnerability-targeted, contingent social protection transfers (VSP) into the social protection system. There are two key elements to the first VSP scheme we model here:

- *Vulnerability Targeted*
  Issues payments to the "moderately vulnerable" (defined as the non-poor who face between a 20 and 80% chance of collapsing into destitution) any time they are hit by a shock that could push them into chronic poverty. Note that like the in-kind transfer program, we assume costless and perfect targeting. Note also that these VSP payments are contingent on the realized state of the world, meaning that these payments rise in bad years.

- *Triage*
  Under this scheme, social protection resources are triaged by first making transfers to the vulnerable who have been hit by shocks, and then transferring the residual social protection budget to the already destitute. We are not advo-

cating this as an optimal scheme, but this assumption allows us to explore the potential of VSP to alter poverty dynamics relative to a budget in-kind transfer program which effectively has the opposite prioritization, spending money first on the destitute.

This scheme can be considered an analogue to the restocking programs in the northern reaches in Kenya in which livestock lost to a drought are replaced by government programs. We refer to this program as VSP Asset Replacement.

Returning to Figure 4, we can see the impact of VSP Asset Replacement on the evolution of the extent and depth of poverty. Looking first at the potential earnings-based poverty measures, we see VSP Asset Replacement does a much better job than in-kind transfers in slowing the growth in the structurally poor. Over the four generations of the simulation, the headcount and poverty gap measures decline by roughly a quarter under VSP.

At the same time, the consumption-based measures shown in the top half of Figure 4 reveal a consumption/production tradeoff in the well-being of the poor. Over the first ten years of the simulation, the headcount and poverty gap measures based on realized consumption are much lower for the in-kind transfer program. Put differently, using the consumption-based measures, indigent households are unambiguously better off over this initial time period under a social protection scheme that prioritizes their needs.

However, by the middle of the first generation, the situation becomes more complex. Average headcount measures under the VSP triage scheme more or less mirror those under the in-kind transfer scheme. The gap is actually higher under the consumption-based even though we know productive output is higher.

Figure 6 gives further insight into the workings and tradeoffs of the VSP scheme. The red line in the figure shows how much of the fixed government social protection budget (of 1200) is left over for in-kind transfers after VSP asset transfers have been made. Two things stand out in the picture. First, the VSP transfers on average eat deeply into the available budget. Second, the amount of funds needed for VSP fluctuates wildly from year to year. In bad years, in fact, VSP transfers consume the entire social protection budget, leaving nothing for transfers to the indigent such that the poverty gap skyrockets. Both of these observations suggest that even though some vulnerability targeting has some potential to improve the overall situation for the poor, there might be a better budgetary and social protection model.

Figure 6: Budget Remaining for in-kind transfers to the Destitute
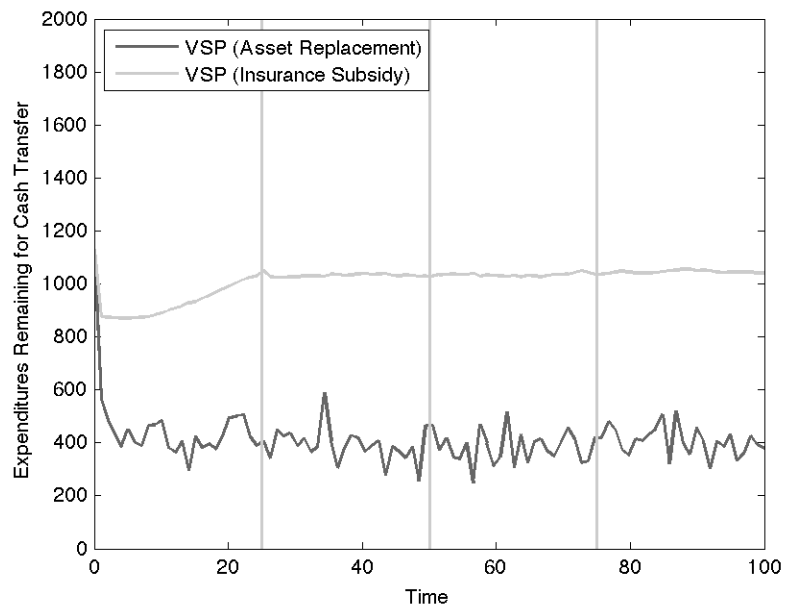
3.3 Using Insurance Mechanisms to Reduce the Social Protection Tradeoff: Mixed Public-private Financing of Social Protection

