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CONTENTS

This work draws significantly on ideas and text from Barnett et al. (2006) and Chantarat et al. (2007). Barrett is senior author; co-authors are listed alphabetically thereafter.

Cover photo: Farmers examining index-based insurance contract, courtesy of D. Osgood, IRI

1. Introduction

Climate shocks can destroy crops, livestock and other productive household assets. The risk of such shocks can induce households to pursue livelihood strategies that constrain wealth accumulation.1 Thus, exposure to adverse climate events has both ex post and ex ante impacts on the incidence of poverty. Many rural households in low-income countries list weather risk as their number one concern. Weather risks and climate shocks are critically important constraints to wealth accumulation, particularly for those in rural areas who are either engaged in agricultural activities or have their livelihoods tied to the well-being of the farming sector. This paper examines these important issues by integrating diverse literatures on a wide range of related topics that enhance our understanding of how weather risks and climate shocks impact both poverty and development. That understanding is used to enlighten our evaluation of the potential developmental role of innovations in index-based risk financing for catastrophic weather shocks.

The combination of considerable ex post, observable losses due to climate shocks and the likewise-substantial, albeit less-obvious opportunity costs of ex ante climate risk management likely play an important role in perpetuating extreme rural poverty in developing countries. A dearth of financial market instruments compounds the problems of ineffective and inefficient ex ante and ex post strategies to manage and cope with climate risks and shocks in developing countries. Poor households in rural areas in developing countries often lack access to formal financial markets that can facilitate consumption smoothing. And while microfinance has shown significant promise in some settings, the success has been limited in rural areas and for farming activities that require longer-term loans than is customary for microfinance (Armendáriz and Morduch 2005). In many cases, missing insurance markets for climate risk can explain why lenders are reluctant to lend or why they charge high interest rates to those engaged in inherently risky enterprises such as farming. Advances in climate risk transfer mechanisms could crowd-in broader access to financial services among the poor.

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[1] We use the terms “risk” to denote an uncertain outcome and “shock” to mean an adverse realization of a stochastic variable. Risk is thus an ex ante concept and shock an ex post one. For our purposes, shocks include slow onset events such as droughts even though the word shock generally communicates something that is more sudden.

The objective of this paper is to frame the key issues and summarize the current state of knowledge about and innovations in index-based risk transfer products (IBRTPs) as they relate to the management of climate risk for poverty reduction, especially of chronic or persistent poverty. In the past several years, interest in and experimentation with weather index insurance and other IBRTPs has grown rapidly. Though no one should expect that these innovations alone can solve the problem of chronic poverty, index-based financing opens up a range of intriguing possibilities.

The remainder of this paper is comprised of five major sections that discuss:

1) how weather risks and climate shocks impact the poor in developing countries;
2) the concept of poverty traps, highlighting how conventional risk management strategies typically do not work well for managing covariate weather risk;
3) the limitations and opportunities of financial innovations using index-based risk transfer products (IBRTPs) for reducing or transferring weather risks and climate shocks;
4) a poverty traps-based typology of IBRTPs;
5) key remaining challenges in developing and implementing index-based risk financing for use in the global struggle to end chronic poverty.

2. Background on Weather Risks and Climate Shocks

Climate shocks associated with extreme weather events—e.g., cyclones, drought, floods, hurricanes, typhoons—devastate poor communities with distressing frequency. While natural disasters rose sharply worldwide over the last decade, the biggest rise was in low-income countries, which suffered an increase of disaster incidence at twice the global rate (IFRCRCS 2004). This reflects spatial patterns in human, animal and plant diseases, and pests, but especially in climate patterns because weather-related disasters outnumbered geophysical disasters by nine to one over the past decade. Drought and flooding impact more people worldwide than other types of natural disasters.

Weather-related disasters disproportionately affect rural peoples and the agriculture sector through drought and flooding, the effects of which are compounded by less reliable physical and institutional infrastructure for responding to shocks. These patterns are aggravated by spatial inequality in the coverage and effectiveness of public and veterinary health systems, which strongly favor richer areas. Overall, people in low-income countries are four times more likely to die due to natural disaster and cost per disaster as a share of GDP are considerably higher in developing than in OECD countries (Gaiha and Thapa 2006). While hard evidence on within-country variation is scarce, anecdotal evidence suggests this pattern is mirrored within developing countries, with poorer, rural areas more vulnerable to weather-related disasters than are wealthier and more urban areas. And at the household level, evidence from drought in Ethiopia and hurricane Mitch in Honduras indicates that the medium-term effects of shocks vary by initial wealth, with poorer households feeling the adverse effects more acutely and for a longer period (Carter et al. 2007). Changing weather patterns appear likely to further increase the frequency and intensity of adverse weather events (IPCC 2007).

There is widespread awareness of the losses directly inflicted by climate shocks, of the severe disruption of livelihoods that occurs due to dampened crop yields and livestock productivity, damaged infrastructure that impedes commerce, and destruction of the few productive assets the poor possess—their land, livestock, homes and businesses. The epidemiological consequences of weather-related disasters, due to predictable, if transitory, increases in water- and insect-borne disease transmission compound the losses and precipitate human health shocks that are especially strongly associated with long-term collapse into poverty (Gertler and Gruber 2000; Krishna 2006). Furthermore, catastrophic weather shocks can trigger destructive coping responses, such as withdrawal of children from school, distress sale of assets, severe reduction of nutrient intake, refugee migration and crime, that further contribute to severe human suffering. The adverse impacts of the immediate shock or the subsequent behavioral response often persist as children's physical growth falters, children fail to return to school, and household productivity, asset accumulation and income growth are dampened (Dercon and Krishnan 2000; Hoddinott and Kinsey 2001; Dercon and Hoddinott 2005; Hoddinott 2006).

These well-known, ex post effects of adverse climate shocks understate the damage done to the poor by climate risk, perhaps quite substantially. The reason is that people routinely undertake costly behaviors as a means of reducing their exposure to uninsured risk. In the case of climate risk, poor farmers routinely apply less fertilizer and are less likely to use improved seed than they might if they had greater confidence in the quality of the coming growing season. They invest less in building up businesses, farms, and herds than they might if there were less uncertainty about whether nature might rob them of these hard-earned gains. The poor's ex ante risk management behaviors thereby commonly tradeoff expected gains for reduced risk of suffering catastrophic loss. These opportunity costs of risk avoidance seem greatest for poorer peoples whose risk aversion also appears, on average, greater than that of better-off neighbors.

3. Poverty Traps: The Roles of Risk and Financial Markets Failures[2]

As poverty research has evolved over the past decade or two, increased attention has been paid to how well-being evolves over time, with much interest in resolving the important puzzle of why some individuals, households, communities and nations remain mired in extreme poverty for extended periods and how others are able to avail themselves of new market and technological opportunities to lift themselves out of poverty (Baulch and Hoddinott 2000, Barrett, Carter and Little 2007). Increasingly, the former experience has become summarized as a "poverty trap." This concept has proven extremely influential in development policy circles, perhaps most clearly manifest by the UN Millennium Project (2005) and Sachs (2005).

This section offers a brief, nontechnical discussion of the poverty trap concept, emphasizing in particular the salience of covariate risks, such as weather risk, to the existence of particular types of poverty traps. Hence the importance of attempting to improve climate risk transfer as part of a strategy for reducing the chronic poverty associated with poverty traps.

3.1. Threshold-based poverty traps and the salience of risk

In the economics literature, there exist multiple sorts of poverty traps associated with different mechanisms by which these might emerge (for details, see Barrett and Swallow 2006; Bowles, Durlauf, and Hoff 2006; Carter and Barrett 2006; Azariadis and Stachurski, forthcoming). One special class of poverty traps requires the existence of multiple dynamic equilibrium, at least one of which lies below a standard poverty line. This particular sort of poverty trap is especially relevant to risk transfer because it is characterized by at least one critical threshold above which the expected dynamics of the system are characterized by asset accumulation (i.e., growth and improvements in standards of living) and below which decumulation prevails. Threshold-based poverty traps characterized by such bifurcated wealth dynamics make risk especially salient to understanding the dynamics of poverty and growth.

[2] This section draws heavily on Barnett et al. (2006) and Carter and Barrett (2006).

In a world without multiple dynamic equilibria, everyone follows a growth path towards a unique, long-run standard of living. Different individuals, households, communities and nations might accumulate wealth at different rates and there may be temporary disruptions along the way due to various shocks, even different equilibria for different cohorts. But in such a world shocks should have no permanent effect as people and nations adjust and converge to their natural equilibria; although this can take some years. In this setting, risk merely adds noise to the inexorable process of convergence.

By contrast, shocks can have permanent consequences in the presence of a critical threshold, knocking people from one growth path onto another. Shocks that push people below the threshold can set them onto a downward spiral into destitution from which they do not recover, or keep them from growing their way out of persistent poverty by regularly knocking them backwards as they struggle to climb out of the trap, a real-world Sisyphean tragedy (Dercon 1998; McPeak and Barrett 2001; Dercon 2005; Carter and Barrett 2006; Krishna 2006; Santos and Barrett 2006a; Carter et al. 2007). People's response to shocks can likewise help trap them in poverty. Empirical evidence suggests that poor households commonly liquidate assets in order to cope with shocks, which often drops people into persistent poverty (Krishna 2006). Extremely poor households often choose to forego consumption rather than further liquidating their limited assets; they smooth assets rather than consumption (Zimmerman and Carter 2003; Barrett et al. 2006, Hoddinott 2006, Kazianga and Udry 2006). Such a decision may require reduced expenditures on school fees (i.e., removing children from school), health care or food consumption (Morduch 1995; Foster 1995; Barrett et al. 2006; Hoddinott 2006; Carter et al. 2007). Resulting health and educational deficiencies can reduce the value of human assets, further trapping the household in poverty (Jacoby and Skoufias 1997; Hoddinott and Kinsey 2001; Dercon and Hoddinott 2005; Thomas et al. 2004; Hoddinott 2006).

