Providing index-based agricultural insurance to smallholders: Recent progress and future promise

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May 2010

Abstract

Uninsured risks can have serious welfare consequences for poor households. These consequences have prompted a growing effort to expand the financial risk management tools available to the poor, with particular recent attention focused on the development of index-based agricultural insurance products. These products, in which indemnity payments are linked to aggregate outcomes in a given area rather than to individual farmer losses, solve many of the informational problems associated with traditional crop insurance, and thus could succeed where traditional approaches have failed. But as a growing literature chronicles, index insurance is associated with its own set of difficulties on both the supply and (especially) the demand side: prospective insurers face significant data requirements and start-up costs, and farmers are price sensitive, cash constrained, and hesitant to trust unfamiliar financial products or institutions. These difficulties have limited both private sector investment and farmer up-take of index insurance in the roughly 30 developing countries where it has been attempted. Taken together, existing evidence suggests that index insurance could prove invaluable for managing certain types of covariate risks at both the household and the regional or institutional level, but that significant expansion will happen slowly and only with sustained private- or public-sector investment and innovation in product design. In particular, insurance must be made affordable to smallholders and linked to institutions (insurance providers or intermediary organizations) that they trust, with a potential role for subsidies to promote farmer learning in the early stages of product rollout. The benefits of investment in index insurance need to be weighed carefully against the alternative risk reduction and risk management approaches available at both the household and the organizational levels.

¹ We thank the EGG Foundation for initiating the idea of this paper and for its financial support.
Executive summary

Risk pervades the lives of small farmers ("smallholders") throughout the world, fundamentally shaping their decisions about technology use as well as their broader livelihood outcomes. For almost all of these farmers, risk comes largely from the skies: in the absence of savings, credit, or insurance, a drought year can force farm households to liquidate productive assets or curtail consumption, with large negative implications for both current and future welfare. Because weather shocks are so consequential, the mere possibility of low rainfall can make farmers reluctant to invest in risky but profitable activities and technologies, further lowering their future earnings.

Such risk is particularly important because it is almost never insured, at least not through any formal means. Government or private-sector crop insurance is essentially non-existent in much of the developing world, hamstrung by large informational asymmetries and the high transaction costs of dealing with smallholders. Informal village-level risk management strategies, where they exist, are typically unable to protect against common local weather shocks: when all farmers in a village or broader region experience a drought, risk pooling across households provides little effective insurance.

Here we attempt to synthesize exiting knowledge and experience surrounding a promising new approach to agricultural risk management: index-based agricultural insurance. The logic of this new approach is compelling: unlike traditional crop insurance in which indemnity payments are linked to individual farmer yields, index insurance links payments to an independently observable outcome such as local rainfall, which is presumably highly correlated with yields. Such an approach could solve many of the cost and informational problems associated with traditional crop insurance. In particular, the insurer no longer must monitor thousands of individual farms, only the local rainfall gauge. Reduced insurer costs could then lower premiums, allowing poorer farmers to participate in the market, and the insurance market to expand.

While index-based agricultural insurance is still in its relative infancy, a growing number of program reports and a handful of careful academic studies allow an initial summary of what is known - and what isn't - about the success and failure of various approaches to index insurance provision. Such approaches come in two main flavors: insurance in which policies are held by smallholders themselves (what we...
will call *individual insurance*), and insurance purchased and held on behalf of smallholders by organizations such as producer groups, governments, or relief agencies (what we call *institutional insurance*). Because these approaches face distinct issues, we review them separately in what follows.

At the individual scale, there are currently index-based smallholder products in roughly 15 developing countries, most of which are in pilot phase, use rainfall as their index, and are being implemented by a variety of private companies, local NGO partners, government agencies, and outside expertise. Only one of these products (a rainfall-indexed insurance program in India) has thus far reached substantial scale. Constraints to scale-up on the supply side appear mostly technical and thus in principle solvable, although further innovation will be important to lower insurer costs. Difficulties appear larger on the demand side: farmers are highly price sensitive and liquidity constrained, not always financially literate, and understandably hesitant to trust unknown financial institutions with their money. Resulting take-up of individual insurance in existing programs is typically low, suggesting that successful scale-up will likely require sustained interventions, significant involvement of trusted local partners for distribution and marketing, and risk-sharing arrangements or transition subsidies from the government or international donors. Importantly, there are also many situations where index insurance is unlikely to be the best risk management tool. Better understanding for which categories of farmers will individual index insurance be most appropriate, and how best to deliver it, are thus pressing research and public policy questions.

At the institutional level, there are currently index-based products or arrangements in about 20 developing countries, many of which implicitly insure large numbers of farmers. Based on this limited number of case studies, institutional level index-insurance appears to have been more easily deployed than individual level insurance. Overall implementation of these schemes, however, remains low, despite the availability of several mechanisms (such as international re-insurance markets) to insure against losses caused by large-scale natural disasters. Increased risk pooling at the country, regional, or organizational level appears a promising approach to further reduce premiums and encourage take-up of institutional insurance.

The current gap between high promise and low take-up suggests a promising research agenda to learn lessons from current programs and to experiment with alternative approaches on both the supply and demand sides of individual and institutional products.
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1. Introduction

Agriculture is risky business for farmers around the world. Random fluctuations in weather can provide a bumper crop one season and a dismal crop the next, and unexpected swings in prices for both farm inputs and outputs can further amplify or diminish farm income. Because the large majority of the world’s poor continue to live in rural areas and depend directly or indirectly on agriculture for their income (World Bank 2008), this agricultural risk plays a fundamental role in the lives of much of the world’s poor, and is thus of significant policy concern.

Much of the risk faced by farmers comes from the skies\(^2\): when the rains fail or temperatures climb, crop yields can decline dramatically, threatening household welfare. Despite the importance of weather-related risk, however, most smallholders in developing countries rarely have access to formal tools to help them manage it. Crop insurance supplied by either the private or public sector is essentially non-existent in most poor countries, limited by large informational asymmetries and the high transaction costs of dealing with many small farmers. In their absence, farmers often rely on informal approaches to risk management such as accumulating precautionary savings, planting lower-value crops less sensitive to weather fluctuations, and diversifying their sources of income away from the most profitable options. When hit by a shock, they may have to cope with its consequences by using methods that can create long run irreversibilities on welfare such as selling productive assets, reducing child nutrition, and taking children out of school. Such efforts can help to smooth income over time, but typically offer only partial insurance and can depress longer-run earnings.

Farmers are not the only actors facing weather-related risk. State and national governments as well as relief agencies often wish to help farmers cope with weather-related agricultural shocks, but typically face intermittent revenue streams and competing demands on their resources. As a result, they are often unable to mobilize relief in a timely manner once a weather-related shock does arrive.

New innovations in agricultural insurance markets have the potential to address both of these problems, helping farmers smooth incomes in bad years and helping governments and relief agencies respond quickly and fully to weather-related disasters when they occur. Principal among these innovations is index-based

\(^2\) Following Hoddinott (John Hoddinott 2009), we define “risk” as the probability of an event that generates a welfare loss, and “shock” as a specific realization of that risk.
insurance, which links indemnity payments to easily and publicly observed outcomes (such as rainfall) instead of individual farmer yields, as is typical in traditional insurance. Such an approach has clear advantages: insurers only have to monitor a single index instead of potentially thousands of individual fields, greatly reducing costs. Furthermore, because payments are linked to externally measured outcomes rather than farmer effort, index insurance does not suffer the same moral hazard and adverse selection problems of traditional crop insurance: insured farmers have no incentive to reduce effort, and all farmers receive the same payout regardless of their individual risk. And because there is no longer a need to verify individual claims, an index-based approach could also substantially improve the timeliness of indemnity payments. Rainfall and other variables can be measured in near real-time, such that payments can be made as soon as the predetermined threshold in the insurance contract is reached.