The tradeoffs potentially induced by the system of VSP analyzed in section 3.2 motivate the search for alternative financing mechanisms. The VSP asset replacement scheme analyzed in Section 3.2 operates like a publicly funded insurance scheme: those suffering shocks receive payments in the wake of a shock that drives them below the Micawber Frontier. This observation motivates the question as to whether vulnerability-targeted social protection could be offered in the form of an insurance contract that is funded in part by beneficiary contributions to the insurance premium.

Index insurance has recently received attention as a possible resolution to the moral hazard and adverse selection problems that have historically crippled the use of insurance amongst poor populations, although such products still suffer from basis risk (for recent reviews, see IFAD (2011), Miranda and Farrin (2012) and Carter et al. (2015)). Despite being seemingly valuable to poor populations, demand for insurance products has been lower than originally expected (Cai, de Janvry, and Sadoulet, forthcoming; Cole et al., 2013; Dercon et al., 2014; Gine, Townsend, and Vickery, 2008; McIntosh, Sarris, and Papadopoulos, 2013; Mobarak and Rosenzweig, 2012; Patt, Suarez, and Hess, 2010; Jensen, Mude, and Barrett, 2014). We recognize the challenges regarding the design of and demand for insurance, but leave deeper discussion of these issues to other work.

We consider an index-based insurance contract designed to issue payouts based on the realization of the covariant climatic shock to assets, rather than actual total losses ($\theta_t = \varepsilon_t^e + \varepsilon_t^i$). In this paper we assume the covariant shock, ε_t^c, is observed directly without error so that basis risk is determined solely by idiosyncratic shocks, ε_t^i, rather than contract design. In this way ε_t^c can function directly as the index that triggers payments.[11] We denote $s \geq 0$ as the strike point or index level at which insurance payments begin. We assume a linear payout function such that insurance payouts, δ, are given by:

$$\delta(\varepsilon_t^c) = \max((\varepsilon_t^c) - s),\ 0).$$

Under this specification, the insurance fully indemnifies all losses (driven by covariant events) beyond the deductible level, s. In our model 1, the household now chooses the level of insurance coverage, I_{dgt} given the insurance premium p. The budget

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[11]In practice, the covariant asset shock is not directly observed, but is instead predicted by some measure of common stress conditions (such as rainfall or forage availability).

constraint becomes:

$$c_{dgt} + pI_{dgt} \leq A_{dgt} + f(A_{dgt}, H_{dgt})$$

and future assets update according to:

$$A_{dgt+1} = [f(A_{dgt}, H_{dgt}) + (1 - \theta_{dgt+1})A_{dgt}] - c_{dgt} + [\delta(\varepsilon_t^c) - p]\,I$$

Janzen, Carter, and Ikegami (2015) explore the demand for index insurance using a variant of model 1. Intuitively, we might expect the vulnerable to voluntarily purchase insurance as they have the most to gain. As Janzen, Carter, and Ikegami (2015) detail, while it is correct that insurance is highly valuable to vulnerable households, it is also the case that these households are the most liquidity-constrained, and incremental assets are highly valuable (as a form of protection) for these households. Note that it becomes optimal for these vulnerable households to purchase insurance as soon as they build up their asset stocks. In the end, the long-run prospects of vulnerable households is substantially changed by the availability of insurance. It does not, however, completely eliminate their vulnerability.

Because the unwillingness of the vulnerable to purchase insurance is primarily driven by liquidity constraints, it may be suspected that their demand would be highly price elastic and sensitive to partial subsidization of insurance. Janzen, Carter, and Ikegami (2015) confirms this intuition. When subsidies cut the cost of insurance in half, demand by the vulnerable responds rapidly, with implied gains in reduced vulnerability. This insight suggests that the vulnerable may be able to foot some substantial portion of the bill for their own social protection that might eventually benefit the already destitute. Note that in addition, the government's share of an insurance contract would be smooth over time, unlike the VSP Asset Replacement program considered in the prior sub-section.