Knowing these prospective consequences of shocks, people may go to extraordinary lengths to manage risk exposure, for example by selecting low-risk, low-return asset and activity portfolios that reduce the risk of greater suffering but limit growth potential and investment incentives (Eswaran and Kotwal 1989, 1990; Rosenzweig and Binswanger 1993; Morduch 1995; Bardhan, Bowles and Gintis 2000; Zimmerman and Carter 2003, Dercon 2005; Carter and Barrett 2006, Elbers et al. 2007). For example, farmers in riskier environments in South India choose asset and technology portfolios that are less sensitive to rainfall variation but also less profitable, such that portfolio choices associated with a one standard deviation change in the variability of the date of the onset of the monsoon lead to a 35 percent decline in the profitability of production for the poorest quartile but only 4.5 percent on average (Rosenzweig and Binswanger 1993).

Because risk aversion is typically negatively related to wealth, poorer people are typically more likely to select livelihood strategies partly for risk avoidance purposes (Dercon 1996, Ellis 2000), reinforcing inherited patterns of chronic poverty. Risk also tends to discourage both adoption of improved technologies (Feder, Just and Zilberman 1985, Marra, Pannell and Abadi Ghadim 2003) and the short-term sacrifices necessary for longer-term investment in productive capital accumulation (Barrett, Carter and Ikegami 2007). The resulting foregone gains can be considerable. For example, an improved method of rice production increases estimated average output by more than 84%; yet the increased estimated yield risk associated with the new technology makes it unattractive to small farmers within usual ranges of relative risk aversion, thereby helping explain the very modest uptake of the new method (Barrett et al. 2004).

And because risk exposure leaves lenders vulnerable to default by borrowers, uninsured weather risk commonly limits access to credit, especially for the poor who lack collateral to guarantee loan repayment. The combination of conservative portfolio choice induced by risk aversion that is strongly associated with poverty and credit market exclusion because risk exposure dampens lenders' willingness to lend help perpetuate poverty.

Risk can thus have two distinct, crucial effects in a system characterized by multiple equilibria. First, ex ante efforts to reduce risk exposure can dampen accumulation – either voluntarily or through credit rationing – thereby creating a low-level equilibrium. Second, the ex post consequences of a shock—both the shock's direct biophysical effects or those due to coping strategies taken in response to the shock—can knock vulnerable people back into a poverty trap.

3.2. The importance of financial markets failures

Of course, if financial markets permit people to insure against shocks ex ante or to borrow ex post so as to achieve quasi-insurance through ex post loan repayment (rather than ex ante insurance premium payment), these adverse effects of risk should be attenuated or eliminated and risk need not contribute to the existence of poverty traps. Unfortunately, credit and insurance are routinely undersupplied in low-income areas, especially to poor people, partly due to uninsured risk. Financial market failures thereby contribute both directly and indirectly to the persistence of chronic poverty (Carter and Barrett 2006; Barrett 2007; Skees and Barnett 2006).

Formal financial failures arise due to several factors. Three are of particular relevance to the present discussion: covariate risk, asymmetric information, and high transaction costs. Spatially-correlated catastrophic losses can exceed the reserves of an insurer or lender, leaving unsuspecting policyholders or depositors unprotected. Such covariate risk exposure explains why crop insurance policies are generally available only in countries where governments take on much of the catastrophic risk exposure faced by insurers (Binswanger and Rosenzweig 1986; Miranda and Glauber 1997). Covariate risk due to weather is a major cause of financial market failures in many low-income countries (Besley 1995).

The economics literature identifies two primary types of asymmetric information problems: adverse selection (or hidden information) and moral hazard (or hidden action). Adverse selection occurs when potential borrowers or insurees have hidden information about their risk exposure that is not available to the lender or insurer, who then becomes more likely to erroneously assess the risk of the borrower or insuree (Rothschild and Stiglitz 1976). Those who are misclassified to their benefit (detriment) are more (less) inclined to borrow or purchase insurance. As a result the credit or insurance program is likely to experience losses that exceed the projections used to establish lending and premium rates, inducing pricing adjustments that only compound the problem, leading to an even more adversely selected group of insurance purchasers. Unless the underlying information asymmetry can be addressed, adverse selection will cause financial markets to fail. Furthermore, it is costly to address these problems.

Moral hazard, the second common asymmetric information problem, occurs when, as a result of borrowing or purchasing insurance, individuals engage in hidden activities that increase their exposure to risk, leaving the lender or insurer exposed to higher levels of risk than had been anticipated when interest or premium rates were established. Unless the lender or insurer can effectively monitor individuals' behavior so as to enforce policy provisions, moral hazard will also cause financial markets to fail.

The transaction costs of financial contracting in rural areas are much higher than in urban areas due to limited transportation, communication, and legal infrastructure (Binswanger and Rosenzweig 1986), and higher for smaller contracts than larger ones, often leading to credit and insurance rationing in equilibrium (Carter 1988). Thus, high transaction costs that emerge due to both the high cost of delivery (and loss adjustment in the case of insurance) and the necessary information systems to control adverse selection and moral hazard are another important cause of insurance market failure in rural areas of low-income countries.

Because formal insurance and credit markets are limited in rural areas of most low-income countries, people tend to rely heavily on informal risk management tools instead. In particular, people use a wide variety of informal risk transfer mechanisms to smooth consumption in rural areas of low-income countries (Besley 1995). These mechanisms vary from socially-constructed reciprocity obligations within family, village, religious community, or occupation (Fafchamps and Lund 2003; Townsend 1994, 1995; Rosenzweig 1988; Coate and Ravallion 1993; Grimard 1997) to semi-formal microfinance, rotating savings and credit, or state-contingent loan arrangements (Udry 1994; Hoff and Stiglitz 1990). These family and community oriented mechanisms may be better able to address the asymmetric information and transaction costs problems that plague formal insurance and credit markets (Arnott and Stiglitz 1991; Udry 1994; Stiglitz 1990; Rosenzweig 1988). However, social factors can prevent reciprocity obligations from functioning as effective mutual insurance (Platteau 1997). Moreover, these informal mechanisms tend to fail in the presence of large covariate risks (Zimmerman and Carter 2003; Townsend 1994; Rosenzweig 1988; Rosenzweig and Binswanger 1993; Dercon 1996) and can be compromised by the existence of threshold-based poverty traps (Santos and Barrett 2006b).

Informal risk transfer mechanisms must tradeoff asymmetric information and transaction costs problems against covariate risk exposure. The more (less) geographically proximate the participants, the fewer (more) the asymmetric information and transaction costs problems but the higher (lower) the exposure to spatially covariate risk (Grimard 1997). There is also evidence that access to these informal mechanisms is positively related to existing wealth (Jalan and Ravallion 1999, Santos and Barrett 2006b, Vanderpuye-Orgle and Barrett 2007). This is not surprising since the poorest of the poor would have little to offer family- or community-based mutual aid institutions and tend to be less well integrated into social networks than their better-off neighbors.

It is important to note that many of the factors that contribute to poverty traps at the household level (e.g., barriers that create scale economies and limited access to insurance or credit) can also exist at more aggregate levels of analysis (Barrett and Swallow 2006; Barrett et al. 2006). Poverty traps at higher levels of aggregation necessarily constrain economic opportunities at lower levels of aggregation and thus, accentuate poverty traps at the household level (Carter and Barrett 2006; Mehlum, Moene, and Torvik 2005). For example, governments that cannot easily finance safety nets to respond to major climate shocks shift households' accumulation patterns (Barrett, Carter and Ikegami 2007), limiting the tax base from which the state can raise funds. Finding solutions to covariate climate risk for individuals but also for larger-scale institutions (firms, NGOs, governments) is thus central to strategies to liberate people from poverty traps. This is where IBRTPs open up new opportunities.

4. Climate Risk Reduction and Transfer: The Promise of IBRTPs

A variety of means other than index-based financing exist for reducing or transferring the climate risk faced by the rural poor. As we discuss below, it is important to think about suites of tools for managing different layers of risk. Thus before moving into a more in-depth discussion of IBRTPs, we must first briefly acknowledge other, inherently complementary approaches to climate risk management for the rural poor.

Much of the international agricultural research community is organized around the objective of improving technologies so as to protect assets (e.g., livestock) and stabilize and increase expected incomes in the face of stochastic weather patterns. Continued technological improvement is a foundational strategy for helping the poor reduce climate risk and has a longstanding history of high returns on investment (Alston et al. 2000). Similarly, livelihood diversification has long been practiced by rural households seeking to assemble asset and activity portfolios that reduce climate risk exposure (Ellis 2000). The objective of climate information systems is likewise to reduce uncertainty through forecasts of upcoming weather patterns, timely and accurate reporting of current weather conditions, or climate-based prediction of phenomena of more direct interest to affected populations. Finally, efforts to improve market integration through improved storage, transport and communications infrastructure and policies to encourage competition among traders have likewise been a central strategy for transferring price risk through trade across space and time so as to dissipate supply disruptions caused by climate shocks. These tools remain important to holistic approaches to address climate risk for poverty reduction. But the emergence of index-based risk financing creates new possibilities worth seriously exploring. The remainder of this section explores these opportunities, as well as the limitations inherent to these products and implementation and upscaling challenges that exist.