The elegance of these products from the insurer’s perspective is not as immediately apparent from the farmer’s. To be attractive to farmers, such insurance must use an index that is well correlated to outcomes that they care about, such as crop yields. Because the large majority of smallholder agriculture is rainfed, particularly in Africa, most index insurance schemes use rainfall as an index. Unfortunately, rainfall (or any other single variable) is never perfectly correlated with farmer yields and measurements are frequently taken at points quite distant from the farmer’s field, and the resulting problem of "basis risk" - the imperfect match between the index and individual farmer outcomes - will discourage some farmers from purchasing the product. But even if a given index was to perfectly predict farmer yields, index based schemes could face other demand side difficulties. Farmers must be capable of understanding the contracts, able to afford the premiums, and trusting enough in the system to make initial premium payments in exchange for uncertain future payouts. These are non-trivial demands for households that are often extremely poor.

Despite these concerns, many private and public organizations around the world are selling or experimenting with index insurance, with some remarkable successes as well as some puzzling failures. Because such efforts are in their relative infancy, there exist only a handful of careful studies that attempt to systematically answer questions such as why a particular approach worked or didn’t, which farmers purchase index insurance, and which factors affected their decision to purchase. And
almost no studies attempt to document the broader effects of insurance adoption on livelihood outcomes such as yields or farmer incomes\(^3\).

Nevertheless, a growing body of program reports and white papers, in addition to the few published academic studies, provide an initial picture of what products have been tried and what factors might have contributed to their success. Here we attempt to synthesize the available literature and extract a broad set of lessons common to existing index insurance programs, as well as to identify salient research questions that the existing literature has not addressed. The report is organized as follows. The next two sections motivate the need for index insurance by exploring the causes and consequences of risk for smallholders (Section 2), and the set of issues faced by governments and relief agencies in helping manage that risk (Section 3). Section 4 explores the basic structure of typical index insurance products. Section 5 describes the experience to date of providing these products directly to smallholders, and Section 6 the experience of governments and relief agencies buying index-based products on behalf of smallholders. Section 7 concludes with a summary of lessons learned, and priorities for future research. Throughout the report, our main focus is on the African continent, drawing on experiences from other areas where applicable.

2. Causes and consequences of risk for smallholders

Smallholders in developing countries face numerous sources of risk. Much of this risk is directly related to agricultural production: years of low rainfall or hot temperatures can reduce crop yields dramatically, as can outbreaks of crop pests or diseases. Similarly, market-related risks, such as fluctuations in market prices for farm inputs or outputs, can also threaten livelihoods by raising smallholder costs or lowering the value of what they produce. Threats to household labor supply can also be important: if key members of households become sick, both farm productivity and off-farm wage income can decline. And other unexpected demands on household income such as weddings, funerals, or loss of employment can also impact livelihoods.

While few systematic data exist, available survey data suggest that weather-related risk looms particularly important for most smallholders, with quantitative and qualitative evidence from around the world indicating that variation in rainfall and temperature is often the largest determinant of year-to-year changes in farmer yields and incomes. For instance, 89% of Andhra Pradesh households in a recent study cite

\(^3\) Fuchs and Wolff (Fuchs and Wolff 2010) is the one exception we are aware of.
rainfall variability as the most important source of risk that they face (Cole et al. 2009). Similarly, both self-reports and statistical analysis of an Ethiopian panel dataset suggest that rainfall shocks are the largest source of risk to consumption in Ethiopian households (Christiaensen and Dercon 2007).

Broader statistics on weather-related natural disasters on the African continent paint a similar picture. Over the last 30 years, data from the International Disaster Database indicate that an estimated 1,000 natural disasters took place in Africa, affecting 328 million people with damages estimated at US$24 trillion4. While floods have accounted for the most total disaster events, droughts are the hazard that has affected the most people and caused the most damage, accounting for 80% of people affected and 40% of total economic damages (Table 1). Together droughts and floods dominate the African risk landscape, with half of Sub-Saharan countries affected by at least one drought every 7.5 years, and half impacted by at least one flooding event every three years. Relative to other regions of the world, mortality from these events is very high (see Annex 1, Maps 1-2).

Table 1. Frequency of events, people affected, and damage cost by disaster type and by region in Africa, 1980-2010

<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Frequency of events by disaster type (%)</th>
<th>People affected by disaster type (%)</th>
<th>Damage cost by disaster type (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sub-Saharan Africa</td>
<td>Other African Countries</td>
<td>Sub-Saharan Africa</td>
</tr>
<tr>
<td>Drought</td>
<td>18.9%</td>
<td>13.4%</td>
<td>82.8%</td>
</tr>
<tr>
<td>Earthquake (seismic activity)</td>
<td>3.4%</td>
<td>10.7%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Extreme temperature</td>
<td>0.6%</td>
<td>2.7%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Flood</td>
<td>59.0%</td>
<td>61.5%</td>
<td>12.9%</td>
</tr>
<tr>
<td>Storm</td>
<td>16.7%</td>
<td>11.8%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Volcano</td>
<td>1.4%</td>
<td>0.0%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Source: EM-DAT: The OFDA/CRED International Disaster Database. www.emdat.be - Université Catholique de Louvain - Brussels - Belgium

These weather shocks can have serious consequences for smallholder livelihoods, particularly when they are uninsured. These consequences are a combination of two effects: ex-post effects, or the impacts of a realized weather shock on household

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4 EM-DAT: The OFDA/CRED International Disaster Database. At least one of the following criteria must be fulfilled in order for an event to be entered into the database: i) 10 or more people killed; ii) 100 or more people affected/injured/homeless; iii) declaration of a state of emergency and/or an appeal for international assistance.
incomes and consumption, and ex-ante effects, or households’ often costly attempts at reducing their exposure to future weather related shocks.

2.1 Ex-post impacts

The ex-post effects of a weather shock are the most obvious and often the most gripping. Periodic drought across the Sahel and Horn of Africa and its devastating effects on human and animal life are the archetypal images of how weather-related shocks can impact African smallholder livelihoods, but various studies suggest that less severe weather fluctuations can also have serious impacts. For instance, drought-related reductions in farm income can cause households to liquidate productive assets or curtail educational or health expenditures in order to maintain food consumption (Barnett, Barrett, and Skees 2008; Jacoby and Skoufias 1997). These short-run coping strategies can have severe longer-run consequences as well, significantly reducing household income growth, educational attainment, and health over time (Dercon 2004; Maccini and Yang 2009). A growing literature also suggests the presence of risk-related poverty traps, in which a weather shock pushes a household below a critical threshold, below which a downward spiral of asset decumulation and earnings decline ensues (Barnett, Barrett, and Skees 2008). In this view, uninsured shocks have level effects as well as growth effects, pushing some poor households to a destitute low-level state from which it is difficult for them to escape.

2.2 Ex-ante effects

These ex-post effects are compounded by households' often costly efforts to hedge risk ex-ante. The mere existence of weather-related risk can encourage investment in technologies and crop portfolios with lower risk but lower expected return (Rosenzweig and Binswanger 1993). For instance, Dercon (Dercon 1996) finds that poorer Tanzanian households grow more sweet potatoes (a low-risk, low-return crop), trading lower risk for up to a 25% reduction in average earnings. Households also attempt to manage uninsured weather risk by increasing their non-farm sources of income, but the more profitable of these opportunities often have high entry costs that greatly limit smallholder participation (Dercon 2000). A lack of insurance can also discourage farm households from taking out loans, for fear of suffering a negative weather shock, being unable to repay the loan, and losing productive assets that were used as collateral (Boucher, Carter, and Guirkinger 2008). A similar logic can apply to investments in agricultural input use: uninsured smallholders are reluctant to invest
in farm inputs such as fertilizer for fear of losing their investment if a lack of rainfall causes crop failure (Christiaensen and Dercon 2007).