Building on this intuition, we consider the impact now of a mixed VSP insurance scheme which relies on insurance mechanisms and a mixed public-beneficiary funding model. For the analysis to follow we assume the following:

- *Capped Insurance Subsidy for all Dynasties*
  In contrast to the precisely targeted VSP in-kind asset replacement transfers, we here assume that the government simply offers a 50% subsidy for the purchase of insurance for anyone with fewer than 35 units of productive assets. This assumption in effect means that benefits leak to non-vulnerable and non-destitute households. Sharper targeting could improve the relative performance of this insurance-based scheme.

- *Triage*
  As with the VSP scheme analyzed in section 3.2, we assume here that the

20

fixed government budget is first used to pay 50% of the cost of all voluntary insurance purchases. Remaining budget is then allocated to in-kind transfers.

The impacts of this scheme are demonstrated by the lightest grey bar in Figure 4. Because individuals purchasing insurance anticipate the protection it will provide in the event of adverse events, the Micawber Frontier shifts to the northeast, and dynasties become more willing to invest (what we call the "risk reduction dividend"). When combined with the fact that insurance helps brake the descent into poverty by the vulnerable, this risk reduction dividend leads to substantial drops in both the extent and depth of poverty over the long-run. Figure 5 shows that the combined impact of these forces is a substantial growth in GDP, which ends up some 20% higher under this insurance-based social protection scheme than it did under the budget neutral in-kind transfer scheme.

All this said, Figure 4a still reveals an intertemporal tradeoff in the well-being of the poor. Although the depth of poverty is lower under insurance, for roughly the first 10 years of the simulation, poor dynasties are fewer under a pure in-kind transfer scenario. From year 10 onward, they tend to be better off under an insurance scheme that gives second priority to their needs.

The differences between the insurance scheme and the VSP asset replacement scheme is visible not only in Figure 4, but also in Figure 6. As can be seen in this latter figure, the budgetary draw down of the VSP insurance scheme is both lower and more stable than the requirements of the VSP asset replacement program. These savings are of course good for destitute dynasties, and for the future human capital of their children.

4   Raising the Stakes: Poverty Dynamics and Social Protection in the Face of Climate Change

Climate change raises the stakes through heightened risk and increased vulnerability. To analyze the effect of an increasingly unfavorable climate, we assume that the climate shifts discretely with the changing of each generation. While obviously unrealistic, this approach allows us to look carefully at the impacts of climate change. Importantly, we assume that each generation knows exactly the climate risk that it faces and adapts consumption and investment rules to it. Insurance is also re-priced to conform with the new risk levels at each generational transition. However, no generation anticipates the further deterioration in climate that will take place and be confronted by its children, grandchildren, etc.. While this assumption departs

somewhat from the economist's usual rational expectations specification, it does not seem highly unrealistic in this case.

The first graph in Figure 7 shows the baseline scenario our prior analysis has assumed in terms of the distribution of the covariant component of the stochastic mortality or asset depreciation shocks faced by dynasties. A discretized approximation to the livestock mortality data from northern Kenya used in the analysis Chantarat et al. (2012), this baseline risk scenario is meant to represent the extent and severity of risk faced by pastoralist households circa the year 2000. While we do not have down-scaled climate change projections for this precise region, the other three graphs in Figure 7 show what we assume happens over a time span of four generations to the distribution of risk faced by these households. As can be seen, while in baseline, we assume that droughts occur only one year in five, at the end of our climate change scenario that probability has increased to one year in three. In addition, we assume that shocks become increasingly severe, with proportionately larger increases in the probability of severe shocks that may destroy as much as 60% of a dynasties' productive assets.