4.1. Index-Based Financial Instruments: Emerging Products and Opportunities[3]

The objective of index-based financial instruments is to transfer risk so that it is allocated in a more economically and socially desirable fashion. Index-

[3] This section draws heavily on Barnett et al. (2006).

based risk transfer products (IBRTPs) are financial instruments that make payments based on realizations of an underlying index relative to a pre-specified threshold. The underlying index must be correlated with economic losses for IBRTPs to be useful in transferring risk. The principle advantage of using this form of risk transfer is that it does not require farm-level loss adjustment and can potentially be much less costly than traditional forms of insurance. However, the underlying index must be transparent and objectively measured. Examples include area average crop yields, area average crop revenues, area average livestock mortality rates, cumulative rainfall (to capture either drought or excess rainfall), cumulative temperature, flood levels, and even the use of satellite images with process models that translate these images into data that capture the impact of extreme weather events. IBRTPs can take on any number of forms including insurance policies, option contracts, catastrophic bonds, or derivatives. Some highly standardized IBRTPs are actively traded in secondary markets. However the focus here is on IBRTPs that are customized to fit the specific weather-related covariate risk management needs of the purchaser and to highlight the potential role of these instruments in addressing rural poverty. Those prospective clients and uses are multiple, as section 5 explains. In this sub-section we aim merely to explain these products and their promise for helping better manage covariate risk for poverty reduction.

IBRTPs make payments when the realized value of the underlying index either exceeds or falls short of a given threshold.4 For example, an IBRTP that protects against crop losses would be based on an index that is presumed to be highly correlated with farm-level yields. IBRTPs with indices based on cumulative rainfall, cumulative temperature, area livestock mortality, and satellite imagery have been developed for agricultural producers (Turvey 2001; Martin, Barnett, and Coble 2001; Mahul 2001; Miranda and Vedenov 2001; Deng et al., 2007; Skees and Enkh-Amgalan 2002). Much recent attention has focused on the potential for using IBRTPs in low-income countries to protect agricultural assets from losses caused by various climate perils (Sakurai and Reardon 1997; Skees 1999 2000; Varangis, Skees, and Barnett 2002; Hess,

[4] IBRTPs are conceptually analogous to European options on the underlying index (Skees and Barnett, 1999; Barnett, 1999, 2000). The instruments can be constructed as "calls" (a payment is made when the realized index value exceeds the threshold) or "puts" (a payment is made when the realized index value falls short of the threshold).

Stoppa, and Richter 2002; Hess et al. 2005; Skees et al. 2001, 2005; Skees, Hazell, and Miranda 1999; Skees, Barnett, and Hartell 2005; Skees and Enkh-Amgalan 2002; Mahul and Skees 2006)).

Perhaps the best known examples of IBRTPs have emerged in the Mexican public reinsurance program, Agroasemex, that has marketed weather index insurance policies to state governments to insure against drought, and which has links to the national natural disasters social fund, FONDEN (Alderman and Haque 2007). In 2006, 28 percent of the unirrigated cultivated area was covered, with the main limitation being the availability of weather stations. In Mongolia, private index-based livestock mortality insurance has been developed for sale to individual herders, with the government addressing reinsurance through a contingent debt facility with the World Bank Group (Alderman and Haque 2007, Mahul and Skees 2006). In India, a microfinance institution, BASIX, has served as an intermediary between individual rural clients and the insurance firm ICICI Lombard and its reinsurers, while a parastatal agricultural insurance company, AICI, introduced a weather index insurance product in 2004. In Malawi, weather-based index insurance covers the loans necessary to finance the planting of certified groundnut seeds with payments going directly to banks to settle the farmers' loans (Alderman and Haque 2007); more recently, products have been developed for maize growers as well (Osgood et al. 2007). As these innovations are still in pilot stage it is difficult to evaluate their impacts or their potential for sustainability. In Mongolia, lenders did offer lower interest rates to herders purchasing the index-based mortality insurance.

If an IBRTP is to be effective, the underlying index must meet several conditions. It must be highly correlated with the loss being insured against over a relatively large geographic area. Sufficient historical data must exist from which to estimate the probability distribution of the index. The data must be adjusted for any trend (area yield data will almost always have to be adjusted for positive technology trends). For example pronounced downward trends in rainfall may suggest a localized climate change. This was an issue in some early work to develop a drought insurance product in Morocco (Skees et al. 2001). When the rainfall insurance products were priced in the market, the trend adjustment resulted in lower thresholds for the drought insurance product and in higher prices than were expected. As a result, this highly touted index-insurance product was never launched. Another issue that is critical when examining historical data involves testing for hetroskedasticty (increasing variance over time). Of course, if the incidence of extreme weather events is increasing over time due to climate change (see below), using a long time series of weather data without adjusting for the increase in variance will generate IBRTP premiums that are too low. Thus, advanced statistical procedures are needed when developing IBRTPs. These procedures can be enhanced with climate models that aid in making judgments about whether the statistical phenomenon is a short term anomaly or a true artifact of climate change or technology trends.

IBRTPs can obviate several of the problems that bedevil financial contracting in low-income rural areas and can thereby help reduce financial markets failures that contribute to persistent poverty. Since realizations of the index are exogenous to policyholders, IBRTPs are not subject to the asymmetric information problems that plague traditional financial products. Thus, moral hazard and adverse selection problems should be considerably less than with traditional insurance products. Transaction costs are also typically much lower since the financial service provider does not have to verify farm-level expected yields or conduct farm-level loss assessment. This is particularly important in low-income countries that are dominated by households that operate small parcels of land. In many countries, these households also produce multiple crops and utilize complex inter-cropping systems. It is not feasible to provide farm-level crop insurance in these environments as records on yield per parcel of land do not exist. Thus, in many settings the only possible form of cost-effective insurance for climate shocks is likely IBRTPs. More fundamentally, as will be more fully developed below, IBRTPs may be used in a number of ways that remove catastrophic weather risks facilitating both quick response and greater access to financial services for the poor.

4.1.1. Limitations of Index-Based Financial Instruments

IBRTPs can also potentially have important limitations. These can be grouped into two categories. The first category involves the degree of correlation between actual losses and the index underlying the IBRTP. This speaks to both a potential basis risk problem and the ability of the developer of the IBRTP to understand the nature of the correlated risk problem for a wide range of users. These are interrelated problems that require careful attention. The other category of potential limitations surrounds important questions about how to design the IBRTP and considerations for how it fits into the larger institutional setting in a developing country.

When IBRTPs are being sold to small households, it is possible that the household will experience a loss and not receive a payment or they may receive a payment when they don't have a loss. This type of basis risk exists with many risk-management instruments (e.g., hedging using futures or options contracts or even with loss-adjusted crop insurance when mistakes are made in estimating yield potential). Various studies have empirically examined the effectiveness of IBRTPs in the presence of basis risk (Black, Barnett, and Hu 1999; Vedenov and Barnett 2004; Barnett et al. 2005; Deng, Barnett, and Vedenov 2007; Turvey 2001; Martin, Barnett and Coble 2001; Deng et al. 2007; Wang et al. 1998). The findings from these studies are mixed. Careful construction of IBRTPs can reduce exposure to basis risk. However, for heterogeneous regions with many microclimates or with sparse meteorological stations for reliable data collection, basis risk may be too high for IBRTPs to be effective. It is important to remember that the very characteristic that causes basis risk in IBRTPs is also what eliminates asymmetric information problems—namely, that payments are based on realizations of the exogenous index rather than actual losses experienced by the household. Thus resolving one problem inherently creates another. Furthermore, if IBRTPs are focused on truly catastrophic climate shocks that impact a wide region (a covariate risk), having access to even an imperfect IBRTP is likely better than having no insurance. The greater the spatial correlation for extreme weather shocks, the more likely that IBRTPs will work for a wider range of households, even though the households may be impacted differently by the same severe event. At some level, extreme weather shocks will negatively impact a large number of households. Given concerns about basis risk, it should be clear that for regions with varied microclimates or highly idiosyncratic risk, IBRTPs are unlikely to work well unless the index can take advantage of high-resolution weather observations or proxy data from remote sensing. Under these conditions, formal or informal risk pooling mechanisms may be a better alternative. However, formal crop insurance markets will also be unlikely to work even in these settings due to asymmetric information problems and the associated high transaction costs of delivery.

The other major challenge for IBRTPs involves the details of appropriate contract design and the potentially complex issues surrounding implementation. Simply put, there has been insufficient experience across a range of settings to have established a set of best practices for contract design and delivery. As Osgood et al. (2007) describe with respect to contracts recently developed in Kenya, Malawi and Tanzania, however, the contract development and evaluation process has led to a set of contracts that appear to have performed well thus far. If this can be replicated in other settings and sustained over a cycle of climate shocks, the transactions costs of product development and delivery should come down and uncertainty (faced by all parties) surrounding contract design risk should diminish appreciably.

Design questions are highly related to institutional and implementation issues as well. In lower income countries IBRTPs must generally be structured as insurance products since regulatory structures for other types of contingent claims contracts are unlikely to exist. A proper regulatory structure is critical to provide oversight regarding consumer education and insure adequate ex ante financing of these special products. Where such structures are absent, IBRTPs are unlikely to prove commercially viable.