The absence of formal means to insure or save encourages a variety of additional informal risk coping and risk management strategies, including borrowing from neighbors or holding as precautionary savings relatively liquid assets such as livestock or grain reserves that can be sold in the event of a negative shock. The success of these systems depends to a large degree on whether realized shocks are idiosyncratic (affecting only a few households at any given time) or covariate (affecting most or all households in a region simultaneously). For instance, region-wide shocks such as drought can prompt simultaneous liquidation of similar assets by households, greatly reducing their value just as it is most needed. Correspondingly, Harrower and Hoddinott (Harrower and J. Hoddinott 2005) find that among households in northern Mali, idiosyncratic shocks are frequent but have little impact on consumption (presumably due to inter-household risk pooling), whereas negative covariate shocks are almost always associated with consumption declines. Dercon and Christiansen (2007) find that covariate rainfall shocks have large effects on consumption in a set of Ethiopian villages, but idiosyncratic rainfall shocks have little or no effect.

Are shocks that smallholders face mostly common or idiosyncratic? This is an important question, both for the success of informal risk management strategies, and particularly for the relevance of the index-based insurance products discussed below. Existing household survey evidence indicates surprising variation in the relative contribution of idiosyncratic and covariate risk to variance in household yields and incomes (Table 2). Data on co-variation in the weather-related risk factors themselves paint a similar picture. Map 3 in Annex I shows the extent to which rainfall at three different African locations correlates with rainfall elsewhere on the continent (Map 4 repeats the same exercise for temperature). The data show clearly that while rainfall is much more spatially variable that temperature, local weather realizations are quite highly correlated.5

Even if risk is highly covariate, however, insurance might not always be the optimal risk management tool. Where farmers have access to credit or to trustworthy ways to save, taking out loans or drawing down savings is likely preferable to

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5 These correlation calculations are based on 0.5 x 0.5 degree gridded monthly climate data (roughly 50km x 50km at the equator). While temperature variations tend to be smooth across space, rainfall is much less so, and as a result this grid scale could mask considerable rainfall variation at the local level (e.g. at the farm level). As such, these data likely overstate rainfall covariance between any two farms.
insurance as a way of smoothing small fluctuations in income. Unfortunately, as with insurance, such options are not always available. Small farmers often lack the collateral to obtain a loan or face rigid microfinance guidelines that prohibit the use of credit to cover income shocks. In these situations, efforts to expand the financial services available to smallholders should carefully consider the appropriateness of the various alternatives (e.g., credit versus insurance) in light of the type of risk faced by local farmers. It is unlikely that expanding insurance will be first-best for all categories of farmers and of risks, and hence despite its clear value one has to be cautious not to oversell the benefits of weather insurance.

**Table 2. The importance of idiosyncratic versus covariate risk for smallholder yields and incomes**

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Dependent variable</th>
<th>Covariate (% of total)</th>
<th>Idiosyncratic (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Udry 1990)</td>
<td>Nigeria</td>
<td>Yields</td>
<td>58%</td>
<td>42%</td>
</tr>
<tr>
<td>(Carter 1997)</td>
<td>Burkina Faso</td>
<td>Yields</td>
<td>36-72%</td>
<td>28-64%</td>
</tr>
<tr>
<td>(Dercon and Krishnan 2000)</td>
<td>Ethiopia</td>
<td>Self-reported crop failure</td>
<td>34%</td>
<td>66%</td>
</tr>
<tr>
<td>(Morduch 2004)</td>
<td>India</td>
<td>Income</td>
<td>4-25%</td>
<td>75-96%</td>
</tr>
</tbody>
</table>

In summary, weather-related risk plays a significant role in both the immediate and the longer-run livelihoods of smallholders, and represents the type of risk that existing informal risk strategies are least equipped to handle. In situations where such risk is particularly covariate, where it causes relatively infrequent but severe losses for smallholders, and where it is well captured by an easily measureable index such as rainfall, index insurance would appear to be a very useful tool for assisting farmers in managing weather-related risk.

2.3 **The current state of smallholder insurance**

Despite the high welfare costs of uninsured risk to poor households, both market-based and public sector agricultural insurance schemes are essentially non-existent in much of the developing world, particularly Sub-Saharan Africa. One recent estimate suggests that Africa accounts for just 1% of global agricultural insurance premiums, Latin America 2%, and Asia 18% (Iturrioz 2009). Countless anecdotes from the literature suggest that most developing-country smallholders - again particularly in Africa - have had no experience with insurance whatsoever.
A standard explanation for the current low coverage are the asymmetric information problems common to insurance provision everywhere: farmers have less incentive to work hard if their harvest is insured (moral hazard), and farmers who take more risks might be more likely to purchase insurance, raising the costs of insurance provision (adverse selection). A second explanation is that traditional insurance schemes in poor countries typically face very high transaction costs, a result of the difficulty in both writing policies and assessing claims for large numbers of spatially dispersed smallholders often linked by poor transportation infrastructure. Because these costs are largely fixed per household, total costs as a percentage of insured value rise as farm and policy size decline (Barnett et al 2008), further reducing profitability for the insurer or raising premiums for small farmers. Third, poorly developed legal institutions can hamper contract enforcement.

Finally, the nature of the uninsured risk itself might restrict firm entry. Viable insurance schemes rely on the ability to pool large numbers of uncorrelated outcomes, and this system is undermined when policyholders face highly covariate risks, with large correlated losses emptying insurer coffers and leaving policyholders potentially unprotected. If most risk is covariate in a given area, insurers might find it difficult to adequately pool risk, and absent easy access to international re-insurance they might therefore be reluctant to enter the market.

Experience with traditional crop insurance elsewhere offers some insight into the difficulties. In developed countries such as the US, for instance, most crop insurance schemes have been supported by heavy government subsidies, with farmer-paid premiums in the US covering only about 30% of total costs (USAID 2006). These subsidies are needed to maintain a system in which loss ratios (indemnities divided by premiums) typically exceed 1-1.5 in many parts of the country (Glauber 2004). Even if beneficial from a social welfare standpoint, such subsidies are more affordable for countries where farmers represent a small proportion of the total population. This will be less true when agricultural activities make up a greater percentage of total economic activity in a country, as is typically true in most low-income developing countries.

Thus providing agricultural insurance to smallholders at a large scale will likely necessitate innovation with regard to the standard informational problems associated with insurance provision, the high transaction costs of doing business with smallholders, and the covariate nature of the risk being insured, as well as to issues of premium affordability and farmer trust. As discussed below, index-based insurance
has the potential to offer compelling solutions to these problems, and various products are now supplied to farmers at an impressive scale.

3. Institutional level risk management strategies

Institutional level risk management strategies constitute efforts by institutions to manage various risks that they or their constituents face. These risks are typically highly covariate, infrequent natural disasters such as earthquakes or hurricanes, but also include smaller more frequent risks, such as local droughts or pest outbreaks experienced by farmers in the country. The risk management strategies to handle these hazards are designed and implemented by state and national governments as well as international organizations due to their potential to generate disproportionate damage on the population across vast geographic areas.

Currently, the institutional response to disasters in the vast majority of low- and middle-income countries is after they’ve already happened, with little attention paid to prevention or ex-ante risk management schemes. This focus on so-called "recovery" is a consequence of governments’ limited awareness of risk exposure, their generally weak institutional capacity in disaster risk management, and the often ample availability of free or inexpensive post-disaster third party financing (Cummins and Mahul 2009).