In results available from the authors, we show that increasing risk of this sort shifts the Micawber Frontier to the northeast and causes a deterioration of the chronic poverty map. Rather than focus on these maps for each policy scenario, Figure 8 traces out the impact of climate change using the consumption-based poverty measures introduced earlier. The first generation results are as in Figure 4 above, climate change kicks in beginning with the second generation (year 26 and beyond). The budget is held fixed for comparison with the baseline scenario[12]. As can be seen, without social protection, both the poverty headcount and poverty gap measures worsen substantially in this stylized system in which risk is a major driver of poverty.
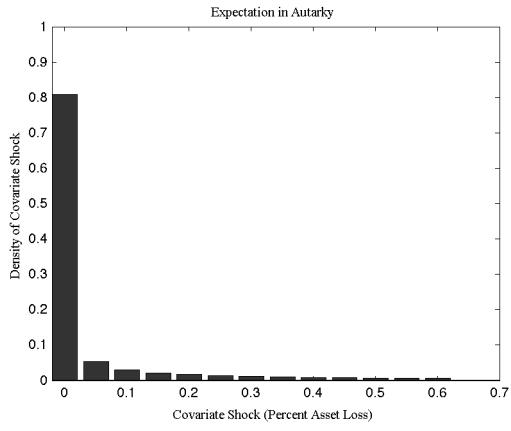
Importantly, under the climate change scenario, in-kind transfers become much less effective than the insurance-based subsidy scheme. Whereas without climate change, the insurance-based scheme modestly outperformed in-kind transfers, under climate change the insurance-based scheme has poverty rates and gaps that are roughly half those of the budget neutral in-kind transfer scheme. Interestingly, the insurance-based scheme holds up quite well to climate change over generations 2 and 3[13]. However, by generation 4, the insurance scheme begins to feel the pressure of climate change and poverty rates begin to climb higher.

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[12]An alternative experiment is to keep "performance" in terms of poverty similar and calculate the requisite budget as climate change increases.
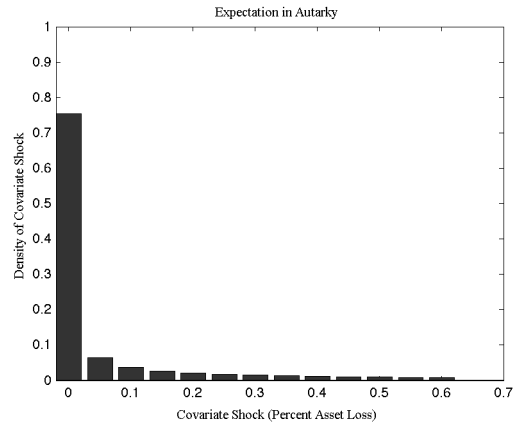
[13]Note also that the VSP asset replacement program also begins to perform relatively more favoably following moderate climate change.
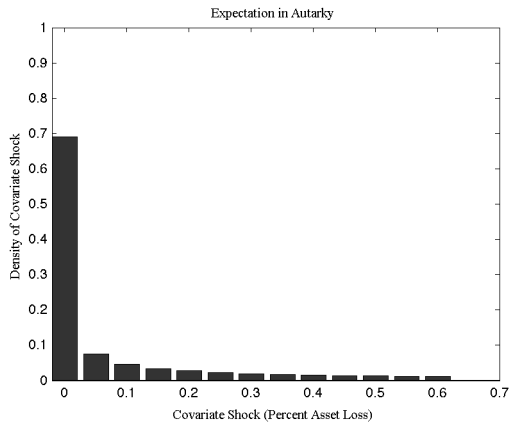
Figure 7: Climate Change Scenarios

(a) Base Case

Expectation in Autarky

(b) Generation 2

Expectation in Autarky

(c) Generation 3

Expectation in Autarky

(d) Generation 4

Expectation in Autarky
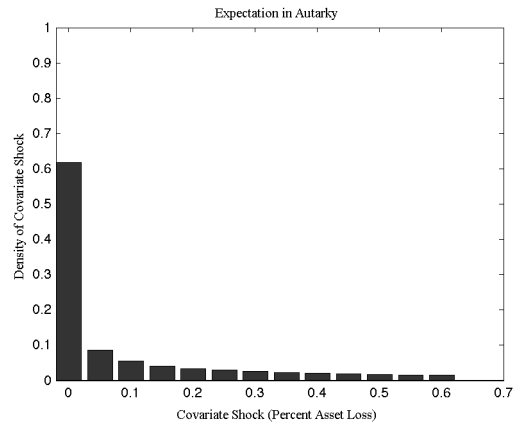
Figure 8: Climate Change & Poverty Dynamics under Alternative Social Protection Scenarios

