

CHAPTER 4

The Roles of Weather Insurance and the Carbon Market

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Abstract

This chapter discusses two financial markets — the carbon and weather markets — and their potential role in helping stakeholders address climate change more effectively. While this chapter focuses on how these markets can benefit the poor in developing countries, it also examines the major constraints that must be addressed before the poor can gain access to carbon and weather markets. It also suggests how governments and donors might effectively facilitate sustainable carbon and weather market activity in developing countries.

Poor households in developing countries are particularly vulnerable to weather shocks. To the extent that climate change may make such shocks more frequent, weather shocks and climate change are particularly troublesome given that proportionally more of the poor live in marginal areas and under marginal conditions. Furthermore, many of the world's poor rely on rain-fed agriculture with limited ability to adapt to climate change (Corbera et al., 2006; Nicholls et al., 2007; Stern, 2006). What is not understood are the specific impacts climate change will have at sub-regional or local levels; therefore, planning for these future events remains a challenge for households, firms, and policy makers (IPCC [International Panel for Climate Change], 2007a; Lobell et al., 2008; Morton, 2007).

Climate change projections depend on a variety of assumptions made by researchers regarding uncertain future weather patterns and feedback effects of reduced emissions (Hare and Meinhausen, 2006; Hulme et al., 2001; Stern, 2006; Yohe, 2006). This uncertainty challenges stakeholders trying to prioritize their efforts based on two overarching strategies for addressing climate change (IPCC, 2007a): *mitigation* to reduce anthropogenic contributions to climate change; and *adaptation* to adjust to the physical impacts of climate change. The authors argue that investments in adaptation are probably more critical for developing countries than investments in mitigation. This argument is based on the faster payoff of these investments relative to investments in mitigation.

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Carbon markets are a mitigation tool that uses price signals to reduce the overall rate of GHG (greenhouse gas) emissions. The right to emit GHGs is traded as a commodity on these markets. In theory, the use of price signals allows for the reduction of emissions at the lowest possible cost. Firms purchase carbon offsets when the cost of doing so is lower than the cost of changing production practices to meet emissions reduction regulations. Pricing pollution in this fashion also provides incentives for new technologies that will lower carbon emissions. The United Nations Convention on Climate Change (UNFCCC) has led mitigation efforts; the Kyoto Protocol establishes binding commitments for emissions reductions. Carbon markets have emerged from the mechanisms outlined in Kyoto and the specific regulations of the developed countries that have ratified Kyoto. Carbon markets primarily serve large firms in developing countries as these firms are the largest contributors to GHG emissions and must adhere to emissions reduction regulations (UNFCCC, 2007).

Carbon offsets are the instrument used in carbon markets that is most directly relevant to developing countries. The Kyoto Protocol does not require developing countries to reduce emissions; however, they can participate in mitigation efforts by reducing their GHG emissions. Credits for emissions reductions are sold on carbon markets to firms in developed countries that must meet emissions standards, or in the case of the United States, firms that seek to acquire carbon offsets at lower prices as a hedge against future restrictions. Thus, carbon emitting firms in developed countries finance global mitigation efforts. Large firms in China, India, and Brazil generate over 80 percent of the carbon offsets created through carbon offset projects in developing countries (Capoor and Ambrosi, 2008). The UNFCCC, the World Bank, and others are working to build capacity in the least developed countries so that they can also participate in carbon offset projects (UNFCCC, 2007).

Regarding adaptation, investments that reduce the vulnerability of the poor, especially infrastructure and new technology investments, are needed to manage the risk of specific climate change impacts. Many of these investments are badly needed irrespective of climate change. To be clear, weather shocks are common now and existing systems are vulnerable to those weather shocks. Climate change impacts will only serve to increase the vulnerability of the poor by increasing the frequency and/or severity of extreme weather events.

Weather markets, such as for weather insurance and weather derivatives, enhance risk management strategies. They can serve as an adaptation tool to aid decision makers at many levels by sending price signals regarding weather risk and by providing cash payments that can be used to adapt to changing climate impacts. Adaptation must occur in the form of a specific risk in a specific local context, which can require among other things changes in household production strategies (Fankhauser et al., 2008). Weather insurance reduces revenue volatility in weather sensitive industries. It may also serve as a tool to finance restoration of critical infrastructure that is designed to lessen the affects of extreme weather (e.g., levies, irrigation systems, etc.).

Weather index insurance is a relatively new form of weather insurance. It is gaining popularity in developing countries, creating new opportunities to protect the poor from the natural disasters that devastate their livelihoods and impede economic development (Barnett, Barrett, Skees, 2008). The most prevalent use of weather index insurance is for agriculture. Payouts are based on an important weather variable tied to agricultural production such as rainfall. Basing insurance payouts on an objective index reduces the loss adjustment and asymmetric information costs of traditional agricultural insurance. Weather index insurance protects against catastrophic risk (e.g., drought), and relies on international reinsurance markets to transfer the risk of extreme losses.

Challenges remain in providing weather index insurance at rates affordable to poor households: 1) the start-up costs of developing attractive weather index insurance for the working poor create a significant barrier to entry for local insurance companies; 2) insurance companies in developing countries are simply not ready to take on this special form of highly correlated risk, as they may have limited access to global reinsurers to transfer the risk out of the country; 3) insurance laws and regulations in developing countries are not in place to facilitate this special form of insurance; and 4) in many regions, the underlying weather risks overwhelm an insurance solution for risk management.

Index-based weather risk transfer products can be written either as insurance or derivatives. Over-the-counter weather index derivatives are becoming more common. Over-the-counter products are typically developed for a single user and have many of the characteristics of insurance (e.g., a well-defined event that triggers a payment in exchange for a fixed premium payment). Still, due to the difficulties associated with regulating over-the-counter weather derivatives, these instruments should not be sold directly to small households. Insurance regulators in developing countries are in a much stronger position to protect consumer interest when these products are structured as insurance rather than derivatives — much progress has been made in creating the proper regulatory environment for weather index insurance in developing countries (Carpenter and Skees, 2005).

Actively traded weather derivatives are also playing an important role in weather risk transfer, such as heating and cooling days for major US cities. In contrast to over-the-counter weather index insurance products, which are tailored to each client, actively traded weather derivatives are standardized weather derivatives contracts that are traded on financial exchange markets (e.g., the Chicago Mercantile Exchange). Actively traded weather derivatives are typically designed for large energy firms in developed countries. Lessons from these markets may improve the development of markets for the poor because experience with weather derivatives on financial exchange markets illustrates that actively trading weather risk improves price discovery and creates more efficient pricing.

Reinsurers that are actively involved in weather index insurance and weather derivatives markets are improving linkages between these markets to reduce the costs of weather index insurance. This may have important implications for developing countries, especially in regions where extreme weather events occur as a

consequence of specific, global weather anomalies such as El Niño Southern Oscillation (ENSO). Climate change presents additional challenges to weather markets, especially in designing sustainable weather index insurance products that are affordable for poor households. The authors make four primary conclusions regarding climate change and weather markets:

1. when weather risk is increasing, weather markets can help stakeholders manage their associated revenue volatility;
2. to be viable, someone will ultimately have to pay for the increasing risk through premiums for weather insurance,
3. some public policy responses to higher premium costs such as premium subsidies can undermine the primary advantage of weather markets — pricing the risk in a way that leads to more rapid adaptation strategies; and
4. as risks increase due to climate change impacts, weather markets will continue to adjust the price of the underlying weather risk. Thus, in the long term, insureds pay for the cost associated with climate, and weather markets manage revenue volatility, not climate change. Insurers are uncertain about how climate change will affect the weather risk they are insuring; this uncertainty and the associated ambiguity creates upward pressure on the price of weather insurance.

A climate market — a financial exchange of products that can hedge against future climate risk — could potentially facilitate adaptation in several ways. These include alleviating some of the challenges climate change presents to weather insurance markets, which in turn could increase access to weather index insurance for the poor. By using financial exchange markets, the interaction of buyers and sellers would integrate myriad sources of information including climate change projections to develop a price for the risk under consideration. Such a market could reduce the pricing difficulties of insurers and allow firms, governments, and donors to hedge against extreme climate change effects.

To illustrate, we provide the case of a potential ENSO index — a product to hedge ENSO risk. ENSO has a strong influence on global weather patterns (McPhaden, 2003). Climate change effects on ENSO cycles would have economic impacts in many regions. Creating a short-term ENSO index that makes payments when El Niño events occur could help hedge the risk associated with ENSO, including the risk that climate change affects the ENSO cycle. Active trading in short-term climate markets could lead to trading longer-term climate risks, though it is fully acknowledged that creating longer-term exchange markets has been an illusive goal for many commodities.