Furthermore, the type of education and promotion that accompanies marketing and sales of IBRTPs is critical. It may be ill-advised to present a rainfall insurance product as being insurance for a specific crop. This gives the wrong impression that the household is purchasing crop insurance. In India, ICICI-Lombard has introduced weather products for three distinct periods during the growing season. During the planting and flowering period drought insurance is offered. During the harvest period excess rainfall insurance is offered. Farmers can select any or all of these three periods based upon what weather events concern them. These products are not presented as protecting against losses for individual crops. Rather they are presented as seasonal weather products that can compensate for a wide-range of losses. These could extend to losses for those who have livelihoods that are tied to the well-being of farming (i.e., laborers who depend on the harvest for income, input suppliers, processors, etc.).

Finally, as these products are put into a larger institutional framework and as they are used to provide ex ante financing for disaster aid one must be concerned about a prospective dependency problem. This can be a problem even in developed countries. As decision makers anticipate transfers in the event of a catastrophe they are less likely to pay for financial services. This problem can be addressed with a proper deign that attempts to layer the risks so that protection against the most catastrophic losses are provided as a social program and more frequent losses are provided in commercial markets. The Mongolia index-based livestock insurance program has been explicitly designed to address this issue (Mahul and Skees 2006).

4.1.2. Implementation and Upscaling Challenges

Several critical hurdles must be overcome in integrating climate-related IBRPs into poverty reduction strategies at a significant scale.

Capacity building: The first challenge is that capacity for new product development and adaptation must transition from global research institutes to local stakeholders. It is not cost-effective for each index insurance project to be the product of a research institute. Moreover, the need to build capacity for local design and adaptation of contracts increases in importance if the insurance is successful in allowing economic development. A product that is designed to provide a stepping stone for farmers into the cash economy must adapt once these farmers make that transition and begin to establish credit ratings and accumulate money in savings accounts. With each step of the development process, the insurance tools must evolve with the clientele.

As the projects upscale from pilots to developed markets many solutions that are effective for a particular pilot may not be sufficiently robust or scalable for a large scale heterogeneous market. Thus, it is critical that the pace of product upscaling does not exceed the pace of capacity development, product communication and project improvement. If financial stakeholders do not have the sufficient understanding and capability to update the products, they may not understand the important limitations of index products, and farmers may not understand what risks the contracts do not provide protection for. This is particularly important for index products, since both the provider and client must fully understand that the product does not protect against all losses, and must understand how to build risk protection against things the contract does not address. Since in many of the index insurance projects, donor participation is focused on product design and the product is completely financed by the smallholder farmers, overly rapid rates of scale up may place the burden on the smallholder farmers themselves.

Interpolation and remote sensing: One barrier to low cost scalability is the source of data for indexes. Weather stations have been used in most of the recent pilots in developing countries, though questions remain over how to use such information for more widescale products. This is because the weather station is a point estimate of the climate. For the Malawi pilot, farms were only allowed to take out a policy if they were within 20km of the weather station (Osgood, et al., 2007). One aspect of the problem is extrapolation. In the above example, the product design assumes simple extrapolation over the 20km radius. More complex interpolation methods carry with them uncertainties in the reliability of risk estimates, which are critical for the viability of index insurance products. If an interpolated product uses differing numbers of stations over time, then time series at given locations may be considered unsuitable for index insurance. Station records also carry with them issues of expense. Monthly data are may be more easily available, whereas daily data, while often recorded, are generally more difficult to access digitally and can be far more expensive. The density of stations required for given capture rates of events is an area for further research, but one that could be undertaken with a cost-benefit analysis in mind, to estimate the value of varying densities of data network.

Satellite products offer the prospect of spatially continuous information, with reliability in real-time provision. Satellite rainfall estimates have become more accurate over time since the inception of the first products around 1980 (Dinku et al., 2007). A problem with satellite data is the shortness of records of most of the best products. However, opportunities may exist for merging satellite and station data into statistically homogeneous series that could then be updated in real time by satellite-only products. So far, indexes based on rainfall estimates using satellites are still generally considered experimental and not for use in index insurance, although this too is an evolving area as research and pilot implementations are being undertaken that may soon alter that perception. Indeed, analyses with satellite estimated greenness of vegetation (Normalized Difference Vegetation Index) have now been sufficient to warrant use of that product in index insurance products. The NDVI data extend back to the early 1980s at a resolution of approximately 10km, so are one of the few examples of a satellite product deemed sufficiently robust and to have a record of such length. Even then, there are challenges in changes in satellite procedures over time that need to be accounted for with statistical corrections (Kalnay et al., 1996). Also, at a scale of 10km, there are often seemingly random fluctuations not explained by climate; indices averaged over several pixels are often more robust. There are also issues of the extent to which land use changes modify greenness measures and might thereby affect the design of robust and meaningful indices.

Increased sophistication in index development: The low cost development of effective indices will be an important task in implementation and upscaling. If the index is too complex, clients may not be able to use it as an effective risk management tool, but may end up facing risks that are not addressed through other means, and may not even be anticipated. Therefore, as index sophistication increases, the task is not only to decrease basis risk and lower development costs, but also to provide simpler, more transparent contracts to the end user.

Alternatives being utilized currently include the water requirement satisfaction index (WRSI), which uses a cumulative ratio of actual water use to evaporative demand, calculated from a simple soil water balance model, to estimate water stress (Frere and Popov, 1979, 1986). An alternative approach is to derive a simple combination of rainfall totals during key crop growth stages, and calibrating it to WRSI simulations or historical yield data (Bown et al., 2000, Hess and Syroka 2005, McCarthy 2003, Skees and Leiva 2005, Varangis et al., 2001). Questions also remain concerning the appropriate timescale of data aggregation properly indexing risk. There may be gains to integrating new sources of data (such as remote sensing) into existing indexes. A key question continues to be the extent to which knowledge of climate-crop relationships is sufficient to allow meaningful indices to be designed for all locations, given that reliable historical records of crop yield are often not available.

Pilot index insurance projects have focused mainly on drought stress for annual crops. Extension to other potential indices may raise new technical issues as each insurable event has its own signature of climate knowledge and climate data issues. Perhaps the one with most potential for widely assisting in development is flood risk. However, floods are less spatially coherent than drought, so the density of data monitoring required is higher for a given level of risk capture.

Seasonal climate forecasts: Forecasts have been shown to provide significant skill in predicting seasonal temperature and precipitation in many parts of the world (Goddard et al., 2003, Mason and Goddard, 2001). It is important to quantify what skill seasonal forecasts have in predicting the climate risks associated with insurance payouts (Hansen et al. 2006). Forecast information has the potential to undermine insurance or weather-linked credit through intertemporal adverse selection when premiums are set before, but contracts are sold after a forecast becomes available (Luo et al. 1994). That is, a client should not be able to use forecasts to undermine the financial stability of the insurance by purchasing insurance only in years when drought is forecasted. This is not an issue in current pilot implementations, for which total demand is greater than the pilot size. However, as projects scale up, it becomes increasingly important. One option is to close contract sales before forecasts are released. For example, climate modeling work in Peru demonstrated that El Nino could be predicted with some accuracy a full 7 to 8 months in advance of serious problems (Khalil et al. n.d.). In response to this information, the developers of the ENSO index insurance for Peru recommended a sales closing of June 15 (Skees, Hartell, and Murphy 2007).

A second way to address potential adverse selection problems associated with weather information (including indigenous forecasting skills) is to organize more complex IBRTPs. For example, a multiple year contract that would involve rolling the premiums forward may mitigate the adverse selection problem for insurance products. One could also consider selling options on the right to purchase the insurance. Weather derivative markets can also be used. However, in a developing country context, the implications of these solutions are complex. Lenders often use climate information when underwriting loans. For example, when forecasts suggest an El Nino will affect Peru, many lenders refuse to make agricultural loans, which may be harmful to farmers if lenders respond in an overly conservative manner. If lenders could offset their exposure to catastrophic weather events using IBRTPs, they may be less likely to excessively reduce credit under these circumstances (Skees, Hartell, and Murphy 2007).

It is important to note that variation in credit availability in response to weather forecasts may benefit smallholder farmers by more accurately reflecting climate-related variation in agricultural risk and thereby reducing defaults and losses in bad years and providing easier credit access in good years (Osgood, et al., 2007). Because profit-maximizing input levels vary considerably with variations in seasonal rainfall, and are at least partially predictable (Jones et al., 2000), adjusting insurance prices and credit availability in response to forecasts may provide a useful market incentive to farmers to choose season-specific farming strategies (e.g., crop choice, cultivar cycle length, fertilizer application rate) appropriate to the expected weather pattern (Carriquiry and Osgood, 2006). Properly designed, index insurance might protect against the uncertainty of the forecast, allowing more effective and widespread forecast use. But the integration of IBRTPs and forecast information remains an under-developed area on which research is critically important.

Spatial Structure: Index contracts and reinsurance must be designed acknowledging regional and global climate features, since large scale climate processes often lead to negatively (or positively) correlated seasonal rainfall between regions, across the globe (Ropelewski and Halpert, 1987) or even on opposite sides of a mountain range (Waylen et al., 1996). For example, an ENSO state that is associated with higher probabilities of drought in Southern Africa is associated with ample rainfall in the Greater Horn of Africa. By using climate science to provide insight into the driving processes, it may be possible to identify effective strategies that could not be uncovered simply through statistical analysis of the small number of payouts based on historical data (Osgood, et al., 2007).

As the ability to manage risk depends on the scale of the institutions involved, the ability to estimate risks with a given data network also varies with spatial scale. Increasing spatial scale may average out noise. It may also decrease precision in indexing a particular risk. Analyses are needed to evaluate the optimum spatial structuring of IBRTPs. For example, if regional scale risks are substantially more reliably estimated, then this may a worthwhile factor to weigh in with other implementation goals in determining the preferred scale of structures for risk transfer.