(a) Headcount under Climate Change

(b) Poverty Gap under Climate Change
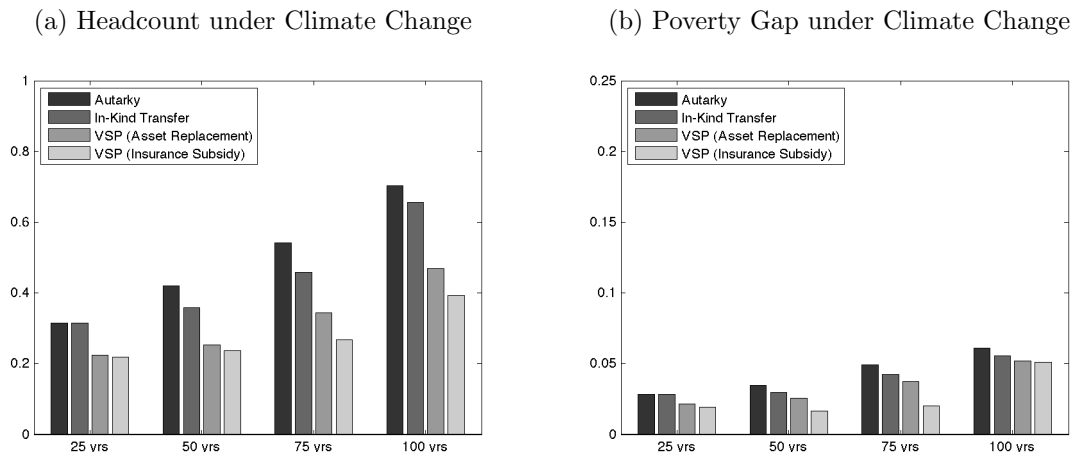
5 Conclusion

Climate-based risk and vulnerability have long been seen as key drivers of poverty, particularly in many rural areas of the developing world. In this paper, we have developed a dynamic stochastic programming model of such an area. In such a model, the relatively poor, but vulnerable will tend to "asset smooth" – that is they choose to absorb a larger fraction of any realized climate shock through reduced consumption. Unlike prior models, our analysis has drawn out the full consequences of this behavior by the vulnerable by incorporating the long-term impacts of consumption shortfalls (induced by the optimal asset smoothing coping behavior of the vulnerable) on the human capital and long-term well-being of multi-generational family dynasties.

In the context of this model, we then explore how best to control poverty by a budget-constrained program of social protection. We first show that a standard program of conditional in-kind transfers, which target only the destitute, but not the non-poor vulnerable, has limited efficacy in the medium run as realized through constantly boosting the ranks of the destitute, diluting the amount of cash available for each poor household. We then show that the long-term level and depth of poverty can be improved by incorporating elements of "Vulnerability-targeted Social Protection" (VSP) into a national system of social protection. As modeled here, the first VSP program we considered (asset replacement) effectively operates as a restock-

ing program, replacing the assets of the vulnerable population so that they retain the ability to be non-poor into the future. However, these VSP asset replacement payments, if publicly funded from the same fixed social protection budget, implies less funds for in-kind transfers targeted at the destitute. Moreover, the budgetary requirements of VSP asset replacement payments vary sharply across years. In the worst years, they in fact absorb almost all the social protection budget, leading to a sharp uptick in the average depth of poverty amongst the poor.

In an effort to mediate this tradeoff between the well-being of the destitute and the need to keep the number of destitute from rising, we then explore the degree to which an insurance mechanism can be used to implement VSP. Using this mechanism not only allows the public sector to smooth its spending on helping the vulnerable, it also opens the door to having the vulnerable pay a portion of their own social protection. While empirical demand for insurance in a variety of contexts has been modest, we have shown in other work (Janzen, Carter, and Ikegami, 2015) that demand by vulnerable households is highly price elastic. That is, the demand for insurance by the vulnerable responds strongly to partial price subsidies.

Exploiting these insights, we then study the impact of having the public sector fund 50% of the cost of a market-based insurance scheme for vulnerable households, while the other 50% is paid for privately by insured beneficiaries. Subsidies are again paid out of the fixed social protection budget. Unlike the simple VSP asset replacement program, after the first few years of the simulation, insurance-based VSP performs at least as well on poverty metrics as the in-kind transfer system. It also results in higher levels of investment and 20% higher GDP in the simple model economy.