Responding after a disaster has already occurred is costly for low- and middle-income countries. Despite the increasing number of international organizations and donors that respond to disasters, the percentage of economic losses from natural disasters covered by donor assistance is fairly low, ranging between 1.9% and 14.2% in 1990-2003 (Figure 1). Given that insurance penetration is quite low in most of these countries, country governments end up absorbing most of the costs of large-scale disasters themselves (Cummins and Mahul 2009), or in the worst case passing them on to their constituents. And even if countries are able to recoup some of their disaster related losses in the longer run, they might face the full financial cost of recovery in the short-term. Financial funds from the international community and donors often take several months to materialize and are generally earmarked for specific types of disasters.

The development of insurance markets would help shift the focus from recovery to mitigation, prevention, and risk management. Such a shift would help to reduce the economic burden faced by disaster-prone countries, and to further promote timely
responses to disasters. Because these disasters don't happen every year and are relatively idiosyncratic across the globe, such weather-related risk should in principle be insurable on international markets. A strong insurance market for country-level weather risk would allow state and national governments to spread risk and thus to implement more rapid and capable response strategies in affected regions while smoothing public budget outlays over time.

International organizations tasked with providing basic goods and services following weather-related disasters (e.g., the World Food Program) often face similar issues. These organizations depend on donor support for disaster relief funding, which is often only forthcoming in large amounts long after a disaster has already occurred, again limiting timely response. These organizations might also benefit from strong international insurance markets as they could hedge their operations in disaster-prone countries, thus reducing their financial effort while guaranteeing a steady flow of goods and services to countries in the event of extreme weather events.

Figure 1. Economic losses from natural disasters covered by donor assistance (percentage)

Source: Cummins and Mahul (2009).

Finally, international financial organizations (e.g., the Word Bank) could play an important role in helping develop the insurance market in low- and middle-income countries by increasing support in strategic areas. These organizations might
increase the provision of financial and technical support to assess country-specific risk exposure, a requirement for building a sound insurance market. They could also help governments pay the cost of developing or implementing innovative insurance products that offer solutions to the primary natural disasters that they face. Finally, they could guarantee that payouts will indeed be made when disaster strikes, increasing trust in private providers.

4. How index insurance works

Index-based weather insurance ties indemnity payments to the behavior of relevant weather indicators that are correlated to crop yields or other outcomes of interest. Indemnities are therefore based on objective, observable, and verifiable weather variables (e.g., rainfall or temperature) instead of direct economic losses suffered by farmers. Under this approach, every farmer with the same insurance contract in the same region receives identical indemnity payment regardless of his or her actual economic loss.

The basic payment structure of a weather-indexed product centers around two main values: the threshold and the limit. The threshold denotes the value of the index at which indemnity payments kick in, and the limit denotes the point at which payments reach a maximum level. Indemnity payments typically increase as the index approaches to the limit, with the rate of increase a function of the threshold, the limit, and the actual value of the weather index (USAID 2006).

As an example, consider an index-based policy covering drought-related losses. Here the relevant weather index could be the total accumulated rainfall during a specific period of time measured in millimeters (mm). Assume a threshold of 120 mm, a limit of 60 mm, and that the policyholder buys a liability of $100,000. Since this policy provides insurance against deficit rainfall, the payment rate could be defined as the difference between the threshold and the actual value, divided by the threshold minus the limit (USAID, 2006).

The payments for this example under different rainfall realizations are shown in Table 3 and Figure 2. The insurance contract does not provide payments when the rainfall index is at or above the threshold (120 mm), implying that the risk of drought did not materialize. Payments increase linearly once the rainfall index falls below the threshold according to the payment rate and reach a maximum of $100,000 (equal to the total liability purchased) when the rainfall index is at the limit of 60 mm. The
contract pays $100,000 for rainfall values below 60 mm. It is important to note in this example that the "liability purchased" does not represent the total cost to the farmer, only the actuarially fair price (cost of pure risk) of the insurance. Premiums will likely be much higher due to insurer "loadings", which include the additional costs of insurance provision discussed below.

Table 3. Payments under different rainfall scenarios. Payment rate refers to the percentage of liability purchased that is paid out at given rainfall realizations.

<table>
<thead>
<tr>
<th>Total rainfall (Actual value)</th>
<th>Payment rate (%)</th>
<th>Liability purchased ($)</th>
<th>Indemnity payment ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>0%</td>
<td>100,000</td>
<td>-</td>
</tr>
<tr>
<td>120</td>
<td>0%</td>
<td>100,000</td>
<td>-</td>
</tr>
<tr>
<td>110</td>
<td>17%</td>
<td>100,000</td>
<td>16,667</td>
</tr>
<tr>
<td>90</td>
<td>50%</td>
<td>100,000</td>
<td>50,000</td>
</tr>
<tr>
<td>70</td>
<td>83%</td>
<td>100,000</td>
<td>83,333</td>
</tr>
<tr>
<td>60</td>
<td>100%</td>
<td>100,000</td>
<td>100,000</td>
</tr>
<tr>
<td>50</td>
<td>100%</td>
<td>100,000</td>
<td>100,000</td>
</tr>
</tbody>
</table>

Source: Authors

Figure 2. Payments under different rainfall scenarios. Dark black line gives payouts as a function of rainfall amount, and orange represents the historical distribution of rainfall at the location. The threshold and limit are represented by the dotted lines.

Source: Authors
4.1 Cost structure of traditional versus index based insurance products

Comparing the cost structures of traditional and index-based insurance products is particularly illustrative. The cost associated with traditional insurance provision consists of the following components:

- **Cost of pure risk**, equal to the expected economic loss covered by the insurance policy, or equivalently, long-term average of indemnities that would be paid out under the insurance policy.
- **Information requirements to control adverse selection**. Insurance might attract riskier farmers into the market, and policy-holders with higher risk should pay an extra premium.
- **Information requirements to control moral hazard**. Traditional insurance incentivizes farmers to work less hard, so insurance companies must monitor the production techniques adopted by the policy holder to avoid paying for self-inflicted losses.
- **Loss adjustment**. Insurance companies must estimate actual economic losses that are produced by the covered risks.
- **Delivery cost**, including costs related to marketing, selling and delivery of the insurance product, in addition to management costs.
- **Capital cost**. The insurance provider must have quick and easy access to financial resources in order to be able to pay out indemnities that exceed premiums paid by policy holders. This can be done in the reinsurance international market.

Index-based insurance will reduce or eliminate many of these costs, as shown schematically in Figure 3. Most importantly, loss adjustment procedures are not required when implementing index-based products since the actual economic losses do not play any role at the indemnity payment process. Similarly, index insurance also greatly cuts down on informational requirements. Moral hazard disappears because indemnity payments are determined solely by objective weather variables that policyholders cannot influence. And adverse selection problems are also

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6 Adapted from USAID (2006). An insurance product is called “traditional” when the indemnities payments are based upon actual losses incurred by the policy holder. In this context, the insurance company has to verify on the field that producers actually suffered an economic loss that was caused by the risk covered by the insurance policy. Once the verification is made, the insurance provider makes the indemnity payments.

7 Figure 3 is illustrative. It does not intend to measure the total cost of each product, the relative size of each component, and the actual cost difference between traditional products and index-based products.
eliminated because insurers no longer must determine who is a risky farmer, because all farmers will receive the same payment regardless of their individual risk.

Although index-based products are superior to traditional products from a cost perspective, they introduce the additional challenge of “basis risk”, or the difference between the indemnity payments and the actual losses suffered by policyholders. Basis risk arises in index-based products because payments are based upon a weather indicator that is imperfectly correlated with crop yields, rather than on crop yields themselves. While basis risk does not directly raise insurer costs, high basis risk is likely to lower farmer demand for the insurance product, constraining opportunities for market expansion. These issues are discussed in detail below.