Climate change, decadal variation and limited long term data: As a first estimate, risks are often evaluated using a so-called burn analysis of the data – that is, by simply computing the frequency and magnitude of loss in the historical record. A key question is the extent to which this provides a reliable estimate of the risk of the trigger event in a given season. Traditionally, climate statistics in the meteorological community are estimated using about 30 years of data; the lengths of satellite rainfall products starting around 1980 are now approaching this length. However, because IBRTP events are often extreme, there is a question over just how reliable estimates of such risks are with series of length 30. Fitting statistical distributions and generating large samples of data with a parameterized stochastic weather model, consistent with climate knowledge, may improve estimates of risks, particularly in the tails of distributions.

The ability to estimate risks in a changing climate is a key issue. Regional climates have always varied naturally on timescales of 10-100 years, with associated changes in climate extremes (Metha et al., 2006). A rapidly-changing, anthropogenically-induced climate forcing is expected to cause greater regional climate changes over the next century (IPCC 2007, Solomon, et al., 2007), with likely associated changes in extremes (Tebaldi et al., 2006). This should increase demand for tools to manage weather risk. At the same time, it creates a challenge. For structures that are built around a single season or year, updating estimates of risks from past years will likely provide only modestly biased estimates of risks for the coming year, provided that risk estimates properly account for any past trend or low-frequency variations. However, this bias should be quantified and factored into expected payout frequencies. Simulation approaches, making assumptions about magnitudes of change informed by global model projections, should provide valuable insights. The situation is likely most problematic for financial structures with a time frame of several years – the statistics of the last 30 years, while providing a reasonable estimate of risk for the next year, will likely be more substantially biased in providing estimates for the risks over the next 10 years. Since most weather index insurance has so far been of the form of policies for the coming season/year, the key concern is if the relatively short time-period represented by available data can be used to accurately reflect the true probability of rainfall in the coming year given the potential for shifting statistics. On the other hand, gradual changes in risk have an important implication for the long-term affordability and profitability of index-based financial products and hence for the willingness of the industry to invest in new markets.

5. A Typology of Different Uses for and Users of Climate Information and IBRTPs

This section now integrates the previous two sections' concepts in order to introduce a poverty traps-based typology of three different basic uses for climate information and IBRTPs, each associated with a different wealth category, product function and set of prospective clients. The aim is an integrative framework for understanding how different products and distinct threads of the relevant literatures fit together coherently. Current IBRTPs target an array of different clients, with some projects designed to offer contracts to individuals, and others to farm cooperatives, banks, microfinance institutions, or national governments. As implementation projects proceed, it is important to better understand the most appropriate roles for different IBRTPs within the complete system.

The distinction between ex ante risk management and ex post risk coping and the bifurcated welfare dynamics inherent to threshold-based poverty traps provide a natural, unifying framework for coherently integrating the disparate literatures on climate information and various IBRTPs proposed for developing countries. Some of that literature emphasizes the possibilities IBRTPs open up for enhanced humanitarian response to natural disasters (Barrett and Maxwell 2005, Hess and Im 2007, Chantarat et al. 2007). Other threads of the literature focus more on the possibilities for perhaps reducing some of the risk- and information-related factors that impede credit and insurance access in rural areas of developing countries, and thereby facilitating increased investment and uptake of improved production technologies in low-income agriculture (Hellmuth et al. 2007, Osgood et al. 2007, Skees, Hartell, and Murphy 2007). Since different objectives imply different uses and clienteles for these products, there is a certain amount of talking past each other in the extant literature as people focus on inherently different uses and markets for seemingly similar products.

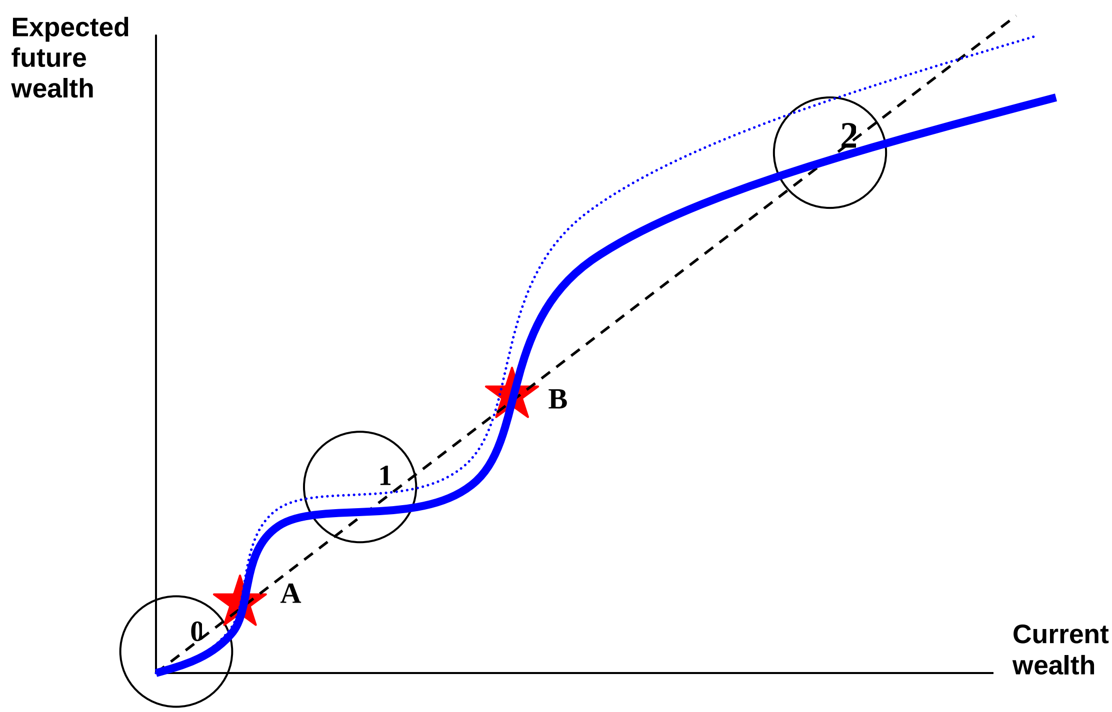
This insight is perhaps most easily represented visually. The horizontal axis in Figure 1 represents current period wealth, the vertical axis reflects expected future wealth, and the dashed 45-degree line therefore depicts all the possible dynamic equilibria, i.e., points where expected wealth tomorrow is exactly equal to today's wealth. The solid blue curve depicts expected wealth tomorrow conditional on current wealth.5 That curve provides a heuristic representation of highly nonlinear wealth (or welfare) dynamics of the sort recently uncovered econometrically in Ethiopia, Kenya and South Africa (Adato et al. 2006, Barrett et al. 2006, Lybbert et al. 2004, Santos and Barrett 2006a). Over the ranges where the blue curve lies above (below) the 45-degree line, households are expected to accumulate (decumulate) wealth.

In this stylized setting, there exist three distinct, stable long-run equilibria, or attractors, represented by the circled points labeled 0, 1 and 2. Think of the 0 equilibrium as an irreversible state of permanent physical impairment—in the extreme, death—due to severe physical deprivation. At the other end, 2 represents a relatively high-level equilibrium associated with significant steady state wealth and well-being. In between those two extremes, equilibrium 1 then represents a low-level but non-calamitous standard of living, the classic poverty trap associated with stagnant living conditions, clearly better than 0 but far less comfortable than 2.

Between each pair of stable dynamic equilibria there exists an unstable equilibrium, at the points marked A and B, where wealth dynamics bifurcate, meaning that just above the unstable equilibrium, one is expected to accumulate wealth and move upwards, from A towards stable equilibrium 1 or from B towards stable equilibrium 2. Conversely, just below the unstable equilibria, one is expected to steadily lose assets, converging in the other direction, towards the lower-level equilibrium, dropping from A to stable equilibrium 0 or from B to stable equilibrium 1. These unstable equilibria are the system's critical thresholds, the tipping points that define poverty traps. The existence of such tipping points is the reason risk weighs so heavily on people living in systems characterized by poverty traps. Asset or productivity shocks that cause one to move suddenly along the X axis can quite fundamentally affect the attractor towards which one subsequently proceeds. Small favorable shocks that bump someone above A or B can lead to permanent improvements in well-being. Conversely, shocks (small or large) that knock one beneath one (or both) of those points can precipitate a collapse into destitution or worse.

[5] Note that this is not fully deterministic, in that actual realizations can be affected by random deviations from expected dynamics. But in the interests of keeping things simple, we focus just on these expected wealth dynamics.

Figure 1: Threshold-based poverty traps and three types of climate risk management



This conceptualization of threshold-based poverty traps and risk provides a useful typology of three different basic uses for IBRTPs, each associated with a different wealth category, function and set of prospective clients. The sub-sections that follow discuss each of these three types in turn. But let us quickly define these in reference to one another using figure 1. The three IBRTPs types we discuss are:

- Type I designed to prevent households from moving below threshold A and entering into the abyss of equilibria 0.
- Type II designed to encourage greater investment in productive assets and facilitate movement from low-level equilibria (such as 1) to higher level equilibria (such as 2).
- Type III designed to protect households from the financial consequences of adverse shocks, thus preventing movement from higher level equilibria (such as 2) to lower level equilibria (such as 1).