As carbon and weather market activity increases in developing countries, a key question remains: to what extent will the poor be included in these markets? Currently, governments and donors are working to connect the poor to carbon and weather markets. The authors conclude that to increase the participation of the

poor in these markets and to improve their ability to address climate change, decision makers can a) improve incentives for the poor to mitigate emissions, b) use mitigation and adaptation funds to seed environmental finance markets (especially credit and insurance) for the poor, c) increase the role of the private sector in developing countries as intermediaries between the poor and these markets, and d) create climate markets that facilitate adaptation.

1 Introduction

Financial markets provide important tools. These range from basic financial services such as credit, savings, and insurance, to more complex mechanisms such as derivatives, options, and securities, that can potentially help stakeholders address climate change more effectively. This chapter discusses the role of two financial markets — carbon and weather markets — and how these markets can benefit the poor in developing countries.¹ The authors also examine major constraints that must be addressed before the poor can gain access to carbon and weather markets, and how governments and donors might facilitate these markets in developing countries.² Recent applications in developing countries are used throughout as examples.

The overarching strategy to address climate change occurs on two fronts: *mitigation* and *adaptation*. Mitigation refers to efforts to reduce anthropogenic (man-made) contributions to climate change. Adaptation refers to efforts to adjust to the physical impacts of climate change. (IPCC [International Panel for Climate Change], 2007a; Stern, 2006; UNFCCC [United Nations Framework Convention on Climate Change], 2007a). For financial markets, the distinction between mitigation and adaptation is important.

Mitigation requires investments and behavioral changes that reduce greenhouse gas (GHG) emissions (den Elzen et al., 2008). For example, improving energy efficiency among firms is a key mitigation effort that requires firms to change production strategies and invest in new technology. As other chapters in this book explain, firms need capital for these efforts. Credit is one important financial mechanism that facilitates mitigation.

Likewise, adaptation requires investments and behavioral changes to adjust to risks created by climate change (Lobell et al., 2008); however, these risks can also increase revenue volatility as weather shocks disrupt production and destroy assets (Lecocq and Shalizi, 2007). Thus for adaptation, both credit to fi-

¹ Our focus is the working poor in developing countries. The majority of the working poor live in rural areas and operate small enterprises, in particular smallholder agriculture (World Bank, 2007).

² By framing the question in this fashion, this paper does not investigate the relative benefits of a carbon market versus other choices for abatement. It is taken as a given that carbon markets will exist in some form in the future.

nance investments and behavioral changes, and insurance to manage weather risks and provide lump sum payments that may be used for adaptation investments, are important financial tools. For example, farmers may want to adjust their planting decisions or invest in irrigation due to erratic rainfall. They may need to purchase insurance for years of extreme drought when water shortages damage crops for non-irrigated agriculture and reduce access to water for irrigated agriculture (Leiva and Skees, 2008).

In this chapter, carbon markets that finance mitigation and weather markets are discussed. These markets can facilitate adaptation by managing the financial consequences of weather risk. The authors provide an overview that is relevant to the focus on how these markets might be better structured to serve the poor in developing countries. This chapter is divided into five sections: 1) setting the stage for how carbon markets aid mitigation and how weather markets aid adaptation to climate change; 2) a discussion of how carbon markets can be used by the poor; 3) a review of weather markets and how they may be used to facilitate adaptation by the poor; 4) an introduction some basic ideas about creating climate markets; and 5) final comments about the intersection of carbon and weather markets.

The authors view, developed later in this chapter, is that adaptation strategies will be more critical to the poor in developing countries than mitigation strategies. Also, weather markets are only one tool that may facilitate adaptation — and probably not the most important one.³ Given that weather insurance markets are being widely touted as an adaptation mechanism for climate change, weather markets are examined more thoroughly than carbon markets.⁴ *Weather insurance is not climate insurance.* Weather insurance is typically designed for a short time frame, often rainfall over the next year. However, longer-term climate change will have important implications for weather markets. The view emerging from climate change experts is that extreme weather events will occur more frequently in the future than in the past. If insurance underwriters also take this view, the price of weather insurance will rise. Consequently, these challenges may open the way for climate markets that would trade longer-term weather patterns.

The final section of this chapter highlights the intersection of carbon and weather markets. Carbon markets provide an explicit linkage to adaptation through a rule that designates that a percentage of carbon market funds must be contributed to an adaptation fund that finances adaptation in developing countries (Müller, 2008; UNFCCC, 2007). Among other things, these funds could be applied to assist in developing weather markets. In addition to links between carbon markets and adaptation, which may be imposed institutionally, there may be important overlaps in the delivery systems for carbon and weather markets for the poor.

³ See Müller (2008) for a comprehensive review of how to fund these strategies.

⁴ Weather markets can be structured as futures and/or options contracts traded on exchanges or as index-based insurance contracts.

2 Setting the Stage: Climate Change, Mitigation, Adaptation, and the Poor

Developing countries are more vulnerable to extreme weather events than developed countries (Carter et al., 2007; Morton, 2007; Fankhauser et al., 2008; Stern, 2006). The poor in developing countries are even more at risk, given where they live and that so many of them depend on rain-fed agriculture (Corbera et al., 2006; Nicholls et al., 2007; Stern, 2006). The poor tend to live where more affluent households choose not to settle — flood zones, vulnerable coastal areas, and regions where frequent droughts occur — which are the areas most affected by extreme weather events (Carter et al., 2007; Kundzewicz et al., 2007; Stern, 2006).

Increased frequency of extreme weather events may be the most significant concern associated with climate change (Corbera et al., 2006; Morton, 2007). Few models of the economic cost of climate change are adequate to examine the impact of extreme weather events (IPCC, 2007a). Most of this research is grounded in a framework that uses the expected values of important weather variables as the metric for examining the benefits and cost of mitigation and adaptation (Fankhauser et al., 2008; Yohe, 2006). Despite this focus on average future conditions, concerns about the potentially negative impacts of climate change are growing (Bindoff et al., 2007; Carter et al., 2007; IPCC, 2007a; Lobell et al., 2008). If increased frequency of extreme events could be modeled more effectively, the cost/benefit evaluation of mitigation and adaptation would probably change significantly.

Addressing climate change requires both mitigation and adaptation (IPCC, 2007a, Lecoq and Shalizi, 2007; UNFCCC, 2007). Mitigation involves multiple policy responses targeted at the abatement of GHGs, primarily carbon dioxide.⁵ Adaptation involves a wide range of proactive and reactive strategies, both public and private, designed to buffer the adverse affects of climate change (Lacoq and Shalizi, 2007).⁶

2.1 Climate Change and Uncertainty

Uncertainty remains a significant challenge in preparing for climate change. Global circulation models inform climate change projections; however, these models are largely deterministic (primarily using trends in temperature from different climate

⁵ To avoid confusion, “mitigation” is used by those working on climate change to mean efforts focused on reducing emissions of greenhouse gases. For those working on insurance, mitigation means efforts to reduce the exposure to a hazard; which is referred to as “adaptation” by those working on climate change. We use the terminology adopted by the climate change community.

⁶ Many definitions of adaptation (e.g., IPCC, 2007b) are more generic and account for behavioral changes associated with positive or negative climate change outcomes. For example, farmers in some northern temperate climates may experience a longer growing season and adjust farm practices accordingly. We focus exclusively on adaptation for negative climate change outcomes.

models) while many of their assumptions remain uncertain (Hulme et al., 2001; Yohe, 2006). For example, the costs and effectiveness of various mitigation policies are dependent on assumptions of economic growth, implementation of technological advancements, and consumption patterns (Hare and Meinhausen, 2006; Stern, 2006). Additionally, the feedback effects of reduced emissions on the global climate are uncertain; this uncertainty greatly challenges long-term predictions of the effects of climate change and estimates of the level of mitigation required (IPCC, 2007a; Stern, 2006).

Preparation and prioritization of adaptation efforts should occur at sub-regional and local levels. However, climate change effects at a sub-regional level — and even a regional level for some variables such as rainfall — are nearly impossible to model (IPCC, 2007a; Lobell et al., 2008; Morton, 2007). For example, in 2007 the International Panel for Climate Change (IPCC) reported that by 2020, between 75 and 250 million people would experience increased water stress due to climate change in Africa. These kinds of general forecasts lack the specificity needed to plan adequate adaptation and safety net strategies (Lecocq and Shalizi, 2007). Additionally, projecting extreme events that have the largest impact on vulnerable populations, such as drought, extreme temperatures and rainfall, cyclones, etc., is more difficult than projecting average climate conditions (IPCC, 2007a). Nonetheless, the consensus view that extreme events will occur more frequently in some regions does require a public policy response to help the poor cope with extreme events (Corbera et al., 2006; IPCC, 2007a; Morton, 2007).

Leading organizations (e.g., IPCC, UNFCCC, etc.) agree that mitigation and adaptation must play a significant role in adapting to climate change; however, given the many uncertainties, it is difficult to determine how to prioritize climate change policies (Lecocq and Shalizi, 2007). Decisions regarding mitigation policies and adaptation investments impose real costs to households, firms, and governments (Perkins, 2008). Governments and multilateral organizations increasingly recognize the importance of a risk management approach to climate change policy that diversifies investments relative to the likelihood and severity of outcomes (IPCC, 2007a; Yohe, 2006).