**Figure 3. Cost structure of traditional and index-based insurance products**

5. Index-based insurance: experience at the individual level

Table 4 lists individual-level index insurance products for which basic summary data exist at the time of writing. These products span roughly 15 countries and are quite diverse in their approach, scale, and stage of development. They have expanded rapidly in recent years and now represent an estimated $1 billion in total insurance coverage (Hess and Hazell 2009). We first characterize the main supply side issues associated with index insurance provision, before turning to the arguably more important demand-side constraints.
5.1 Evidence on the supply side

From an insurer perspective, index-based insurance has clear attractions relative to traditional crop insurance. As noted above, writing contracts on easily observed weather variables should be much more straightforward than contracting on individual farm outcomes across many dispersed smallholders: insurers need only to monitor a weather index rather than observe outcomes on potentially thousands of individual farmer fields. Nevertheless, experience to date suggests three main difficulties for prospective providers: obtaining data to price and monitor insurance contracts, pooling risks when shocks are covariate, and overcoming cost issues associated with start-up and potential competition with subsidized government programs.

Table 4. Selected individual-level index insurance schemes. "Scale" represents authors’ best estimates of the number of beneficiaries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Policyholder</th>
<th>Project name</th>
<th>Instrument</th>
<th>Scale</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>2001</td>
<td>Participants in government seed program</td>
<td>AgroBrasil</td>
<td>Area-based yield index</td>
<td>15,000</td>
<td>Government pays 90% of premium</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>2007</td>
<td>Teff and bean farmers</td>
<td>HARITA</td>
<td>Rainfall index</td>
<td>300</td>
<td>Ongoing</td>
</tr>
<tr>
<td>India</td>
<td>2003</td>
<td>Smallholders growing various crops</td>
<td>BASIX, ICICI Lombard, others</td>
<td>Rainfall, temperature index</td>
<td>150,000</td>
<td>Ongoing. See Cole et al 2009.</td>
</tr>
<tr>
<td>India</td>
<td>2007</td>
<td>Potato farmers under Pepsico contract</td>
<td>Pepsico</td>
<td>Temperature and humidity index</td>
<td>4000</td>
<td>Ongoing</td>
</tr>
<tr>
<td>India</td>
<td>2004</td>
<td>Smallholders</td>
<td>AIC</td>
<td>Rainfall, temperature index</td>
<td>1,000,000</td>
<td>Government premium subsidy; ongoing</td>
</tr>
<tr>
<td>Kenya</td>
<td>2009</td>
<td>Smallholders</td>
<td>Rockefeller</td>
<td>Rainfall index</td>
<td>500</td>
<td>Pilot stage</td>
</tr>
<tr>
<td>Kenya</td>
<td>2009</td>
<td>Maize and wheat smallholders</td>
<td>Kilimo Salama</td>
<td>Rainfall index</td>
<td>200</td>
<td>Pilot stage</td>
</tr>
<tr>
<td>Malawi</td>
<td>2008</td>
<td>Maize, tobacco farmers</td>
<td>MicroEnsure, others</td>
<td>Rainfall index</td>
<td>2500</td>
<td>Initially maize, moved to tobacco; ongoing</td>
</tr>
<tr>
<td>Millennium Villages (Kenya, Ethiopia, Mali)</td>
<td>2007</td>
<td>Smallholders</td>
<td>Millennium Villages</td>
<td>Rainfall and satellite-based greenness index</td>
<td>1000</td>
<td>Premiums paid by MVP; not continued</td>
</tr>
<tr>
<td>Country</td>
<td>Year</td>
<td>Type</td>
<td>Insurer</td>
<td>Index Type</td>
<td>Threshold</td>
<td>Status</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>-----------------</td>
<td>--------------------</td>
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</tr>
<tr>
<td>Mongolia</td>
<td>2006</td>
<td>Herders</td>
<td>IBLIP</td>
<td>District-average livestock losses</td>
<td>5000</td>
<td>Ongoing</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>2008</td>
<td>Smallholders</td>
<td>World Bank</td>
<td>Rainfall index</td>
<td>200</td>
<td>Pilot stage</td>
</tr>
<tr>
<td>Rwanda</td>
<td>2009</td>
<td>Smallholders</td>
<td>MicroEnsure</td>
<td>Rainfall index</td>
<td>500</td>
<td>Ongoing</td>
</tr>
<tr>
<td>Tanzania</td>
<td>2009</td>
<td>Smallholders</td>
<td>MicroEnsure</td>
<td>Rainfall index</td>
<td>400</td>
<td>Ongoing</td>
</tr>
<tr>
<td>Thailand</td>
<td>2007</td>
<td>Smallholders</td>
<td>BAAC</td>
<td>Rainfall index</td>
<td>400</td>
<td>Ongoing</td>
</tr>
</tbody>
</table>

Source: (Hellmuth et al. 2009; Hill and Torero 2009)

5.1.1 Data concerns

Prospective insurers need data to both price and monitor a contract. From a social welfare perspective, contracts should be written on weather variables that matter to farm outcomes, with payout thresholds set at welfare-relevant levels. Determining the relationship between weather variables and crop yields necessitates reasonably long time-series data on both, which are unavailable in many developing-country settings. But because farmers presumably understand how variations in rainfall and temperature affect their yields, a functioning insurance market should sort out good insurance products from bad, with farmers willing to buy only those products that suit their needs. Thus in order to price index-based products, the private insurer really only needs historical data on the index, and historical weather data are typically much more widely available than historical crop yield data. A common strategy in many existing index insurance schemes (e.g., the BASIX program in India) has been for insurers to develop initial products based on available data, and then repeatedly consult with farmers to refine the products and make them more attractive in the market as experience accumulates (Hellmuth et al. 2009).

Providing index insurance clearly also requires a dependable way to monitor the index in near real-time at locations nearby policyholders. This latter requirement is particularly relevant for rainfall, which can vary significantly over small distances (particularly in mountainous geography). While the spatial covariance of rainfall in any particular area is an empirical question, a rule of thumb adopted by some index-based schemes is that policyholders need to be within 20km of a weather station for rainfall-indexed products, and 40km for temperature-indexed products. Because weather station coverage in most developing countries is rarely this dense, insurers acting alone or with government or donor assistance have installed additional weather stations to make monitoring feasible. Anecdotal evidence suggests costs of around a few thousand US dollars per automated weather station (Hellmuth et al
An alternate strategy has been to make use of increasingly available high-resolution satellite-based weather measurements. Unlike individual weather stations, satellite data have the added appeal of being physically tamper-proof, but could increase the risk (real or perceived) of data manipulation on the part of the insurance provider (Hellmuth et al 2009). Furthermore, ground validation of existing satellite rainfall estimates have shown relatively poor performance over mountainous terrain in Africa (Dinku et al. 2008). Nevertheless, many index insurance schemes now use satellite-based data either exclusively, or as a complement to existing data collection networks (Hellmuth et al 2009). An interesting solution worth exploring is a “reverse-lemons” approach whereby clients who want to reduce basis risk to their advantage engage in self-provisioning of third-party verifiable weather measurements. This could be part of the research agenda suggested by this review.

5.1.2 Pooling covariate risk

A second concern for providers of index insurance is the nature of the risk being insured. As discussed above, weather risk is typically covariate, a characteristic central to the functioning of index insurance: if a single index is meant to proxy for losses across many farmers, one hopes that those farmers experience losses simultaneously. But covariate risk also makes risk pooling difficult, and insurers must have the resources on hand to honor contracts in the face of large common shocks - e.g., when all rainfall gauges in a region indicate significant drought. A typical strategy for insurers to manage covariate risk is to transfer this risk to international reinsurance markets. Hess and Hazell (2009) report that over half of existing index insurance programs have purchased reinsurance, but that these re-insured programs account for 99% of existing policies. And although most index insurance programs have apparently been successful in purchasing re-insurance, Hellmuth et al. (2009) note that lack of data about historical risk exposure or potential scale of the program can make reinsurers reluctant to enter the market, or be willing to do so only at high cost. Thus solving the data concerns noted above appears crucial not only for basic contract pricing and monitoring, but also for ensuring broader program stability via the ability to purchase reinsurance on international markets.