Type I uses of IBRTPs serve to block transitions below the unstable equilibrium A and thus avert humanitarian disasters associated with collapse to the stable, irreversible, equilibrium at point 0. These are safety nets as commonly understood: instruments to protect human life and the most basic rights to life, food, etc. as enshrined in the Universal Declaration of Human Rights. In the context of climate risk management, Type I uses of climate risk mitigation methods are essentially famine prevention instruments: IBRTPs for pre-financing natural disaster response. Type I uses are targeted at compensating for direct losses associated with climate shocks.

To address the costly ex ante behavior associated with high levels of risk aversion among the poor, Type II IBRTPs would be targeted at moving households from equilibrium 1 to equilibrium 2.6 These are cargo net interventions7 aimed at helping lift people over the threshold B or enabling them to climb over the threshold B. This can happen in either of two ways. First, and perhaps most obviously, IBRTPs that resolve credit markets failures and thereby enable people to borrow to invest today generate an upward movement in current asset holdings, potentially bumping people beyond B and onto a new, upward accumulation trajectory towards higher-level equilibrium 2. The second, less obvious, effect of IBRTPs is to change the wealth dynamics, here represented by an upward movement of the relevant portion of the curve to the dotted blue line. Note that this necessarily lowers the unstable equilibria and increases the welfare level associated with both the intermediate and higher-level stable equilibria. This has the effect of increasing the well-being of everyone not in the basin of attraction around the catastrophic equilibrium 0 and, most dramatically, of switching onto a positive accumulation trajectory those people who were previously just below B but now lie just above it in asset space. Barrett, Carter and Ikegami (2007) explain and demonstrate how reduced risk exposure (both ex post but especially ex ante) fundamentally changes the shape of such wealth dynamics. If IBRTPs can be developed so that the poor have greater access to insurance-type products when there is a climate shock, they may be more willing to invest in new technologies and move to a portfolio mix that has higher risk but higher

[6] Since we treat the catastrophic equilibrium 0 as irreversible, upward movements out of it are ruled out.

[7] The term "cargo net" in this context was coined by Barrett (2005) who explains the concept and its labeling in greater detail.

returns. Thus, Type II uses could not only aid the household but could contribute to real economic growth for the country.

The final, Type III uses of climate risk mitigation tools likewise relate to safety net functions, but with respect to a quite different population. Now the objective is to block downward movements past threshold B, i.e., to protect the assets and well-being of the vulnerable, many of whom will currently be non-poor. Type III IBRTPs represent what Barrett, Carter and Ikegami (2007) term "productive safety nets", i.e., instruments for safeguarding past investments of those who at some point cinch up their belts and forego current consumption to invest in building up productive assets or to adopt improved technologies for use tomorrow. By protecting the assets of individuals who are able to surmount threshold B—whether by good fortune (e.g., birth into a wealthy family or lottery winnings) or by cumulative past sacrifice—Type III tools help stem the undesirable entry of new people into the ranks of the chronically poor. Although these subpopulations are commonly non-poor, their vulnerability to climate risk makes them a natural market for IBRTPs and helping keep them out of the ranks of the chronically poor is crucial to any effective poverty reduction strategy (Krishna 2006, Barrett, Carter and Ikegami 2007).

These three distinct types of tools for climate risk management in the presence of threshold-based poverty traps thus focus on different directions of movement, different subpopulations within an economy, or both. As the Appendix Table clearly documents, such products are emerging rapidly and for all three purposes. Collectively, we could identify at least 21 distinct IBRTPs developed or proposed in developing countries as of mid-2007. The target users range from micro-level clients such as nomadic herders and small rice or groundnut farmers, to meso-level institutional clients such as water users groups or financial institutions, to national governments and United Nations agencies. While drought has overwhelmingly been the event triggering most payouts, there also exist products targeting flooding, excess rain, and area-based crop yield or livestock mortality. The diversity of IBRTPs and the rapidity with which they are now emerging motivates our typology, lest people grow confused by the plethora of products increasingly on offer. We now consider each type of IBRTP in somewhat greater detail.

5.1. Type I: Safety Nets for Emergency Humanitarian Response[8]

Historically, "most famines in poor economies are associated with the impact of extreme weather … [and] the worst famines have been the product of back-to-back shortfalls of the staple crop" (Ó Gráda 2007, p.7). While weather shocks are neither necessary nor sufficient to induce famine, there is a strong historical correlation. And following the Golden Hour principle in emergency medicine, rapid response is essential in order to minimize the risk of catastrophic results from a shock. The confluence of the strong relation between intense, widespread human suffering and weather shocks, and the need for rapid response creates important opportunities for IBRTPs to help ameliorate or avert humanitarian disasters.

IBRTPs can be used to pre-finance safety net or disaster assistance programs (Goes and Skees 2003; Hess et al. 2005). Weather insurance, in particular, offers several different, potentially major improvements to the global response to climate-related, slow-onset emergencies such as drought. First, insurance by its nature enables the insured to smooth its stream of payments. Rather than incurring irregular, massive expenses for emergency response, one pays a far smaller amount regularly in the form of insurance premia, but receives large indemnity payments when resources are needed. Given liquidity constraints and the value to expenditure smoothing, this should be advantageous to operational agencies and donors if such insurance can be reasonably priced in the market.

Second, the irregularity of need for famine prevention resources underscores the value of insurance for low-probability, high-impact events as part of an effective risk layering strategy. Communities can easily absorb modest variability in rainfall. For example, migratory pastoralists have developed highly adaptive livelihood strategies over many centuries of coping with volatile rainfall patterns while crop producers commonly use off-farm labor markets to adjust to climate shocks. So a layer of individual and community-level self-insurance is feasible. Bigger covariate shocks commonly demand some outside interventions. Agencies and donors can readily handle small-scale crises within their usual budgets and operational mandates. The problem emerges when rare, widespread and devastating shocks occur and

[8] This section draws heavily on Chantarat et al. (2007).

probabilistically threaten famine. With insurance in place to provide resources necessary for such low frequency but potentially catastrophic weather events, other actors can focus better on insuring the range of commonplace risks over which they possess comparative advantage.

Third, index insurance would permit an improved and immediate link between emergency response and recipient need. With most emergency response still based on the provision of food aid that remains tied to procurement, processing and shipment from donor countries, drought response for famine prevention remains doubly tied: to food as the primary form of response and to donor countries as the primary source of that food. Indeed, a common quip in Ethiopia is that the availability of food aid depends not on whether it rains locally, but on whether it rains in North America. Put differently, the supply of food aid—which is a complex function of donor country harvests and farm support policies, global prices, freight costs, geopolitics, etc.—remains as important a determinant of food aid deliveries as is the need of at-risk populations. Current food aid programs are not responsive enough to weather shocks, at least partly due to supply-side obstacles that could be reduced via the proposed weather index insurance, which links cash payouts entirely to predicted humanitarian need.

Fourth, timely and adequate funding are huge obstacles to effective response to slow-onset disasters such as drought. Present disaster financing systems tend not to deliver resources in as timely and cost-effective fashion as is possible. The United Nations' Consolidated Appeal Process (CAP) attempts to coordinate global cooperation in emergency response. On average, however, funds raised via CAP amounted to only 56% of requirements by the end of October in 2003-6 (OCHA 2007). WFP Emergency Operations (EMOP) covers the majority of the humanitarian response, especially related to food security and famine prevention. While the WFP experience is better than that of the CAP, it too suffers significant shortfalls and delays. On average, only 70% of EMOP funding needs were provided by donors in 2001-2006, ranging from 57% in 2005 to 79% in 2004, and each year, only an average of 36% of EMOP needs were confirmed for donors' contributions by the beginning of June for early intervention with as low as 22% need fulfillment in mid 2004 (WFP 2007). Moreover, donor contributions take months to arrive. For example, the median response time for U.S. emergency food aid is just under five months from the filing of a formal request (a “call forward”) to port delivery (Barrett and Maxwell 2005).

Delays are costly. The costs to operational agencies emerge because as an emergency progresses, unit costs per beneficiary increase sharply as more expensive, processed commodities become increasingly needed for therapeutic feeding, donors pay premia for faster transport (including airlift), and populations migrate to camps where broader support costs (e.g., shelter, water, medical care) become essential. But there are also major costs to populations affected by climate shocks because late-arriving assistance often fails to protect their livelihoods. In such cases, as discussed previously, their coping responses commonly include distress sale of productive assets, reduced nutrient intake, migration, or some combination of these. The problem is that such responses make them more vulnerable to future shocks.

In spite of significant improvements in early warning systems, supply chain management and other key response functions, operational agency interventions continue to lag behind global media reporting on disasters. The 2004-5 Niger emergency provides a disturbing example. After a November 2004 international appeal by the Government of Niger and the United Nations, WFP initial food deliveries in February 2005 cost $7 per beneficiary. But global response was anemic. In June 2005, the Niger situation was relabeled an "emergency," and graphic global media coverage in July-August led to a sizeable, but slow global response. The cost per beneficiary for WFP August deliveries—i.e., the same delivery organization, but with badly delayed response—had risen to $23, more than three times the cost six months earlier, due to far greater need for supplemental and therapeutic foods instead of cheaper, bulk commodities, and the need for airlift and other quicker, but more expensive logistics. By enabling rapid payout when the trigger is reached rather than merely starting an appeals process likely to drag on for months and be only partly filled, IBRTPs can substantially reduce drought response costs and provide greater asset protection to affected peoples.