2.2 Carbon and Weather Markets and Developing Countries

Carbon and weather markets fit squarely into a portfolio of responses to climate change. Carbon markets are a *mitigation* tool that use price signals to reduce the overall rate of GHG emissions. In theory, price signals allow for the reduction of emissions at the lowest possible cost. Carbon markets use tradable pollution permits to find least cost mechanisms to reduce emissions of GHGs. On the adaptation side, weather insurance markets are expanding in developing countries, and Article 4.8 of the UNFCCC explicitly mentions insurance to encourage adaptation to climate change. Weather markets are an *adaptation* tool that can aid decision makers. For weather risk, this is accomplished through price signals and by providing cash payments that may be used by those affected to adapt to a changing climate. Recent climate change discussions have addressed the potential for developed

countries to assist developing countries in the creation of weather markets as a compensatory measure, given developed countries' inordinate contributions to carbon emissions. [Table 1](#) compares and contrasts some important issues of mitigation and adaptation that are relevant for carbon and weather markets.

Table 1. Comparing and Contrasting Mitigation and Adaptation

	Mitigation	Adaptation
Definition	Reducing anthropogenic contributions to climate change	Reducing vulnerability to the physical impacts of climate change
Stakeholder focus	Big emitters (e.g., energy-inefficient firms, firms that reduce vegetation such as logging companies, etc.)	The most vulnerable (e.g., stakeholders living in marginal areas, those with agricultural livelihoods, low-skilled laborers, etc.)
Geographic focus	Global	Sub-regional/local
Timeframe	Long-term	Short and/or long-term
Can require that stakeholders	Change production strategies Adopt new technology	Change production strategies Adopt new technology Manage revenue volatility Improve infrastructure Relocate
Financial market role	Capital to finance investments Increase efficiency in emissions reductions	Capital to finance investments Smooth revenue volatility
Financial market mechanisms	Credit Carbon market	Credit Weather market (e.g., Weather insurance)

Source: Authors

Carbon and weather markets are different in many ways, but in developing countries these markets face similar challenges. Both markets are constrained by inadequately defined property rights or inappropriate regulatory policies. Delivering any market services to smallholders in remote locations is extremely costly. When transaction size is quite small, fixed transaction costs render it unprofitable to provide services to remote regions. In these situations, it may be more cost efficient to use an intermediary (e.g., a rural bank, donor organization, farmer cooperative, etc.) to aggregate carbon credits and weather insurance contracts. In some cases, a single entity may serve both markets. So far, donors and governments have been heavily involved in creating links between the poor and carbon and weather markets. In general, the private sector has limited incentives to foster these markets without government or donor help (Chapple, 2008).

Still, carbon and weather markets differ in a number of ways, including their origins, constructs, and reliance on government intervention. For example, carbon markets emerge when governments decide to impose restrictions on GHG emissions, or if it is expected that these restrictions will be imposed. However, weather markets have emerged to manage risks associated with extreme weather events. Carbon and weather markets also differ because the primary benefits for developing countries are likely to be on the selling side of carbon markets and on the buying side of weather markets.

3 Mitigation Using Carbon Markets

Mitigation is a long-term strategy aimed at curtailing future climate change effects. GHG levels are measured on a global scale in terms of atmospheric concentrations (parts per million) of their CO₂ equivalent (den Elzen et al., 2008; IPCC, 2007a). IPCC (2007a) reports with “high agreement and much evidence” that given current climate change policies on mitigation, GHG emissions will continue to grow. The global community is establishing standards for measurement and verification that have opened the way for carbon markets.

Since 1994, the UNFCCC has played a crucial role in efforts to mitigate GHGs. The Kyoto Protocol, enacted in 2005, created binding commitments for emissions reductions among participating developed countries. The thirty-seven countries that ratified the Kyoto Protocol commit to reducing greenhouse gases by roughly 5 percent on average of 1990 levels over the 2008–2012 period (Capoor and Ambrosi, 2008; UNFCCC, 2007).⁷

The rules and structure of the Kyoto Protocol provide the foundation for domestic, regional, and global carbon markets. A government places emissions caps on its producers so that it can meet its Kyoto emissions target, while markets have developed to facilitate emissions reductions in the private and public sectors.⁸ Carbon markets reduce the cost of emissions reductions in four ways: 1) enabling firms that cannot cheaply lower emissions to abate emissions in other ways; 2) enabling cleaner and more efficient companies to profit from their contributions toward reduced emissions; 3) connecting buyers and sellers to reduce transaction costs; and 4) providing incentives for innovation in improved technologies that will lower emissions (UNFCCC, 2007).

⁷ Some economies in transition, such as those of the former Soviet Union, do not use 1990 as a target year.

⁸ The European Union-15 acts somewhat as a unit and has more flexibility than the country description provided here.

Kyoto establishes standards and mechanisms by which countries can mitigate their emissions.⁹ For example, one influence on a country's emissions target is its level of vegetation that can act as a carbon sink — categorized as land use, land-use change, and forestry (UNFCCC, 2007). The basic idea is that developed countries can meet the targeted level of emissions in a number of ways (den Elzen et al., 2008). By creating a market to trade emission rights, emitters can adopt new technology that will lower their emissions, or they can purchase carbon offsets as a way to pay for the excess GHGs they emit.

Successful efforts to create this form of pollution trading with sulfur dioxide in the United States led the way for the development of carbon offset markets. Although the Kyoto Protocol promotes carbon markets, developments in the United States have demonstrated that a voluntary market can emerge, for example the Chicago Climate Exchange (CCX), even when the host country (the US) has not ratified the Protocol.

CCX members commit to a voluntary but binding emissions reduction of 6 percent of 1998–2001 levels by 2010. Because the voluntary carbon market is not governed by UNFCCC, some of its standards and guidelines differ, e.g., for carbon offset projects. Comparing the CCX to the European Union Emissions Trading Scheme (EU ETS) illustrates how the price to emit is clearly driven by the standards, rules, and units of trade on these exchanges. In 2007, for example, the EU ETS price ranged from USD 13 to USD 35 per carbon dioxide ton equivalent (tCO₂e), while the CCX price was roughly USD 3 per tCO₂e.

Carbon markets have grown significantly from USD 11 billion in 2005 to USD 65 billion in 2007. Of the USD 65 billion in carbon market volume in 2007, the vast majority of trades occurred in the EU ETS (USD 50 billion). The CCX accounted for only USD 72 million and the Australian New South Wales Exchange accounted for USD 224 million (Capoor and Ambrosi, 2008). A large institutional infrastructure has emerged to support carbon markets, brokers, firms that monitor and evaluate projects, advisors and consultants guiding carbon reduction projects, official exchange-markets, etc. Increasing financial sophistication is enabling firms to manage risks in the carbon market and more effectively plan for their carbon costs.

Kyoto Protocol commitments expire in 2012, creating uncertainty regarding the standards and mechanisms in place after 2012. This uncertainty is affecting carbon markets, especially projects and financial instruments that plan for carbon mitigation in the longer term (Capoor and Ambrosi, 2008). Without more certainty, the price of carbon will decline significantly. The largest source of volatility in carbon market prices is the uncertainty surrounding the rules that are imposed on allowable emissions (caps) and allowable offsets that create the opportunity to trade.

⁹ Greenhouse gas emissions and credits are measured in units of one ton of carbon dioxide equivalent: e.g., methane reductions are measured in terms of their carbon equivalent. The term “carbon markets” comes from this measurement. Carbon markets also include other greenhouse gases recognized by the Kyoto Protocol.

3.1 Clean Development Mechanisms (CDMs): The Potential for Developing Countries

Entities in developed countries can sell carbon emissions allowances to each other, or they may purchase carbon offsets created through GHG abatement projects in developing and transitioning countries. Most relevant for our discussion are carbon offsets from GHG abatement projects — Clean Development Mechanisms (CDMs) under the Kyoto Protocol. CDMs specifically target projects in developing countries where carbon caps and targets do not exist (UNFCCC, 2007). CDMs were developed, in part, because developing countries reported that they were being largely excluded from Kyoto’s efforts (Bozmoski, Lemos, and Boyd, 2008).

CDMs must lead to real and measurable climate benefits. An underlying metric for CDMs is the principle of *additionality* — investments must fund emissions reductions or carbon sinks that would not have occurred otherwise. New types of mitigation projects (new “methodologies”) are carefully managed by the CDM Executive Board — these projects must be funneled through the board of 10 members for final approval. CDMs require approval by all countries involved, and baseline estimates must follow approved methodologies, rigorous monitoring and evaluation, and quality control checks by authorities (UNFCCC, 2007). Critics of CDMs say the rules are too complex and change too often, resulting in increased regulatory risk. They also argue that the transaction costs of CDMs are too high (Capoor and Ambrosi, 2008).¹⁰

CDM transactions in 2007 were sold and traded for a value of roughly USD 13 billion; of that total, USD 7.4 billion were primary issuances of CDMs. China captured 73 percent of CDM transactions. India and Brazil were second and third in terms of CDM transactions, with 6 percent of the CDM market each. Africa as a whole accounts for 5 percent of CDM transactions. Energy efficiency projects such as those reducing emissions of a power plant dominated CDM transactions (40 percent of volume, Capoor and Ambrosi, 2008).