5.1.3 Cost concerns

A final supply-side hurdle, at least from the perspective of potential private-sector providers, is potentially large start-up costs and possible competition with subsidized
government insurance programs. Although index-based insurance appears to solve many of the cost issues associated with provision of traditional insurance, product development won’t necessarily be easy: there is relatively little international experience to draw upon, data requirements can be large, and these products are being marketed to a poor, dispersed population often with little financial literacy or previous exposure to any type of insurance. Even the most developed market for index insurance – India – began with a very small-scale pilot including a few hundred farmers that depended on intensive (and expensive) farmer interaction to improve product design and promote initial adoption, during which time some products were abandoned and others significantly altered (Hellmuth et al 2009). Such early efforts have since blossomed into a much larger market serving around 150,000 farmers across several states without subsidy, demonstrating that these start-up costs can be overcome. Nevertheless, this and related experience suggests that tinkering and patience across many years will be a likely prerequisite for program success. Proving insurance to group of farmers, such as coffee cooperatives, as opposed to individuals, is also an option that can be explored to reduce transaction costs.

Similarly, while the problem of competition with government subsidized programs is unlikely to be a problem in the near term in most African countries (few of which have any sort of crop insurance scheme currently), it has become an issue in more mature index insurance markets such as India. There, private market expansion has reportedly been hindered by large government subsidies for premiums in existing government crop insurance schemes. Similar competition with a government-subsidized program likely contributed to the collapse of a commercial index insurance product in the Ukraine (Hellmuth et al 2009). That the Indian government has copied the private sector and now offers their own (subsidized) index insurance product is certainly an endorsement of the basic product, but such competition will likely challenge expansion of commercial insurance, with uncertain implications for overall efficiency or welfare. While there can be complementarity between private and public provision of weather insurance, it is essential that the rules that establish the coverage offered by each party be well established and enforced if private providers are to be attracted into the agricultural insurance market.

5.2 Demand side issues

While many of the supply side hurdles are technical in nature and thus in principle solvable, the more difficult issues likely lie on the demand side. Despite the clear
negative contribution of uninsured risk to smallholder livelihood, and the compelling logic of weather-indexed insurance products, take up of such products where they have been offered has been surprisingly low. For instance, in studies in both Malawi and India (the two best studied index insurance programs), take-up of index insurance among targeted program participants was only 20-30%, with adopters hedging only a very small proportion of agricultural income (Giné 2009; Cole et al. 2009). Take-up among farmers not explicitly targeted in these programs was much lower. Possible explanations for low adoption abound, but the literature generally centers on four main issues: premium affordability, farmer trust in the insurance provider, financial literacy, and the degree of correlation between the index and farmer outcomes (i.e., basis risk). We explore each of these explanations in turn below.

5.2.1 Premium affordability

Perhaps unsurprisingly, take-up of index insurance products appears strongly related to their affordability. Poor farmers are typically price sensitive and cash constrained, and these factors appear to contribute directly to their willingness and ability to purchase index insurance. For instance, demand for index insurance product in Gujarat and Andra Pradesh, India, proved very sensitive to price: by randomly varying the prices different farmers faced for a rainfall-indexed product offered by BASIX, ICICI Lombard, and others, Cole et al. (2009) estimated large price elasticities of demand between -0.66 and -0.88, and also found large increases in insurance purchase if farmers were "surprised" with a random liquidity shock (authors randomly gave money to some farmers). Similarly, Giné and Yang (Giné and Yang 2009) found that take-up of rainfall-indexed insurance is positively correlated with household wealth among Malawian maize smallholders.

There are numerous ways of addressing these affordability issues. The most basic is to reduce costs on the supply side, but many options here come with obvious tradeoffs. For instance, one strategy would be to set index thresholds such that policies pay out less often (e.g., policies generate payments when rainfall drops below 200mm instead of 300mm in the above example). This would lower premiums, but as discussed below could come at the cost of farmer trust in the insurer if the policy doesn’t appear to pay out very often. Alternatively, if seasonal cash constraints are what binds farmer purchase of insurance (as is common with purchase of other inputs), insurers could collect premiums when farmers are most able to pay, typically
directly following harvest when crops are marketed (Hellmuth et al. 2009). Finally, an innovative new program in Kenya (Kilimo Salama in Table 4) is attempting to reduce premium costs through a cost share with agricultural input suppliers: farmers are able to buy rainfall-indexed insurance for their purchases of certain fertilizer and seeds, with the sellers of these inputs paying half the farmer’s premium (IRIN 2010).

In practice, public or donor support is often used to lower farmer premiums. One approach has been a "risk layering" strategy, in which the government agrees to provide coverage for catastrophic events, with the commercial sector responsible for the smaller, more frequent losses. This structure is currently being explored in an index-based livestock insurance program in Mongolia (IBLIP in Table 4), in which contracts are written with respect to district-average livestock losses (Mahul and Skees 2007). In this scheme, commercial insurance products reach maximum payouts at 30% herd losses, and the government pays the incremental losses above 30%. Private insurers thus no longer bear any catastrophic risk, lowering the premiums farmers face. An alternative approach is exemplified in a pilot project in Ethiopia (HARITA in Table 4), in which insurance premiums are paid in exchange for farmer labor on risk-reducing community projects, such as water-harvesting schemes (Hellmuth et al. 2009). Direct government subsidy of premiums is a final option. While generally contentious, such subsidies could be warranted if cash constraints are indeed binding for the poorest smallholders, or if such subsidies would increase farmer learning about a product known to be welfare enhancing. Subsidies are also warranted if they promote smallholder "learning-by-doing", which then could spill over to other farmers as information on the benefits of insurance diffuses through farmer networks. Where such subsidies crowd out a viable private sector competition, however, they are likely less appealing. One approach might be credibly-announced time-limited or declining subsidies to encourage farmer learning and experimentation with insurance, which could be introduced through a voucher system to target the poor. If successful, such “smart” subsidies could help create a viable market for the private sector in the longer run. Experimentation with such approaches is currently lacking, however, and thus represents a fruitful area for further research.

5.2.2 Farmer trust

Trust in the provider is a second main factor that can limit farmer take-up of index insurance. Insurance is fundamentally different than other smallholder microfinance instruments such as microcredit. In the latter, the farmer bears no immediate risk by
taking on a loan, whereas in an insurance scheme farmers must pay up front to receive uncertain future payouts. Clearly if the farmer does not trust that the insurance provider will make good on the contract, and there is little legal recourse to reclaim the payments, farmers will be unlikely to purchase insurance.

Various methods have been explored to build farmer trust in insurers and their products. The only explicit attempt to measure the role of trust in farmer adoption of insurance is the Cole et al. (2009) study of the BASIX and ICICI Lombard products in India, which found that endorsement of the insurance product from a trusted third party increased product take-up by over 40% relative to farmers who heard of no endorsement. Here endorsement consisted of a positive statement by a local NGO official familiar to the household, or of a subtle reference to the household’s religious faith, that were included in the promotional materials. Qualitative evidence from HARITA (Ethiopia) and the Malawi projects also suggest that working with trusted local partners is critical for scaling up index insurance schemes (Hellmuth et al 2009), and that concerns about trustworthiness often appeared to dominate affordability issues.