Finally, because IBRTPs are based on the realization of a specific-event outcome that cannot be influenced by insurers or policy holders (e.g., the amount and distribution of rainfall over a season), they have a relatively simple and transparent structure. This makes such products easier to understand and consequently to design, develop, and trade, potentially opening up new sources of finance for emergency drought response and famine prevention. The apparent success of pilot programs conducted in Mexico has established the feasibility and affordability of such products (Hess et al. 2005). Weather insurance contracts underwritten by domestic insurers and reinsured or underwritten directly by international investors can provide a new and cost-effective means to transfer low-probability, high-consequence covariate weather risks to global markets where those risks can be easily pooled and diversified as part of global portfolios. If rainfall volumes provide a strong predictive signal of imminent famine, and thus of looming financing needs for emergency drought response, the opportunity exists to design weather insurance to facilitate more effective aid response. This opportunity should be seized.

Necessarily, the clientele for early warning information and IBRTPs are typically not individuals, especially not destitute people lacking the funds to afford safe housing and water and an adequate diet for their families. Rather, the customer base is organizations: national or local governments, international organizations (e.g., WFP), and prospectively non-governmental humanitarian organizations committed to emergency response. Quick disbursing funding mechanisms are essential for such organizations in responding to natural disasters. The World Bank and IMF have introduced contingency financing instruments for developing country governments, although these have been utilized infrequently. For example, Emergency Natural Disasters Assistance financing offered by the IMF was utilized only 27 times for natural disasters between 1962 and 2005 at which time the subsidy rate was increased. Recent World Bank loans to Colombia, Ethiopia and Mongolia have included within the lending contract weather-conditional grants that disburse only if a pre-specified event triggers.

More innovatively, in 2006 the World Food Program recently insured a portion of its emergency assistance exposure to Ethiopia using a French reinsurer, AXA Re.9 That contract, costing $930,000, provided for a maximum payout of $7.1 million in the event of severe drought. Weather risks were quantified in terms of expected income loss by at-risk populations based on estimates of the elasticity of crop production to rainfall at different stages of

[9] For details, see Alderman and Haque (2007), Hess and Im (2007)

crop growth. Crop- and area-specific estimates were aggregated, mapped to income via price estimates, and then converted into a livelihood loss index. The contract covered the entire agricultural season, consisting of two rainy seasons, from March to October, and triggered payment by the end of the contract (in October) when data gathered throughout the contract period indicated that rainfall was significantly below historic averages, pointing to the likelihood of widespread crop failure. The potential for extending similar contracts or even improved versions of them (Chantarat et al. 2007) seems extremely promising for international organizations, including major private relief organizations.

5.2. Type II: Cargo Nets and Facilitating Exit from Chronic Poverty

As discussed in section 3, a vast literature explores the effect of risk on production behaviors. In general, people adopt precautionary behaviors, reducing the use of productive inputs, especially those such as fertilizer or improved seeds that are highly responsive to weather conditions, and eschewing higher-risk, higher-return technologies and livelihoods. And even if they are willing to adopt such inputs or technologies or to invest in accumulating risky assets (e.g., cattle or business machinery), lenders are commonly unwilling to finance such activities because of the uninsured risk. The combination of risk averse behaviors and risk-based rationing of credit can trap people in low-productivity equilibria.

Reducing risk exposure encourages more risk taking, thereby increasing expected returns. For example, Hoffmann and Beegle (2007) find that farmers who, based on past food aid receipt patterns, might reasonably expect to receive food aid in the event of a serious local drought are substantially more likely to purchase and plant improved hybrid maize seed than are those who lack such de facto insurance. These insured Malawian farmers also reallocate labor from lower-return, lower-risk off-farm unskilled wage labor activities to on-farm activities offering higher expected return, but with greater risk and delay.

By reducing risk, lenders also become more willing to extend credit. Weather index insurance pilot projects in Malawi, Peru and Vietnam have, for example, shown that financial institutions and retailers (backstopped by financial institutions) can and will lend to lower-income households for improved seed, fertilizer and other productivity-boosting inputs when IBRTPs provide some guarantee of ability to pay in the event of bad weather (Osgood et al. 2007, Skees, Hartell and Murphy 2007). Greater supply of credit led to lower interest rates offered by lenders in rural Mongolia and Peru. And by reducing individual risk exposure, IBRTPs can also help reduce individual self-selection out of credit markets due to risk rationing, which has been shown to account for a large share of Latin American farmers' lack of financing (Boucher and Guirkinger 2007).

As the recent BASIX experience in India plainly demonstrates, there clearly exist possibilities for direct marketing of IBRTPs to individuals. But empirical evidence from even that relatively successful experiment suggests that many households do not understand the insurance product, and are therefore not inclined to purchase IBRTPs, that insurance contract demand is significantly decreasing in basis risk and in the extent to which household liquidity constraints bind, and increasing in household wealth (Gine, Townsend, and Vickery 2007a,b). These results serve as a caution against over-optimism about the potential to develop a broad market for weather insurance among poor farmers. Moreover, in many low-income settings, liquidity constraints and high distribution costs can prove prohibitive. For example, a recent study in Tanzania finds that latent demand for rainfall insurance is less than the actuarially fair cost of provision, particularly for low income farmers (Sarris et al. 2006). There may be exceptions, particularly through well-functioning microfinance institutions, producer marketing cooperatives, or other collective action organizations,10 but one should guard against inflated expectations of this market.

Meso-level commercial enterprises, such as agricultural input suppliers, microfinance institutions, marketing cooperatives, transportation providers, agricultural commodity processors, and retail insurance suppliers, may be better targets than individual households for Type II IBRTPs. These institutions can, at least to some degree, pool their exposure to household-level idiosyncratic risks but often remain heavily exposed to covariate risks (Hess et al. 2005; Varangis, Skees, and Barnett 2002; Skees, Barnett, and Hartell 2005). In addition, decision-makers within meso-level commercial enterprises are

[10] For example, Gine et al. (2007a) find that being a member of a borewell user association is the single best predictor of rainfall insurance uptake in rural India.

more likely to have some prior familiarity with contingent claims instruments than are household decision-makers (Platteau 1997).

Consider the case of microfinance institutions (MFIs) or other rural lenders. When the losses experienced by borrowers are highly correlated, loan defaults are also likely to be highly correlated (Skees and Barnett 2006). To further stimulate the availability of rural credit, the government or the international donor community could be involved in offering protection against extreme losses (Skees, Hartell, and Hao 2006; Mahul and Skees 2006). If governments wish to be involved in subsidizing the cost of IBRTPs, those subsidies should be focused on the market failure layer. Subsidies for other risk layers are likely to generate perverse behavioral incentives that cause even greater exposure to adverse shocks.

IBRTPs can also be used to reinsure portfolios of either index-based or traditional insurance policies. In OECD countries, IBRTPs are increasingly being used to reinsure portfolios of traditional property and casualty insurance policies against covariate risks associated with hurricanes and earthquakes. IBRTPs facilitate the transfer of such covariate risks into international financial markets. Large investors are attracted to IBRTPs for their diversification value since returns on IBRTPs are largely uncorrelated with returns on traditional debt and equity investments.

Although there are good intuitive arguments for bundling of index insurance with other contracts (such as loan contracts), particularly for Type II (cargo net) interventions, bundling has not been fully addressed in the economic theory of contract design. Through application of contract theory it may be possible to use the strengths of the index-based contract to reduce moral hazard issues in lending, instead of simply reducing the risk to the lender. One result might be contracts that provide incentives for clients to accurately report rainfall, yields, or perhaps livestock disease.

5.3. Type III: Safety Nets for Preventing Collapse Into a Poverty Trap

In environments characterized by threshold-based poverty traps, safety nets can play another role besides emergency humanitarian response (Type I). They can equally protect the productive assets of those who might otherwise fall below the critical threshold and thereby fall onto a decumulation path towards the lower level equilibrium (1 in the figure above) (Barrett and McPeak

2005; Barrett and Maxwell 2005; Dercon 2005). This Type III use of climate information and IBRTPs as safety nets for the vulnerable non-poor is perhaps the most familiar, as it essentially standard insurance. .

Type III safety nets are intended to keep those who experience transitory poverty following a negative shock from becoming chronically poor. However, few developing countries finance such safety net programs. International assistance tends to focus on acute, emergency needs -- rather than on funding safety net programs designed to keep households from falling into a vicious cycle of asset decumulation. As Barrett, Carter and Ikegami (2007) show, productive safety nets that safeguard individuals' assets above a relevant critical threshold from which they can naturally recover and grow back to the higher-level equilibrium (2 in the figure above) can generate significantly higher GDP and technology adoption rates and lower headcount poverty measures than do traditional humanitarian transfers of equal cost in poor economies characterized by threshold-based poverty traps.11 Indeed, by failing to prevent collapse into poverty traps, traditional humanitarian transfers can lead to a relief trap wherein development assistance is increasingly channeled toward emergency relief rather than toward investment in building or protecting productive assets. Thus, the return on investment in productive safety nets to protect the assets of the vulnerable non-poor seems considerable, not only for those individuals but for national economies and the broader international community.

IBRTPs can provide reinsurance-type financing for governments or non-governmental agencies that provide safety nets, much as they can for Type I humanitarian assistance. The main difference is the target clientele. In this case, rather than aiming merely to keep people alive and healthy, the objective is to preserve their wealth and thereby to increase the social and economic resilience of the community. Mexico's FONDEN programs are the principle examples of such projects today, combining Type I and Type III uses of the IBRTP.

[11] The design of the safety net – Do individuals have unlimited access to indemnity payments? What is the asset level below which losses are insured? etc. – matters to both program cost and poverty reduction impacts.