Mitigation efforts focus on the biggest GHG emitters and rapidly industrializing countries, such as China, that capture most of the benefits of CDMs. CDMs are intended to have the dual role of reducing emissions and creating sustainable development. CDM projects are much more concerned about regulating their emissions reductions than about their contributions to sustainable development. As a result, academics, NGOs, practitioners, and policymakers have accused CDM projects of emphasizing mitigation to the detriment of sustainable development (Bozmoski, Lemos, and Boyd, 2008; Chapple, 2008). The data support this contention to some extent, given that by 2012, 75 percent of CDM projects are expected to operate in China, India, or Brazil, while only 1 percent are expected to occur in sub-Saharan Africa (Bozmoski, Lemos, and Boyd, 2008).

¹⁰ Capoor and Ambrosi (2008) report that firms that finance their own mitigation investments are more likely to pursue CDM projects. In contrast, firms that are unable to make mitigation investments without CDM financing are less able to bear the long delays and high transaction costs associated with the CDM review process.

After its initial implementation of CDMs, the UNFCCC (2007) quickly noted that developing countries could not participate equally in capturing CDM projects. Since then, UNFCCC has worked with the United Nations Development Programme, the United Nations Environment Programme, the World Bank Group, and the African Development Bank to engage in capacity building so that more developing countries participate in CDM projects. The World Bank Carbon Finance Unit (CFU) and the Global Environment Fund (GEF) hope to include more developing countries in carbon funds that are relevant to their situations (UNFCCC, 2007).

The World Bank Carbon Finance Unit (CFU)

The CFU leverages capital from carbon funds to engage in mitigation projects consistent with the larger sustainable development agenda of the World Bank. Carbon funds are publicly or privately supported and are intended to facilitate mitigation projects. The CFU includes a variety of carbon funds, such as the BioCarbon Fund, the Community Development Carbon Fund, and the Italian Carbon Fund. Fund participants purchase reductions of GHG emissions from these projects. The CFU acts as an honest broker between carbon offset buyers in developed countries and sellers in developing countries. The CFU also engages in capacity building in developing countries. It has created the first emissions reductions projects in several developing countries (CFU, 2006) that are not big GHG emitters.

Because the CFU works within the Kyoto framework, emissions mitigation must be a component of every project. Where possible the CFU also links into larger-scale World Bank projects designed to have sustainable outcomes. Some of the projects under the CFU engage in complementary mitigation, adaptation, and development efforts. For example, a CFU project supports the reforestation of 10,000 hectares of degraded land with gum-producing acacia trees in Mali (CFU, 2006). Part of this land will be managed by farmers who will receive training in sustaining the plantation while harvesting gum. Additionally, technical assistance will be provided on how to intercrop cowpeas, groundnuts, and other crops among the new trees. This project should 1) create a carbon sink through reforestation which is expected to sequester 1.5 million tCO₂e by 2035; 2) improve soils by increasing nitrogen levels and reducing water and wind erosion; and 3) create sustainable livelihoods for Malian farmers.

The Global Environment Fund (GEF)

The GEF was established in 1991. It funds projects in developing countries that have environmental benefits in coordination with the UNFCCC. This fund has leveraged USD 8.2 billion toward environmentally beneficial projects in developing countries. The UNFCCC Marrakesh Accords in 2001 created an emphasis on adaptation, especially for work that complements mitigation, and expanded opportunities for funding adaptation under the GEF. For example, the GEF now manages adaptation projects through a special Least Developed Countries Fund. This

fund has support exceeding USD 100 million. Also, the Adaptation Fund for developing countries was created, supported by CDM projects. Two percent of payments for offsets from CDM projects are paid into the Fund. (UNFCCC, 2007).

As part of the GEF Small Grants Programme, farmer groups in Tanzania living near Lake Victoria received grants to develop wind-powered irrigation systems. Citing increased agricultural pollution in Lake Victoria, local stakeholders created drawing points for local communities to irrigate farms and water livestock. These points were selected to reduce pollution. Grants from the GEF created access to wind-powered irrigation systems, tools and skilled labor, and funded capacity building to train community members to operate and install them. Farmer groups provided in-kind labor to install the irrigation systems. As a result, communities received water at lower cost and with lower GHG emissions than those using electric- or gasoline-powered irrigation systems. Agricultural pollution in Lake Victoria has decreased and some farmers report more than doubled crop production as a result of access to local water (GEF, 2008).

Carbon Offsets on the CCX

Understanding carbon prices and regulatory differences between the EU ETS and voluntary markets such as the CCX is important for stakeholders planning carbon offset projects in developing countries. The CCX relies on independent sources for verification and monitoring of practices used to offset carbon emissions, which tend to require less rigorous regulation than UNFCCC standards. As a result, some projects are financed through the CCX until they can obtain UNFCCC approval. This can take as long as nine months after a project is certified by the UNFCCC, and perhaps longer for new methodologies. It can then move to the EU ETS, where it will receive a higher price for carbon offsets. Thus, the CCX provides a “bridge” to facilitate development for some carbon offset projects. In other cases, the standards for voluntary markets accommodate projects on the CCX that are ineligible for CDM status because they are difficult to monitor, but they may create important emissions reductions such as projects preventing deforestation, (Chapple, 2008).

A project selling carbon offsets on the CCX that contributes to sustainable development illustrates the potential of carbon offset projects outside the Kyoto framework. Andhyodaya, an NGO in southern India, connects smallholder farmers to the CCX. This project encourages farmers to use biogas digesters — small energy generators powered by animal manure and/or agricultural residues such as organic kitchen waste. These biogas digesters are primarily used to heat water and for cooking with gas. These produce less carbon emissions than generators powered by fossil fuels or that use wood for fuel that is not replanted. Biogas digesters are also 55 percent more efficient than wood burning stoves (CCX, 2007).

Because of the mitigation benefits, this project is funded through carbon credits sold on the CCX, and farmers are paid when these credits are bought. Over 15,000

farmers participated in the initial project phase, receiving roughly USD 1.2 million in gross revenues from 2003 to 2006, or roughly USD 27 per year per farmer. During the second phase, in progress in 2008, roughly 113,000 farmers were expected to displace 500,000 tCO₂e, in aggregate receiving USD 2 million per year or roughly USD 18 per year per farmer. Participants in the program are given carbon vouchers that can be cashed at any branch of the Federal Bank of Kerala, which partnered with the project.

Beyond the mitigation benefits associated with this project, the cleaner, more efficient biogas digesters reduce respiratory and eye problems associated with using traditional firewood; they also have the potential to increase household productivity as household members no longer have to travel to collect firewood. Additionally, manufacturing biogas digesters requires relatively low up-front investments, such that manufacturing plants could potentially be installed in remote rural areas (CCX, 2007).

The noteworthy feature of this type of project is that it may start spontaneously without donor support. Manufacturers of these forms of technology could potentially team with carbon aggregators to facilitate the joint sale of biogas digesters and carbon credits.

Creating Efficient and Scalable Mitigation Projects

As the projects described above illustrate, some mitigation technologies have immediate positive externalities for households, such as better air quality in the home. Stakeholders, especially donor organizations, are puzzling through the challenges of creating efficient and scalable projects using these technologies. Two considerations are noteworthy in this regard: the use of microfinance to increase household access to mitigation technologies and the size of carbon offset revenues for mitigating the emissions of poor households. (Box 1 profiles a successful example of a project that links mitigation technology for rural households, microfinance, and carbon markets.)

Box 1: Grameen Shakti: Microfinance and Energy Efficiency

Grameen Shakti (a subsidiary of Grameen Bank) provides energy-efficient technology to rural households in Bangladesh through microfinance (Chhabara, 2008; Grameen Shakti, 2007). Grameen Shakti sells solar and biogas energy systems and energy-efficient cooking stoves (Grameen Shakti, 2007). The solar-powered energy system has been the most popular item sold; consumers can choose among units that power from 10 to 75 watts. Households typically purchase the 50-watt system, which sells for USD 400 and can power a TV, radio, cell phone charger, or light a room. Households pay from 10 to 25 percent at the time of purchase and finance the remaining balance through a loan from Grameen Bank.

In 2007, the CFU of the World Bank agreed to purchase carbon offsets generated from solar home systems for EUR 9 per tCO₂e (Chhabara, 2008). The CFU (2008) predicts that 200,000 households will gain access to solar home systems by 2015 through this agreement, and that the project will generate over 16,300 tCO₂e per year. Each 50-watt solar home system will earn roughly EUR 4.50 per year at this carbon price. Grameen Shakti is using these revenues to reduce unit costs and improve loan terms for households (Chhabara, 2008).