Finally, we ask what happens when climate change increases the frequency and severity of shocks. While our baseline climate and risk scenario was calibrated on northern Kenya circa 2000, allowing for the sorts of changes expected with climate change shows that the insurance-augmented social protection scheme strongly outperforms the budget neutral in-kind transfer scheme. Over the middle generations of our simulation, poverty headcounts and gaps are some 50% lower under the insurance augmented social protection scheme compared to a standard in-kind transfer system. However, as climate change becomes ever more severe, even the insurance-based system loses its ability to prevent a swelling in the number of destitute households.

These results all emerge from a highly stylized model, and ignore some of the challenges that arise with designing index-based insurance contracts that minimize basis risk, marketing insurance to often illiterate and innumerate populations, implementing complex public private partnerships in weak and often corrupt environments, and perfect targeting. Nonetheless, they do strongly call our attention to the

often overlooked intertemporal tradeoff between the well-being of the poor in the present versus their well-being in the future. They suggest that deviating some budget toward protecting the vulnerable, but not the poor, may pay off big dividends in terms of reduced poverty rates, especially as climate change makes ever more people vulnerable.

References

Alderman, H., J. Hoddinott, and B. Kinsey. 2006. "Long term consequences of early childhood malnutrition." *Oxford Economic Papers* 58:450–474.

Barrett, C.B., and M.R. Carter. 2013. "The Economics of Poverty Traps and Persistent Poverty: Policy and Empirical Implications." *Journal of Development Studies*, July, pp. .

Barrett, C.B., M.R. Carter, and M. Ikegami. 2013. "Poverty Traps and Social Protection." Unpublished.

Buera, F.J. 2009. "A Dynamic Model of Entrepreneurship with Borrowing Constraints: Theory and Evidence." *Annals of Finance* 5:443–464.

Cai, J., A. de Janvry, and E. Sadoulet. forthcoming. "Social Networks and Insurance Take Up: Evidence from a Randomized Experiment in China." *American Economic Journal: Applied Economics*, pp. .

Carter, M.R., A. de Janvry, E. Sadoulet, and A. Sarris. 2015. "Index-based Weather Insurance for Developing Countries: A Review of Evidence and Propositions for Scaling-up." Unpublished.

Carter, M.R., and M. Ikegami. 2009. *Poverty Dynamics: Interdisciplinary Perspectives*, Oxford University Press, chap. Looking forward: theory-based measures of chronic poverty and vulnerability.

Carter, M.R., P.D. Little, T. Mogues, and W. Negatu. 2007. "Poverty Traps and Natural Disasters in Ethiopia and Honduras." *World Development* 35:835 – 856.

Carter, M.R., and T.J. Lybbert. 2012. "Consumption versus asset smoothing: testing the implications of poverty trap theory in Burkina Faso." *Journal of Development Economics* 99:255 – 264.

Chantarat, S., A.G. Mude, C.B. Barrett, and M.R. Carter. 2012. "Designing Index-Based Livestock Insurance for Managing Asset Risk in Northern Kenya." *Journal of Risk and Insurance*, pp. no–no.

Cole, S., X. Gine, J. Tobacman, R. Townsend, P. Topalova, and J. Vickery. 2013. "Barriers to Household Risk Management: Evidence from India." *American Economic Journal: Applied Economics* 5:104.

Colecraft, E., G.S. Marquis, R. Aryeetey, O. Sakyi-Dawson, A. Lartey, B. Ahunu, E. Canacoo, L.M. Butler, M.B. Reddy, H.H. Jensen, and E. Huff-Lonergan. 2006. "Constraints on the Use of Animal Source Foods for Young Children in Ghana: A Participatory Rapid Appraisal Approach." *Ecology of Food and Nutrition* 45:351–377.

Deaton, A. 1991. "Saving and liquidity constraints." *Econometrica* 59.

Dercon, S., R.V. Hill, D. Clarke, I. Outes-Leon, and A. Taffesse. 2014. "Offering Rainfall Insurance to Informal Insurance Groups: Evidence from a Field Experiment in Ethiopia." *Journal of Development Economics* 106:132–143.

Dupas, P. 2011. "Health Behavior in Developing Countries." *Annual Review of Economics* 3:425–449.