The greater difference from Type I IBRTPs is that the target beneficiary population of Type III IBRTPs can typically afford to purchase these products just as they offer have (at least latent) demand for asset insurance for their homes, businesses and automobiles. In this case, the perils are related to specific events. Such insurance can be required for larger loans for durable assets (e.g., business properties, homes, vehicles) or simply to ensure that valuable assets offered as collateral to lenders are not foreclosed in the event of a climate shock. Type III IBRTPs can thus be distributed as retail products, e.g., through microfinance institutions and other channels to which households already turn for financial services.

Yet Type III IBRTPs are not exclusively suited for individual consumers. For example, local governments also have limited ability to withstand covariate shocks. Locally provided public goods (e.g., law enforcement, maintenance of road and water infrastructure, health clinics, schools) may suffer when public assets are destroyed by covariate shocks and/or public resources are diverted to relief efforts (Goes and Skees 2003). Shocks that affect critical public goods can reduce spatial market integration, thus increasing local price volatility and reducing incentives for households to adopt production-increasing technologies (Gabre-Madhin et al. 2002). In principle, local governments could use IBRTPs to transfer some of their exposure to covariate risks. Alternatively, national governments or donor agencies could purchase IBRTPs on behalf of local governments.

A concern sometimes voiced about Type III IBRTPs is that demand for such products is inherently distributionally regressive, meaning that richer households with more assets to protect and easier access to cash to purchase such products are far more likely to make use of IBRTPs for asset protection than are poorer households. Of course, this just mirrors the positive relationship between individual wealth and access to financial products more generally, so no distinctive problem emerges. The hypothetical problem is that in the event of substantial IBRTP indemnity payments to a large, relatively wealthy subpopulation in the wake of a climate shock that reduces local food supply, food prices could spike if local food markets are not well integrated with broader national or global markets. Because IBRTP payouts could boost aggregate demand, they could hurt poor households, who are far less likely to buy such products. While in principle this may be of concern, in practice, the extent of purchase of such products and the coverage chosen are both likely to be too low to generate any noticeable aggregate demand effect that might trigger inflation. For example, when Mongolian herders were given a choice of what share of their herd to insure, the vast majority selected the 30 percent minimum and hardly any fully insured their herd against drought loss. Further, concerns about Type III IBRTPs prospective inflationary effects turn on an assumption of food markets that are poorly integrated across space and time. Yet over the past decade or two, as government control over developing country food markets has relaxed and as economic studies have market integration have become more statistically sophisticated, the body of evidence increasingly points towards reasonably well-functioning markets that quickly transmit supply and demand shocks across space and seasons, dampening price changes where the principle shock occurs (Fackler and Goodwin 2002, Abdulai 2007).

6. Conclusions

Risk is a significant factor in the creation and maintenance of chronic poverty worldwide, especially in rural areas disproportionately vulnerable to natural disasters. The considerable efficiency losses associated with weather risk avoidance and the massive – and growing – losses of wealth (and human life) associated with climate shocks in developing countries underline the need for innovative means to address covariate climate risk. This has motivated a surge of interest in financial innovations associated with new index-based risk transfer products (IBRTPs). Although a burgeoning literature on IBRTPs and a plethora of recent or planned pilot ventures in this area have excited much interest, and although poverty reduction objectives have been used to help motivate IBRTPs in some cases, to date there has been scant effort at integrating thinking about IBRTPs with that on the causes and nature of poverty traps. Hence this paper. We offer an synthetic treatment of these literatures, culminating in a new typology of IBRTPs based on distinct uses of these products in the struggle to avoid or overcome chronic poverty.

As we have emphasized, IBRTPs can play multiple roles for different clientele. First, there is a central role for IBRTPs to help finance emergency response. To date, there have been relatively limited attempts to take up these opportunities, most notably drought insurance taken out for Ethiopia by the United Nations' World Food Programme and Mexican government contracts to provide disaster relief to state governments. There seems considerable untapped potential within this type I IBRTP category, with significant scope for further innovation through famine bonds and insurance, and related instruments (Chantarat et al. 2007).

Second, IBRTPs can play a crucial role in helping the rural poor escape long-term poverty by reducing the uninsured risk exposure that both discourages their innovation, investment and productive activities and by facilitating greater access to credit and on better terms (Skees, Hartell and Murphy 2007). Considerable pilot activity is now emerging in this area and bears careful monitoring and evaluation over the coming years. There would seem to be substantial possible synergies between these Type II IBRTPs and both microfinance innovations and efforts to improve input distribution systems for fertilizer, improved seed varieties and other climate-sensitive commercial inputs to smallholder agriculture.

Third, risk transfer via IBRTPs can reduce the vulnerable non-poor's exposure to catastrophic asset loss, providing a commercially-based foundation for either informal or public safety nets or for retail delivery of insurance products to a growing middle class that can afford to purchase such products but cannot easily recover from catastrophic asset loss due to climate shocks. Since long-term poverty reduction depends as much on stemming structural movements into poverty as it does inducing permanent escapes from poverty, this latter safety net role is equally important for poverty reduction purposes even if it is not targeted towards the poorest subpopulations in developing countries.

While the potential of IBRTPs is great, there are inherent limitations associated with the degree of correlation between actual losses and the index underlying the IBRTP and the institutional settings in which such products might be offered in developing countries. One needs to guard against naïveté or over-optimism with respect to IBRTPs; they are but one arrow in the quiver of risk management tools needed for addressing the multiple layers of risk faced by poor people in developing countries. Moreover, a range of challenges remain to developing and implementing index-based risk financing for use in the global struggle to end chronic poverty, some associated with product development, adaptation and administration capacity in developing countries, others due to technical issues related to data availability, spatial structure and statistical inference, and still others associated with the complications posed by climate change. The challenges are significant, but the considerable prospective gains associated with IBRTPs for managing climate risk for chronic poverty reduction would seem to justify considerable new effort in this area.

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Appendix Table: Summary of Index-based Risk Transfer Products in Lower Income Countries

Type	Country	Risk Event	Contract Structure	Index Measure	Target User	Status
I	Bangladesh	Flood	Index insurance for disaster relief			In development
I	Caribbean Catastrophe Risk Insurance Facility	Hurricanes and earthquakes	Index insurance contracts with risk pooling for reinsurance coverage	Indexed data from NOAA and USGS	Caribbean country governments	Implemented in 2007
I	Ethiopia	Drought	Index insurance	Rainfall	WFP[12] operations in Ethiopia	$7 million insured for 2006. Policy not renewed for 2007.
I, III	Mexico	Natural disasters impacting small farmers, primarily drought	Index insurance	Rainfall, windspeed, and temperature	State governments for disaster relief. Supports the FONDEN[13] program.	Began in 2001. Available in 26 of 32 states. Currently 28% (2.3 million ha) of dryland cropland is covered. Expansion limited by data availability
I, III	Mexico	Major earthquakes	Cat bond and index insurance contracts	Richter scale readings	Mexican government to support FONDEN.	Introduced in 2006. Cat bond provides up to $160 million. Index insurance provides additional funding up to $290 million.
I	Mexico	Insufficient irrigation supply	Index insurance	Reservoir levels	Water users groups in the Rio Mayo area	Proposed
II, III	Bangladesh	Drought	Index insurance linked to lending	Rainfall	Smallholder rice farmers	In development. Pilot launch planned for 2008.
II, III	Honduras	Drought		Rainfall		In development

[12] World Food Programme
[13] Fondo por Desastres Naturales

Appendix Table: Summary of Index-based Risk Transfer Products in Lower Income Countries

Type	Country	Risk Event	Contract Structure	Index Measure	Target User	Status
II, III	India	Drought and flood	Index insurance linked to lending and offered direct to farmers.	Rainfall	Smallholder farmers	Began with pilot in 2003. Now index insurance products are being offered by the private sector and the government with an estimated 300,000 policies sold in 2006.
II, III	Malawi	Drought	Index insurance linked to lending	Rainfall	Groundnut farmers who are members of NASFAM[14]	Pilot began in 2005. 2500 policies sold in 2006 pilot season. $7000 in premium volume.
II, III	Mongolia	Large livestock losses due to severe weather	Index insurance with direct sales to herders	Area livestock mortality rate	Nomadic herders	Second sales season of pilot completed in 2007. Offered in 3 provinces. 14% of eligible herders are participating.
II, III	Morocco	Drought		Rainfall		No interest from market due to declining trend in rainfall
II, III	Nicaragua	Drought and excess rain during production, excess rain during harvest period.	Index insurance	Rainfall	Groundnut farmers	Launched in 3 departments in 2006.
II, III	Peru	Flooding, torrential rainfall from El Niño	Index insurance	ENSO anomalies in Pacific Ocean	Rural financial institutions	Proposed

[14] National Smallholder Farmers' Association of Malawi

Appendix Table: Summary of Index-based Risk Transfer Products in Lower Income Countries

Type	Country	Risk Event	Contract Structure	Index Measure	Target User	Status
II, III	Peru	Drought	Index insurance linked to lending	Area-yield production index	Cotton farmers	Proposed
II, III	Senegal	Drought	Index insurance linked to area yield insurance	Rainfall and crop yield	Smallholder farmers	Proposed
II, III	Tanzania	Drought	Index insurance linked to lending	Rainfall	Smallholder maize farmers	Pilot implementation in 2007.
II, III	Thailand	Drought	Index insurance linked to lending	Rainfall	Smallholder farmers	Pilot implementation in 2007.
II, III	Vietnam	Flooding during rice harvest	Index insurance linked to lending	River level	Smallholder rice farmers	In development
III	Kazakhstan	Drought	Index insurance linked to MPCI program	Rainfall	Medium and large farms	In development
III	Ukraine	Drought	Index insurance	Rainfall	Large farms	Pilot launched in 2005, discontinued due to insufficient sales.