Despite the positive externalities of some mitigation technologies, these products can be major expenditures for poor households. A biogas digester costs between USD 250 and 400 for households in Nepal, which is 25 to 40 percent of annual GDP per capita (CDM Executive Board, 2005; CIA, 2007). As a result, donors are experimenting with mitigation technologies that combine donor subsidies, household cash at point-of-sale, and microfinance (IIED, 2008). To the extent that microfinance is used instead of donor subsidies, the scalability and sustainability of these technologies may increase. In many cases a blend of cash, credit, and donor subsidies may enable households to purchase these products.

If households can earn revenue from carbon markets for their emissions reductions, they would have increased incentives to mitigate, including by purchasing energy-efficiency technology. However, as examples in this chapter illustrate, mitigating the carbon emissions of poor households through energy efficiency technology results in very low revenues per household from carbon markets. Poor households tend to consume very little energy in the home before gaining access to energy-efficiency technology. Instead of attempting to deliver payments such as the EUR 4.50 generated from solar home systems in Bangladesh (see Box 1), organizations like Grameen Shakti are using carbon offset revenues to increase access to microfinance for mitigation technologies at better rates (Chhabara, 2008).

Revenues for the poor may be feasible for land use projects,¹¹ which are relevant to the GHG emissions of poor households. Smallholder agriculture can result in deforestation to create more farmland, overuse of natural resources and important local ecosystems, GHG-emitting tilling practices, etc. Afforestation or reforestation projects on smallholder land are likely to go beyond the typical loan amounts of microcredit; therefore, these projects would probably have to attract the support of donors and/or the private sector.¹²

¹¹ Many factors complicate mitigation projects involving land use in developing countries. These include established property rights, which are beyond the scope of this chapter.

¹² As an example, see the CFU project, "India: Improving Rural Livelihoods," in which a paper company partners with local farmers to plant trees on marginal lands: <http://wbcarbonfinance.org/Router.cfm?Page=Projport& ProjID=9636>.

3.2 Summary Comments on Carbon Markets and Developing Countries

This cursory review of the current state of carbon markets offers a few key lessons: 1) these markets are still in their early stages of development; 2) rules and regulations will play a major role in how these market evolve and the level and stability of carbon prices; and 3) although there are positive examples and progress toward using carbon markets to benefit the poor in developing countries, results to date are quite limited.¹³ But these markets should not be dismissed as being unimportant. They can complement any number of development projects and increase the income of poor households.

Additionally, financing from carbon offset projects has the potential to enhance financial sector development. As illustrated, some mitigation projects could be sustainable and provide income for households and firms; however, converting to these emissions-reducing technologies may be too costly for poor households (Chapple, 2008). Currently, donors often subsidize these costs, though increasing access to credit for carbon mitigation investments may be a more scalable solution than funding individual projects. The potential for environmental finance to become sustainable for poor households will depend on whether firms can profitably offer credit for mitigation projects. In turn, households would be likely to borrow for a mitigation project only if it increased household income or quality of life. Thus, the feasibility of sustainable environmental finance for poor households largely depends on the price of carbon offsets and the ability of firms in developing countries to enter carbon markets on behalf of households.

If funds from carbon markets increase access to credit for carbon mitigation projects, these investments can also enhance financial sector development more broadly, increasing access to credit, savings, and insurance for rural households and firms. Rural banks and microfinance organizations active among the working poor are logical intermediaries, and their local involvement could be leveraged for environmental finance. Enhanced financial services for rural households may also facilitate mechanisms for adaptation, which are explored in the following section.

Staying abreast of these developments and working to place these markets into a larger arena can be valuable for public and private decision makers considering projects that contribute to market development, a cleaner local environment, and/or the reduction of poverty.

4 Adaptation Using Weather Markets

Adaptation includes proactive efforts to prepare for expected long-term climate effects, such as improving coastal city infrastructure to prepare for rising sea levels (Müller, 2008). It also includes reactive adjustments to changing conditions such as in farming systems due to declining rainfall (Fankhauser et al., 2008; Lecocq

¹³ See Chapple (2008) for further discussion about including the poor in carbon markets.

and Shalizi, 2007). Adapting to change is a hallmark of the human experience and a normal behavioral response to emerging conditions (IPCC, 2007b; Morton, 2007; Stern, 2006). Knowledge about changing conditions in weather and climate risk should improve public and private decision making and facilitate adaptation (Corbera et al., 2006; Morton, 2007).

The effects of climate change will vary greatly by region (Lobell et al., 2008; Stern, 2006). Unlike mitigation efforts, which contribute to global reductions in GHGs regardless of where they occur, adaptation efforts are sub-regional and local (Morton, 2007; Stern, 2006). Rising sea levels, higher temperatures, and more extreme weather events are among the commonly cited conditions that portend negative consequences for many sectors (IPCC, 2007a; Lobell et al., 2008; Stern, 2006). Because adaptation depends on geographical and climate risks in a particular region, the cost and effectiveness of adaptation are less understood than those for mitigation (IPCC, 2007a; Morton, 2007).

The adaptive ability of households, communities, countries, etc., is related to three major factors: 1) the extent to which climate change affects risk; 2) the presence of viable alternatives to current practices in the local context (e.g., can a farmer adopt new production practices given local conditions?); and 3) the ability to change behavior — determined in large part by the level of economic development, information and technology available to those most affected by climate change.

Adaptation is critical in developing countries, yet an obvious challenge is that the poor are the least equipped to adapt. Around 75 percent of the rural poor are engaged in some form of farming, making their livelihoods vulnerable to climate change (Anderson, 2002). The poor tend to live and farm on marginal lands and have less access to infrastructure that can protect against increasing weather risks. This makes them even more vulnerable to the negative consequences of climate change, reducing their options for viable livelihood alternatives (Nicholls et al., 2007; Stern, 2006). In addition, the poor are less able to make important behavioral changes such as technology adoption due to high opportunity costs (IPCC, 2007a; Skees and Collier, 2008). At the macro level, the least developed countries and regions are often less able to adapt to climate change than developed countries. At the micro level, poor households in developed and transitioning economies are often less able to adapt.

Many basic adaptation investments must be funded by governments, which may be aided by donors and multinational organizations. These public investments include infrastructure development (levees, water systems, health facilities, etc.), and safety net programs for catastrophic weather events. These investments should increase the availability of viable alternatives for vulnerable households and firms through agricultural research and development (R&D) investments, education and technical training or retraining (Fankhauser et al., 2008).

4.1 Adaptation and Insurance

Insurance facilitates adaptation efforts (Article 4.8 of the UNFCCC). Using insurance to reduce risk facilitate adaptation is consistent with the efforts of insurers who require improved building standards or other risk reducing activities as a precondition for certain types of coverage. For example, in areas prone to earthquakes, insurers may require that properties meet building codes and pass inspections before they are approved for cover. Likewise, insurance companies may give discounts to homeowners who purchase fire extinguishers or who live near a fire station. These links between insurance and risk reduction are far easier to enforce in developed countries than in developing countries.¹⁴

Weather insurance can help households in developing countries engage in adaptation efforts. First, the price of insurance can provide policy makers, households, and donors an estimate of the cost of risk, which can in turn prompt adaptation investments. Insurance prices are based on the expected losses of the insured. If the effects of climate change increase risk, the price of insurance will rise. Obtaining an explicit price for weather risks can provide stakeholders with new information about risks.

The insurance response to weather risks across time and space has significant potential value in prompting adaptation strategies. Underlying this model is the recognition that the cost of weather risk must be paid somewhere in the system — either directly by those most, such as households or firms, or by governments, donors or NGOs that intervene after a major weather event. The price may be very high in terms of human suffering, destruction of productive assets and the increased incidence of chronic poverty, government bailouts, disruptions in economic growth, etc.

For example, consider a situation where maps of flood risk along a river demonstrate that a particular area will be subjected to catastrophic flooding that could completely destroy property in that area in one out of every three years. Considering only the expected losses, an insurance product would cost at least 33 percent of the value of the property insured each year.¹⁵ If decision makers understand that this risk is effectively uninsurable, the commitment to invest in alternative adaptation efforts may become more palatable. Making the cost explicit drives the point home: many of the most damaging aspects of climate change are simply not insur-

¹⁴ The high cost of monitoring risk-reducing behavioral changes or investments diminishes the ability of insurers to provide these incentives in most developing countries. Infrastructure investments — both at the micro level (e.g., in irrigation systems) or at the macro level (e.g., in levies for coastal communities) — are one exception that is relatively easy for insurers to corroborate.

¹⁵ In addition, insurers must include many other costs (e.g., costs of delivery and administrative costs) that will raise the price of insurance even higher.

able. These problems require other solutions such as building dams or relocating households and firms.