Another possible approach to building trust would be to design insurance policies that payout early and often, thus demonstrating to farmers that the insurance is worthwhile, and of broadly diffusing information on payouts when made. To date, payout schemes have not always been designed with the promotion of trust in mind. For instance, Gine, Townsend, and Vickery (Giné, Townsend, and Vickery 2007) estimated that while a rainfall-indexed product in India (ICICI Lombard) offered a very large maximum return (900% of premium in some of the regions), the policies produced a positive return only around 10% of the time, and the expected value of payoffs based on historical rainfall averaged about 40% of the premium. This compares to average payouts of around 60-70% of total premium payments in developed countries (Cole et al 2009). While policies that pay out more often are likely to have higher premiums, Carter (Carter 2009) suggests that innovative non-linear payout structures could keep costs down while providing frequent small payouts to policyholders. Such an approach might have efficiency costs, however, because smaller income shocks are likely cheaper to insure through savings and credit than through index insurance. In this situation, “smart” time-limited premium subsidies might again be a fruitful approach to explore in promoting farmer learning.

5.2.3 Financial literacy
The third demand-side concern with index insurance is that farmers might be unwilling to purchase index insurance products because the contracts are often hard for them to understand. Difficulties with smallholder financial literacy are not surprising given the near-absence of formal insurance throughout much of the developing world, and index insurance is particularly difficult to understand because payments are not linked to individual farmer losses as they suffer from basis risk. Again, the Cole et al. (2009) study in India provides the only explicit evidence of the role of financial literacy in shaping farmer adoption. The study found that households generally scored poorly on basic tests of financial literacy, but most scored well on a test of comprehension of a hypothetical temperature insurance product. Somewhat surprisingly, experimental provision of small amounts of additional financial education had little effect on insurance take-up in their study, but the authors admit that this could have reflected the insufficiency of the education module offered. Nevertheless, overall insurance take-up was correlated with various measures of household’s financial literacy in the study, a finding echoed by Giné and Yang (2009) studying the World Bank/Opportunity International project in Malawi mentioned in Table 4.

If financial literacy constraints are binding, then a clear solution is to promote financial literacy among smallholders. One approach to doing this has been through financial education "games", in which researchers simulate potential gains from insurance with groups of farmers (Carter 2009; Lybbert et al. 2009). However, because the provision of financial education to smallholders is likely costly in time and resources, widespread private-sector implementation of this approach appears unlikely. The public goods aspect of such information will likely mean that its provision will fall to governments or to the NGO community. Cost effective ways of providing financial education have to be designed and are currently being tested, in particular using group training and the role of network externalities for the diffusion of information in a community of farmers (J. Magruder, personal communication).

5.2.4 Basis risk

A final demand-side constraint to adoption of index insurance is basis risk, or the possibility that index-calculated payouts won't match individual farmer losses. Basis risk stems from two main sources: imperfect measurement of weather at farmers' fields, and imperfect correlation between farmer yields and a given weather variable. Because these imperfections are impossible to fully eliminate, some amount of basis
risk is unavoidable. But the higher the basis risk the less useful the insurance will be for the farmer, limiting farmer take-up.

There are two main strategies for reducing basis risk. The first is to measure weather outcomes as close as possible to farmer fields, which is tantamount to increasing the density of weather stations. The correlation between weather at a given farmer’s field and weather at a nearby weather station depends on both the weather variable of interest (e.g., rainfall or temperature) and the particular geography of the region. So for a given density of weather stations, basis risk is likely to be much higher for a rainfall-indexed product over mountainous terrain than it is for a temperature-indexed product being sold in a flat area. As noted above, some existing pilots have adopted the informal rule that farmers need to be less than 20km away from a weather station in the case of a rainfall indexed product, with perhaps twice that distance allowable for temperature-indexed products (Hellmuth et al 2009). Because existing weather monitoring infrastructure is often less dense than this, most existing index insurance projects have had to invest in additional weather stations, at costs that are rapidly declining with technological improvements. An alternate strategy, mentioned above, has been to make use of increasingly available satellite-based weather measurements, but these introduce additional problems of both accuracy and transparency.

The second strategy for minimizing basis risk is to develop an index more highly correlated with farmer yields. Interestingly, while the vast majority of existing index insurance products use rainfall as an index, many recent statistical studies of weather and yields find that temperature variations can explain much more variation in yields than does rainfall variations - a finding true for both the main African cereals using relatively coarse data (Schlenker and Lobell 2010) and for crops in the US using very high resolution data (Schlenker and Roberts 2009). With climate change, temperature variations may become increasingly important. This suggests that basis risk associated with a rainfall-only index might be high, and that inclusion of other variables such as temperature might be warranted.

Correspondingly, some insurance products index payments to other weather variables such as temperature or humidity (e.g., in India) or to blends of multiple weather variables such as estimated evapo-transpiration rates (as in the HARITA pilot in Ethiopia and the Millennium Villages in Africa in Table 4) (Hellmuth et al 2009). Various projects are also experimenting with indexes derived from satellite-based measures of crop productivity (including the Millennium Villages in Kenya, Ethiopia,
and Mali, and Agroasemex in Mexico (Hellmuth et al 2009)). These measures, such as the Normalized Difference Vegetation Index (NDVI), have the potential advantage of more precisely matching agricultural outcomes as compared to a rainfall or temperature index, but the disadvantage of being less verifiable (and thus perhaps less trustworthy) to farmers. Unfortunately, the extent to which these different products actually reduce basis risk has not been explicitly measured in any of the existing studies. But given the importance of basis risk in limiting index insurance take-up, much attention is being given to these alternative approaches to measurement (for example at CIAT and other international research centers of the CGIAR) and rapid progress is likely to be made.

6. Experiences at the institutional level

Index based weather insurance products are now used at the institutional level in roughly 22 countries, a selection of which are shown in Table 5. Although many of these experiences are in pilot phase, they highlight potential benefits of this approach for national governments and international organizations. These experiences also illustrate the challenges to be overcome in order to expand the use of index-based insurance products at the institutional level. While experiences reported here have been at the level of national or state governments and international organizations, other institutions can explore insurance coverage for their members, in particular cooperatives and other forms of producer or community-based organizations,

Table 5. Selected institutional-level insurance schemes

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Policy-holder</th>
<th>Insurer</th>
<th>Instrument</th>
<th>Scale</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caribbean</td>
<td>2007</td>
<td>Governments of 16 Caribbean countries</td>
<td>Caribbean Catastrophe Risk Insurance Facility</td>
<td>Insurance indexed to hurricanes and earthquakes</td>
<td>16 countries</td>
<td>Ongoing</td>
</tr>
<tr>
<td>Colombia</td>
<td>2005</td>
<td>Government of Colombia</td>
<td>World Bank Contingency Credit Line</td>
<td>Earthquake-contingent debt</td>
<td>Country-level</td>
<td></td>
</tr>
<tr>
<td>Ethiopia</td>
<td>2005</td>
<td>World Food Program</td>
<td>AXA Re</td>
<td>Drought-indexed insurance</td>
<td>Coverage for 62,000 households</td>
<td>Premium paid by donors; not renewed</td>
</tr>
<tr>
<td>Country</td>
<td>Year</td>
<td>Government</td>
<td>Insurer</td>
<td>Index Based Insurance Product</td>
<td>Risk Coverage</td>
<td>Status</td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td>-----------------------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Malawi</td>
<td>2009</td>
<td>Government of Malawi</td>
<td>World Bank</td>
<td>Weather derivative on rainfall index</td>
<td>Country-level insured economic losses of corn producers generated by drought</td>
<td>Intend to transition to private insurer</td>
</tr>
<tr>
<td>Mexico</td>
<td>2003</td>
<td>Government of Mexico</td>
<td>Agroasemex (state reinsurance company)</td>
<td>Rainfall index</td>
<td>~800,000 beneficiaries</td>
<td>Ongoing</td>
</tr>
<tr>
<td>Mongolia</td>
<td>2009</td>
<td>Government of Mongolia</td>
<td>World Bank Contingency Credit Line under IBLIP program</td>
<td>Contingent debt, indexed to country-wide livestock losses</td>
<td>5000 herders</td>
<td>Ongoing</td>
</tr>
</tbody>
</table>

### 6.1 National and State Governments

National and state governments have relied on index-based index insurance in order to play a role as direct re-insurers when both smaller- and larger-scale natural hazards occur, to guarantee financial sustainability of public relief funds, and to pool risks at a regional level.