Gine, X., R. Townsend, and J. Vickery. 2008. "Patterns of Rainfall Insurance Participation in Rural India." *World Bank Economic Review* 22:539–566.

Hoddinott, J. 2006. "Shocks and their consequences across and within households in Rural Zimbabwe." *Journal of Development Studies* 42:301–321.

IFAD. 2011. "Weather Index-based Insurance in Agricultural Development." Working paper, International Fund for Agricultural Development and World Food Programme.

Jacoby, H.G., and E. Skoufias. 1997. "Risk, financial markets, and human capital in a developing country." *The Review of Economic Studies* 64:311–335.

Jalan, J., and M. Ravallion. 1999. "Are the poor less well insured? Evidence on vulnerability to income risk in rural China." *Journal of Development Economics* 58:61–81.

Janzen, S.A., and M.R. Carter. 2013. "After the Drought: The Impact of Microinsurance on Consumption Smoothing and Asset Protection." *NBER Working Paper*, pp. .

Janzen, S.A., M.R. Carter, and M. Ikegami. 2015. "Valuing Asset Insurance in the Presence of Poverty Traps." Unpublished.

Jensen, N.D., A.G. Mude, and C.B. Barrett. 2014. "How Basis Risk and Spatiotemporal Adverse Selection Influence Demand for Index Insurance: Evidence from Northern Kenya." Unpublished.

Kazianga, H., and C. Udry. 2006. "Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso." *Journal of Development Economics* 79:413–446.

Kolsteren, P., P. Lefèvre, and M. Paule. 1997. "Nutrition Rehabilitation and the Importance of the Perception of Malnutrition in the Follow-up of Rehabilitated Children." *Asia Pacific Journal of Clinical Nutrition* 6:106–110.

Martorell, R. 1999. "The nature of child malnutrition and its long-term implications." *Food & Nutrition Bulletin* 20:288–292.

McIntosh, C., A. Sarris, and F. Papadopoulos. 2013. "Productivity, Credit, Risk and the Demand for Weather Index Insurance in Smallholder Agriculture in Ethiopia." *Agricultural Economics* 44:399–417.

Miranda, M., and K. Farrin. 2012. "Index Insurance for Developing Countries." *Applied Economic Perspectives and Policy* 34:391–427.

Mobarak, A.M., and M. Rosenzweig. 2012. "Selling Formal Insurance to the Informally Insured." Working Paper No. 97, Yale University, Department of Economics, February.

Patt, A., P. Suarez, and U. Hess. 2010. "How do Small-Holder Farmers Understand Insurance, and how much do they want it? Evidence from Africa." *Global Environmental Change* 20:153–161.

Sauerborn, R., P. Berman, and A. Nougtara. 1996. "Age bias, but no gender bias, in the intrahousehold resource allocation for helath care in rural Burkina Faso." *Health Transition Review* 6:131–145.

Townsend, R.M. 1994. "Risk and Insurance in Village India." *Econometrica* 62:539–591.

Zimmerman, F.J., and M.R. Carter. 2003. "Asset smoothing, consumption smoothing and the reproduction of inequality under risk and subsistence constraints." *Journal of Development Economics* 71:233–260.

Appendix

Table 1: Functional Forms and Parameters used in Numerical Simulations

Production Technology and Parameters
$$F^h(H) = \alpha H_t^{\gamma_L} + \underline{f}$$ $$F^l(H) = \alpha H_t^{\gamma_H}$$ $$\gamma_L = 0.28$$ $$\gamma_H = 0.56$$ $$\underline{f} = 2.95$$
Utility Function and Parameters
$$u'(c_t) = \frac{c_t^{1-\rho}-1}{1-\rho}$$ $$\beta = 0.95$$ $$\rho = 1.5$$
Insurance Contract Parameters
$$s = .15$$ *Actuarially fair premium by climate change scenario* Base Case: $p = .0182$ Generation 2: $p = .0248$ Generation 3: $p = .0331$ Generation 4: $p = .0433$
Idiosyncratic Shocks
$$\varepsilon^i = \{0.0, .01, .02, .03, .04\}$$ $$\Pr(\varepsilon^i) = \{.2000, .2000, .2000, .2000, .2000\}$$