Second, if the event is insurable, cash payments from insurance payouts can help households to adopt new livelihood strategies. The ability of the poor to adapt is often limited. As a result, poor households may be better able to make marginal adjustments in response to climate change if they have indemnity payments. The fact that households receive these payments after experiencing an extreme loss may be a potent incentive, encouraging them to adapt to the exposure they face.

For example, our experiences include extensive work in livestock insurance in Mongolia. During the difficult years following the exit of the Soviets in Mongolia, many people resorted to herding animals as a source of livelihood. When extreme winter storms resulted in large livestock losses at the turn of the century, many herders were forced out of herding and had to find new livelihoods. In this scenario, insurance payments could be used to protect herders who continue to herd and to facilitate transitions to new livelihoods.

Third, insurance can be bundled with alternative production technologies, if there are any. For example, insurance has been bundled with loans for technologically advanced seed in Malawi (Hess and Syroka, 2005). The insurance product covers the value of the loan. If drought occurs and farmers experience low yields, the loan can still be repaid (Alderman and Haque, 2007). As a result, farmers gain access to higher yield seed. This model could be enhanced and used in adaptation: 1) to the extent that R&D advancements can provide seeds resilient to emerging climate change effects (e.g., reduced rainfall), these seeds could be sold to farmers through insurance-backed loans; 2) beyond repaying the bank, the insurance could be expanded to provide insurance payouts to cover household losses.

4.2 Weather Markets

Weather markets are important for considering how insurance can enhance adaptation in developing countries. First, we focus on weather index insurance, a weather market mechanism that is gaining popularity in developing countries. This insurance is flexible, offering a number of ways to protect household income and assets from catastrophic weather risk. Weather index insurance has primarily been used as a form of agricultural insurance, but it is relevant for almost any business that is affected by extreme weather risk. The fact that weather index insurance has primarily been used for agriculture makes it particularly promising for the poor in developing countries, because agriculture is the predominant livelihood of their households. Weather index insurance may be particularly relevant for climate change; many climate change effects result in differing weather conditions, including those that have profound consequences for farming.

Next, we suggest that innovations in actively traded weather markets may address challenges facing weather index insurance. In particular, actively traded

weather derivatives have blended risk transfer markets and capital markets to obtain more efficient product pricing. Significant limitations currently prevent a blending of risk and capital markets for weather index insurance. However, investments that facilitate weather index insurance markets may also facilitate a convergence with capital markets. Learning from such innovations should improve the ability of weather index insurance programs to more efficiently manage challenges in pricing these products, given the uncertainty associated with climate change. This explanation of weather markets in developing and developed markets will be important for the discussion in the final section of the chapter regarding the potential for climate insurance.

Weather Index Insurance

Weather index insurance is a new tool that shows promise in developing countries. Traditional forms of agricultural insurance have been tried in developing countries for many years with little success (Hazell, 1992). Beyond the typical adverse selection and moral hazard problems¹⁶ associated with traditional insurance, transaction costs (e.g., underwriting and loss adjusting) have proved to be too high for smallholder agriculture in developing countries. Feasibility studies of this problem began in the late 1990s. Weather index insurance uses a measure of a weather event as a proxy for losses. For example, weather index insurance that protects farmers from drought was introduced in India in 2003 (see Box 2). Payouts were based on the level of rainfall at the closest weather station (Manuamorn, 2007).

Weather index insurance should have lower transaction costs than traditional agricultural insurance because it avoids farm-level information problems: moral hazard, adverse selection, and individualized loss adjustment make traditional insurance so difficult to implement affordably. As a tradeoff to reduce costs, weather index insurance increases basis risk — the possibility that the insured's losses will not match the level of payout determined by the weather index. Weather index insurance has higher basis risk than traditional insurance because no individualized loss adjustment occurs. Rather, it relies on the weather index to determine payouts; increasing the likelihood of a mismatch between insurance payouts and losses of the insured. As a result, weather index insurance is appropriate only for insuring correlated weather risks — weather events that tend to affect a large geographic area in roughly the same way.

¹⁶ Adverse selection — the fact that the insured know more about their risk than the insurer — and moral hazard — the tendency of the insured to engage in riskier behavior after purchasing insurance — are problems for Multiple Peril Crop Insurance programs. For a review and analysis see the World Bank Report on Agricultural Insurance in China, 2007.

Box 2: Drought Insurance in India

In 2003, BASIX (a microfinance institution), in a partnership with ICICI Lombard (an insurer) and supported by technical assistance from the World Bank, introduced rainfall-index insurance to address high default rates and to increase lending opportunities in rural areas. BASIX conducted a pilot study that sold weather insurance to 230 farmers in Andhra Pradesh that was designed to protect against drought during the groundnut and castor bean growing season.¹⁷

BASIX improved its rainfall insurance program operations and extended its regional scope. It also improved accessibility by reducing costs of delivery by simplifying the underwriting process and training loan agents to sell index insurance.

Almost every season, BASIX has improved the insurance product according to farmer feedback. For example, BASIX added coverage against excess rain during the harvest season, and made their rainfall insurance policies more flexible by insuring any crop — farmers can purchase a certain level of liability and plant whatever they wish.

Due to the success of BASIX' 2003 pilot program, other insurers began selling rainfall insurance in 2004. AICI, the state-sponsored insurance company of India, has become the largest seller of weather index insurance, selling 675,000 policies in 2007/2008. One explanation for the growth of AICI is that farmers who receive loans from the state bank are required purchase agricultural insurance.

Despite the rapid expansion of weather index insurance, market penetration remains very shallow (India has 300 million farmers). Adequate meteorological infrastructure has limited further expansion. Public and private investments are being made to overcome this constraint.

Many weather index insurance programs rely on government and/or donor involvement to fund start-up costs, including technical assistance and education for the target market and facilitating new partnerships among private- and public-sector stakeholders. These include facilitating relationships between insurers, delivery agents, reinsurers, data collection offices, etc. (See [Figure 1](#) for a schematic of key stakeholders for weather index insurance programs). For some projects, donor support has focused on developing the capacity of local stakeholders, such as insurers and delivery agents, to manage the weather index insurance program so that donor support plays a diminishing role as the program expands. For other projects, donors may have to be involved for an extended period. Prolonged donor involvement may be a consequence of low local familiarity with insurance, or it may be due to the sophistication of product design or program structure.

¹⁷ Modified from GlobalAgRisk (2007); Manuamorn (2007) provides much of the detail for this case study and is an excellent source for additional information.

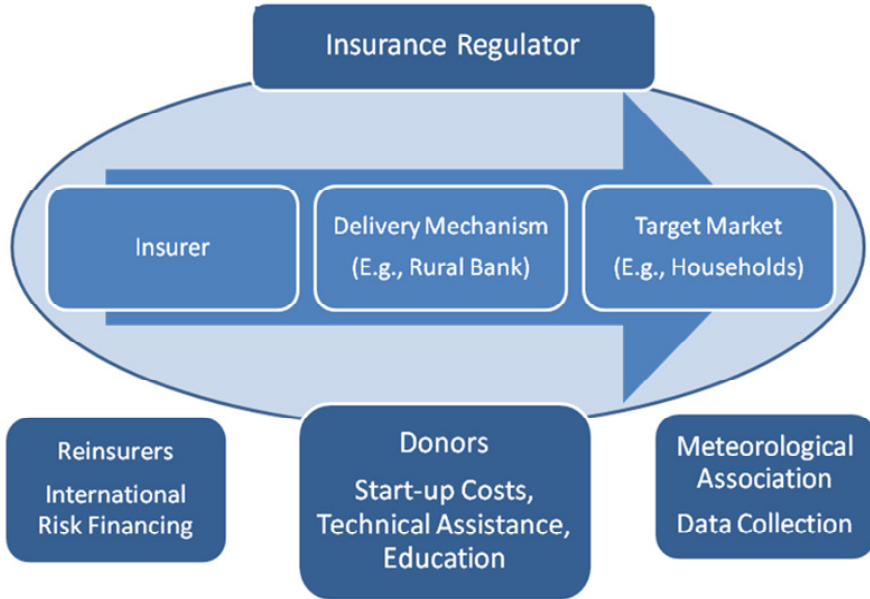


Fig. 1. Stakeholders for Weather Index Insurance

Source: Authors

The World Bank and the governments of Mexico and India have been the largest supporters of weather index insurance. The World Bank typically engages in a weather risk assessment to determine if insurance is a suitable solution, and if the partner is a local insurer with the potential capacity to manage the program. These programs often require establishing delivery channels, improving insurance laws and regulations,¹⁸ and establishing risk financing through international reinsur-

¹⁸ Most often, the largest legal and regulatory constraints are to persuade a country’s insurance regulator that weather index insurance is a legitimate form of insurance. Two issues that are often of concern for regulators are 1) that insureds receive payouts corresponding to the loss, and 2) that individuals purchasing the insurance have an “insurable interest.” Regarding the former, basis risk does create the possibility that the insured may suffer a loss and receive no payout; however, other forms of insurance (e.g., traditional crop insurance) also have basis risk. The important point for regulators is that they be able to evaluate whether the index on which payouts are made is a suitable proxy for the losses the insurance contract is meant to cover. Regulators could benefit from the development of international guidelines to enhance their ability to make this assessment (Carpenter and Skees, 2005).