The Governments of Malawi and Mongolia (see Table 5) have played a direct reinsurance role. The Government of Malawi, with the financial support of international donors such as the World Bank, bought a weather derivative (put option) on rainfall index with the objective of insuring potential economic losses of corn producers generated by a relatively severe drought. If the rainfall index falls 10% below the historical average, the Government receives a payout that should be redistributed to corn producers. On the other hand, the Government of Mongolia, under the Index-Based Livestock Insurance Program mentioned above (Table 5), offers public reinsurance for area-average livestock mortality exceeding 30%, with the private sector insuring smaller losses.

Mexico relies on index-based weather insurance products in order to guarantee the financial sustainability of two relief funds: the National Fund for Natural Disasters (FONDEP) and the Fund to Assist Rural Populations Affected by Weather Contingencies (PACC). National and state governments buy index-based insurance products to manage their operational and financial risks that arise from making weather-contingent payments to rural residents. The use of index-based insurance products is extensive in Mexico, covering 3 million hectares in 2009 and some 800,000 beneficiaries (Table 5).

Sixteen Caribbean countries created the first regional risk facility that allows them to aggregate and pool the risks from natural events (Table 5). The Caribbean Catastrophe Risk Insurance Facility (CCRIF) provides two layers of insurance against...
natural hazards. The first layer offers insurance against weather events with relatively low severity. This first insurance layer is financed through the annual premium each participating country should pay according to its specific risk profile. CCRIF provides a second insurance layer against high-severity natural hazards that is financed through the purchase of index-based insurance products in the international market.\(^8\) According to Cummings and Mahul (2009), this risk pooling strategy results in a substantial reduction in premium cost of 45-50 percent.

6.2 International Organizations

In 2005, the World Food Program (WFP) participated in an index based weather insurance pilot with the objective of improving its post-disaster response in Ethiopia (Table 5). WFP purchased an index based weather contract against droughts in order to hedge a portion of its operational expenses in Ethiopia and to get rapid and predictable funding. Although the contract did not make payouts to the WFP (the rainfall index never fell below the threshold) and was not continued in subsequent years, this pilot set an innovative precedent in showing how the index-based approach could be used to improve the operational and financial situation of international organizations in developing countries. This precedent also deserves further experimentation.

6.3 Other institutional level insurance contracts

Recently, agricultural suppliers have also shown interest in using index-based weather insurance products at an institutional level. In 2007/2008 a tobacco processor and a financial institution located in Malawi purchased index-based insurance contracts to protect their tobacco-related loan portfolio (both the processor and the financial institution provide loans to tobacco producers). The insurance contract was bundled with the loan and its cost was shared between the policyholders and producers. Another similar project is under preparation in Vietnam where an Agricultural Bank will be a mediator between producers and a local insurance company by bundling production loans with index-based insurance contracts against severe floods. The use of index-based insurance products might reduce the risk perceived by agricultural lenders, which in turn could lead to an improved access of producers to formal financial services. Availability of weather infrastructure and side-

\(^8\) The payouts to countries depend on the behavior of selected weather indexes in both the first and second insurance layers.
selling to avoid loan repayment are the main obstacles that deter the expansion of index-based insurance products among agricultural lenders.

Index-based insurance contracts taken by coffee cooperatives are also being explored in Guatemala and Nicaragua. The advantage of this approach is to reduce transaction costs for the insurer and to shelter collectively held assets and contractual obligations. The cooperative can in turn distribute payouts to cooperative members based on an index formula or on direct verification of damages with minimal problems of adverse selection and moral hazard due to social proximity. Hybrid institutional-individual contracts can allow individual members to purchase additional insurance coverage if they deem the cooperative-level insurance contract to be insufficient for their own particular needs. Such institutional-level contracts can be important in helping avoid problems of individual farmer financial literacy and of trust in the insurance provider, with potential great advantages for Africa where these problems prevail.

7. Conclusions and next steps

Existing experience with index-based weather insurance suggests that it is a new financial product with definite promise. Weather risk is critical to smallholder livelihoods and is very poorly managed with existing tools, contributing importantly to the reproduction of low productivity in agriculture and poverty among rural populations. Index-based weather insurance represents a potentially elegant solution to the problems that have undermined provision of traditional insurance to smallholders. But there remain large unanswered questions regarding where, when, and how index insurance will prove most useful and attractive to both smallholders and the institutions that serve them. Along with many encouraging success stories, there have been puzzling failures and overall low take-up, suggesting that the full promise of index insurance has yet to be understood or realized.

The information reviewed here shows a formidable list of hurdles to be overcome in bridging the gap between promise and reality. Problems are both on the supply and the demand sides. Supply side problems to be overcome include paucity of historical data on weather events, difficulty in finding re-insurance options, large startup costs and economies of scale, and government interference in private insurance markets with subsidies and direct relief. On the demand side, critical are problems of pricing and affordability, optimal design of “smart” transitory subsidies to
support learning, liquidity constraints for poor farmers in making insurance premium payments, trust in the insurance provider that payouts will effectively follow insured weather shocks, farmers lack of financial literacy and difficulty in understanding an index-based insurance product, and large remaining basis risks.

Although institutional-level insurance contracts may have been easier to put into place, their coverage is also still minimal. Low-and-middle income countries typically respond to disasters after they have already occurred, rather than focusing on prevention, mitigation, or ex-ante risk management schemes. The experiences in the Caribbean and Mexico illustrate the potential benefits of index-based insurance products in terms of reduced insurance premiums and improved natural disaster response by national or regional governments.

There is a large and critical role for further research into the successes and failures of index insurance. Because getting a new product off the ground can take many years, immediate mileage can be gained through more careful study of existing index insurance programs. Many of these, such as the BASIX/ICICI Lombard products in India, are already well studied, but most other pilots do not have a well-structured evaluation methodology as part of the project. As a result, important opportunities to answer basic questions about index insurance, such as why is take-up typically so low, are being lost. Careful documentation of the successes and failures of new and existing index-based insurance projects, both in terms of short-run indicators such as amount of insurance purchased and longer-run indicators such as improvements in farm yields and incomes, will be critical to future product development.

Finally, if index insurance is ever to reach significant scale, further innovations in product design and delivery will be crucial. Recently there have been promising steps in this direction, such as efforts to link index insurance to agricultural input suppliers and trusted information technology networks, or through the development of contracts that insure groups of farmers, such as cooperatives, using index-based tools. Further development along these lines will be needed, likely with significant support from donor institutions for design and refinement in the early stages of product development.
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Annex 1. African risk profile

Maps 1-2 show drought- and flood-related mortality risk in Africa. Cell colors reflect risk exposure relative to global levels, with red implying highest risk. Source: (Dilley, Chen, and Deichmann 2005)

Map 1. Distribution of drought-related mortality risk
Map 2. Distribution of flood-related mortality risk

Source: Dilley et al 2005.
Map 3. Spatial correlation of rainfall for three African locations. Colors in maps represent 40-year correlation of rainfall at that location with rainfall elsewhere on the continent, with red representing high correlation, and blue low. Figures on right plot average rainfall correlation as a function of distance from the location. (Source: authors calculations)
Map 4. Spatial correlation of temperature for three African locations. Same interpretation as in Map 3, with temperature as the weather variable. (Source: authors calculations, based on data from (Mitchell and Jones 2005)).