Regarding the latter, “insurable interest” standards are meant to ensure that people purchasing the insurance are managing risk rather than engaging in speculation. Regulators are better able to assess that the target market has an insurable interest if it can be shown through historical data that the weather index is correlated with revenues for the target market.

ance. Marketing and educational requirements for the target market, which is typically rural smallholders who have little or no experience with insurance, are also significant.

Educating the target market is important for weather index insurance programs. Gaining familiarity with insurance products and learning to evaluate their costs and benefits take time. Where training and marketing were done on a very limited basis, sales were so low that pilot projects were discontinued after the first year.¹⁹ Weather index insurance programs have used townhall-style meetings, focus groups, advertising, and individualized training to inform households about weather index insurance. Pilot programs provide important experiences that build credibility for the insurance product, provided that households in the region have a positive experience with it.

Many recent tests of weather index insurance focus on households engaged in agricultural production. Innovative delivery mechanisms are also being tested, including composite products that link insurance to credit or goods and services in the agricultural value chain, such as seed or fertilizer. In principal, weather index insurance can also be sold directly to lenders or rural firms in agricultural value chains having revenues that are affected by the weather. Helping these rural firms can help the poor by increasing access to credit or to the agricultural value chain. Governments and donors can also purchase weather index insurance to support relief efforts for natural disasters. For example, Mexico has a weather index insurance program that funds state-level relief efforts when drought occurs.

This flexibility results in many innovative approaches and promising market growth, as decision makers continue to explore how weather index insurance can best be used to address weather risk in developing countries. Our work has evolved to focus on designing weather index insurance products for rural firms, which we have done in Peru and Vietnam (Skees, Hartell, and Murphy, 2007). Targeting these firms creates opportunities for weather index insurance coverage in areas where it is too difficult and costly to target households. Weather index insurance products for firms should establish a market that can expand to include more rural stakeholders, including households.²⁰ Almost thirty pilot tests for weather index insurance have occurred in developing and transitioning countries (see Appendix A). Initial experiences with weather index insurance indicate that these products have the potential to create access to insurance in developing countries where it has not previously been available (see Skees et al., 2007).

Other legal and regulatory conditions are also important to the long-term sustainability of weather index insurance markets (e.g., risk financing and marketing standards). Because several weather index insurance programs exist, some important legal and regulatory precedents are in place and may be helpful for stakeholders interested in developing weather index insurance markets.

¹⁹ See a previous paper prepared for KfW (Skees et al., 2007) for further description of weather index insurance markets.

²⁰ See Skees, Hartell, and Murphy (2007) for more on this approach.

Challenges for Weather Index Insurance

Although weather index insurance shows promise, many challenges remain in the scalability of these programs. These include delivering products to remote households, informing the target market, establishing appropriate legal and regulatory standards, and the availability of appropriate weather data.²¹ Although the transaction costs of weather index insurance are usually lower than those of traditional forms of agricultural insurance, insuring weather risk for the poor in developing countries is not straightforward. Product affordability is a constant concern. Even when poor households recognize the serious weather risks they face, their opportunity cost of purchasing insurance is high. Many of the innovations in this market therefore involve efforts to reduce the premium cost. As experience with weather index insurance increases, some of these costs will decrease. In the meantime, governments and donors will continue to support weather index insurance programs, financing start-up costs and designing products that work within the constraints in areas where the risk can be insured at prices affordable to the target market. Two challenges are discussed in more detail below.

First, large R&D costs are required to create weather index insurance. Since these products must be highly tailored to local conditions, R&D costs cannot be spread across large areas. Two major components of R&D costs are finding sufficient weather and loss data and analyzing those data to determine the structure and pricing of the insurance product. Tailoring weather index insurance to local conditions constrains their scalability. Unlike microfinance, which has relied on a handful of business models to dramatically expand access to credit and savings on a global scale, weather index insurance requires a much greater variety of product and program structures to address the myriad weather risks and their consequences. There are also a number of regions where weather index insurance programs would be relatively ineffective, as in mountainous areas where the major weather risks are not highly correlated across the target market.

As a result of these limitations, institutions interested in implementing weather index insurance programs²² need professionals with a variety of specialized training, including training in risk assessment, product design and risk financing. Private-sector stakeholders in developing countries can and are learning these skills,

²¹ For a more comprehensive review of these challenges see Skees (2008).

²² Legal and regulatory standards often prevent microfinance institutions and other organizations that offer savings and credit from underwriting weather index insurance contracts. When a weather shock occurs, these institutions experience capital shortages due to loan defaults and savings withdrawals, putting them in a poor position to make insurance payouts. Thus, these rural financial institutions cannot simply expand their business to underwrite weather risk as well. In contrast, these financial institutions may be able to sell weather index insurance as a delivery agent for an insurer. In this capacity an insurer, not the credit/savings financial institution, underwrites the insurance product. The bank can bundle weather index insurance with credit or savings products. This is the generalized case: such product linkages ultimately depend on local legal and regulatory standards.

often with technical assistance from donors. These capacity building investments should benefit many households as insurers are able to expand the variety of insurance products offered.

Second, weather index insurance products require international risk financing. Weather index insurance insures spatially correlated risk — everyone in the region may suffer from the same loss event. Insurers selling weather index insurance therefore require careful financing.

Risk financing typically comes from reinsurers in international risk transfer markets. Reinsurers create tailored — over-the-counter (OTC) — contracts for each insurance program. Such OTC contracts are expensive to create and pose obstacles for reinsurers who must still understand the weather risk and local market in the developing country, often with limited historical data and inadequate regulation governing insurance markets. From the perspective of insurers, reinsurers writing OTC contracts have significant control over the price of the product the insurer wants to sell; if no suitable reinsurance agreement can be made, the insurer may not be able to market the product. OTC reinsurance contracts for catastrophic risks have well-documented limitations that include the lack of transparent pricing and cycles in insurance pricing that follow major catastrophic events (Jaffee and Russell, 1997). As a result, alternative risk financing structures would be required. Progress in alternative risk financing has occurred in another part of weather markets — weather derivative markets.

Weather Derivative Markets and Their Relevance for Developing Countries

Actively traded weather derivative markets emerged in the United States in the late 1990s following deregulation of energy markets (Brockett, Wang, and Yang, 2005). Energy companies wanted to manage the risk of extreme temperatures that could adversely affect their profits (Russ, 2004). (For example, a heating oil distributor in the northeast US will lose revenues if winter temperatures are warmer than normal for an extended period.²³) Extreme patterns of either cold or hot temperatures were calibrated into an index of heating or cooling degree days and packaged into financial instruments — weather derivatives — that offset the reduced revenue or increased costs of energy that accompanied outliers in weather patterns. Weather derivative markets continue to grow quickly — in 2007/2008 the notional value of contracts traded in weather derivative markets was USD 32 billion, a 76 percent increase over the previous year (WRMA, 2008).

Weather derivatives are best suited for large and sophisticated firms in developed countries. They are poorly suited to the smallholders and rural businesses common in developing countries. Issues of regulation, market volume, and transaction costs constrain the use of weather derivatives in this context (Skees et al., 2007; Skees and Collier, 2008).

²³ See Russ (2004) for a more specific example.

But weather derivative markets are relevant to our discussion in two ways. First, reinsurers are key stakeholders in these markets, which allow reinsurers to leverage innovations that would improve the weather index insurance market. In the fall of 1997, the first weather derivative OTC contracts were traded by large energy firms (Brockett, Wang, and Yang, 2005). However, the management experts designing these contracts were soon hired by reinsurance firms wanting a larger stake in weather markets. Reinsurers are actively engaged in weather index insurance and weather derivatives.

Second, weather derivative markets quickly expanded to include standardized exchange-traded products on capital markets,²⁴ providing valuable lessons in potential alternative risk financing structures for weather index insurance.²⁵ Because obtaining affordable risk financing remains a challenge for weather index insurance programs, such advancements could be important for increasing access to weather index insurance. As with weather index insurance products, creating OTC weather derivative products is expensive, because the index and associated pricing model have to be developed or at least adapted for the circumstances of the buyer. To reduce these costs and expand the market to smaller firms, the Chicago Mercantile Exchange initiated futures and options contracts in 1999 based on temperature indexes, which has expanded to financial exchange markets for major cities in the United States and Europe (Brockett, Wang, and Yang, 2005).

Bringing natural disaster risks into capital markets creates the opportunity to trade or securitize the risks with many buyers (Doherty, 1997; Skees, 1999). When exchange-traded securities can generate sufficient market volume, more efficient price discovery occurs. Additionally, exchange-traded products are dynamically priced, meaning that the value of the security can fluctuate as new information emerges.

Capital markets could create more efficient financing of weather index insurance in developing countries. However, the tailoring required for a weather index insurance product would probably not generate sufficient market volume to trade on an exchange. Financing weather index insurance through exchange-traded securities is not currently practicable for developing countries. Furthermore, in areas with underdeveloped financial sectors, the infrastructure, regulatory environment, and experience with exchange markets are all likely to be inadequate to support exchange-traded instruments.

²⁴ “Capital markets” generally covers a wide range of activities. It is used here to recognize that catastrophic risk products could take a variety of forms including derivatives, securities, or catastrophe bonds. The focus in this chapter is on standardized products that can be traded on an exchange market (e.g., the Chicago Mercantile Exchange). OTC products may look very similar to exchange traded products. However, they are not as well regulated and the price is negotiated, rather than being the result of the bids of many buyers and sellers.

²⁵ We discuss a possible convergence for exchange-traded products and weather index insurance in Section 4 of this chapter. Exchange trading may help weather index insurance overcome some of the problems that climate change creates for these insurance products discussed in Section 3.3.

The potentially important role of reinsurers and capital markets in weather markets in both developed and developing countries should not be underrated. Reinsurers continue to advance innovative financing structures for natural disaster risk transfer products, such as securitization of natural disaster risks (Swiss Re, 2006).²⁶ Among these activities, reinsurers help to establish a financial architecture in developing countries that can facilitate a future convergence of weather and capital market innovations.²⁷

4.3 Climate Change and Weather Index Insurance

The previous section described weather index insurance and outlined the potential benefits of insurance to facilitate adaptation. In this section, we discuss specific challenges for implementing weather index insurance programs in the context of increasing weather risk due to climate change. This discussion is based on the following: 1) in principal, weather markets can protect against increasing weather risk; 2) with increasing weather risk comes higher premium costs; 3) some policy responses to higher premium costs (such as premium subsidy) can undermine the primary advantage of weather markets, which is pricing the risk; and 4) weather markets cannot protect against long-term climate change trends. Here it is important to note that weather index insurance protects against correlated risks: even small losses can create large insurer liabilities because many insured households will require payment at the same time. As a result, insurers must be very careful when evaluating the risks that they are insuring in order to organize appropriate financing.

If climate change increases weather risk, the price of weather index insurance will increase, significantly affecting the ability of poor households to buy these products. The price of insurance will increase for three primary reasons: increases in pure risk, the potential size of losses, and the ambiguity of the risk.

Increasing Pure Risk

The fundamental element in the price of insurance is the expected losses the insurer is likely to pay. Insurers use historical data to develop probability distributions that predict the likely frequency and severity of future losses — also called the *pure risk*. For weather index insurance, the pure risk is the weather risk for which the insurer is liable. When insurers find trends of increasing weather risk in historic data, such as would occur with climate change, they project these trends to devise their estimates of pure risk for the period they are about to insure. Climate change can affect two aspects of the pure risk.

²⁶ Catastrophe (CAT) bonds are another example (Doherty, 1997).

²⁷ Interestingly, WRMA (2008) notes the expansion of the weather derivatives market in India, Latin America, and Southeast Asia in 2007/2008, which provides some anecdotal evidence of how weather markets already converge.

First, if the frequency of catastrophic weather risks is increasing, the variance of the probability distribution will increase. Because insurance underwrites extreme events, the expected losses will increase. To accommodate this, insurers must raise the price of insurance.

Second, if average weather conditions become riskier (e.g., a decline in average rainfall), the central tendency or median of the probability distribution will shift toward the events of concern. Because the majority of events occur around this central tendency, this shift implies a fundamental change in the weather risk and significantly increases the expected losses of the insurer. Failure to estimate the central tendency can quickly put an insurer out of business. As a result, insurers must raise the price of insurance substantially to accommodate this change — noticeably more than in the case of increasing variance.

Increasing the Potential Size of Losses

Whether the central tendency is shifting toward more risk or if the variance of the distribution is increasing, insurers worry that losses may be more severe than in the past. In this case insurers increased the catastrophe load — a component in the price of insurance that allows insurers to build reserves quickly to cover large losses.

Increasing the Ambiguity of the Risk

Beyond adjusting the pure risk and increasing catastrophe loads, insurers charge “ambiguity loads.” These are an additional cost added to the premium to reflect the possibility that insurers may underestimate future losses. For example, climate change could affect weather risk in a particular region, causing an insurer to misestimate the weather risk. When the risk is changing, the likelihood of misestimating the central tendency increases; thus, if insurers expect that the effect of climate change in a region is increasing the weather risk, they are likely to raise ambiguity loads greatly.

At any given time it is extremely difficult to determine if risk is changing. For example, consider an insurer who experiences an extreme loss or a series of extreme losses in a single year. This loss could indicate that weather risk is changing (e.g., that the variance of the distribution is increasing) or it could simply be the type of low frequency, high severity event accounted for in the probability distribution (e.g., a 1-in-100 year flood).

While our focus on climate change has been in the context of anthropogenic contributions, there are also natural phenomena that contribute to changing weather patterns. When insurers examine historical data, they must make assumptions regarding the distribution of past weather events — are extreme events explained by the probability distribution? Is climate change affecting the probability of losses? Is this change part of natural oscillations in the climate, or do any or all of these changes indicate longer-term, more permanent anthropogenic climate change? Insurers’ conclusions will affect the price of insurance. For example, from the insurer’s perspec-

tive, either cause of changing weather patterns will be ambiguous regarding the assessment and pricing of the underlying risks. Still, the uncertainty of potential anthropogenic climate change is likely to be greater than that of historic climate patterns and can translate into higher ambiguity loads. Thus, different insurers may price the risk differently, based on their assumptions.

Summary

As scientific understanding of the impacts of climate change progresses, especially the impacts at regional and sub-regional levels, insurers should be able to leverage this information to improve their estimates of pure risk and to minimize ambiguity loads.

Providing insurance products for the poor at prices they can pay is very difficult because of the constraints of accessibility and market failure. It should therefore be obvious that climate change poses a significant challenge to creating sustainable weather index insurance products for the poor.

4.4 Climate Change, Weather Index Insurance, and Subsidies

This challenge and the potentially significant advantages of introducing weather index insurance in areas where adaptation is warranted have led some observers to suggest subsidies. However, experience with insurance indicates that unless subsidies are carefully planned, they can reduce incentives to adapt.²⁸

To illustrate, consider the effects of a crop-specific insurance subsidy on household incentives. In general, households recognize when their risks are increasing, especially if the central tendency is shifting. These conditions create incentives to adapt in order to preserve income. Yet when governments or donors subsidize premiums for an increasingly risky livelihood (e.g., cotton farming in a region with insufficient and declining rainfall), it can distort the price signal generated by insurance. As a result, households may try to maximize their income by receiving government subsidies and remaining in an unsustainable livelihood rather than making the difficult transition to a more sustainable livelihood. Thus, household adaptations are delayed; this is ultimately likely to be at great costs to governments or donors.²⁹

Other, more carefully-planned, subsidies — such as subsidizing coverage of the most extreme risk — may be less likely to distort adaptation incentives, but these measures are largely untested. Instead, governments and donors can make signifi-

²⁸ Many lessons can be learned from poorly planned agricultural insurance subsidies in developing countries. A hallmark of these programs is that they provide incentives to take more risks at the expense of the government. For more on this subject, see Goodwin, Vandever, and Deal (2004) or Skees (2001).

²⁹ Experience with subsidizing insurance premiums indicates that the total cost of these subsidies tends to grow over time with high opportunity costs for developing countries.

cant contributions in public investments that facilitate the development of weather index insurance. Other market solutions are also possible, such as promoting insurance regulation that expands the range of insurance products. Good public investments that facilitate weather index insurance, such as improving weather station infrastructure and the availability of weather data, may also have significant advantages in addressing climate change by improving information systems that enhance public and private adaptation planning.

5 Are Climate Markets Possible?

Thus far, we have provided context for the importance of weather insurance as a tool for adaptation in developing countries. We have also made a distinction between weather risks and climate risks — weather risk being year-to-year variability and climate risk being the risk of significant changes in weather patterns. Generally, weather products are available only for events one year in advance, yet even these products must be priced using the best estimates of climate change effects on the pure risk (Skees, Barnett, and Collier, 2008). No markets yet exist to trade climate risk, i.e., the longer-term expectations regarding important weather variables.

This section makes the case for markets trading climate risk, and provides basic concepts for creating climate markets. Stakeholders still have to pay for the expected losses associated with climate change impacts which are included in the premiums for products sold on climate markets. Moreover, climate markets will provide a hedge against the risk that losses will be greater than expected. Climate markets are relevant to adaptation efforts for the poor in developing countries because they could 1) provide useful hedging mechanisms that allow insurers and reinsurers supplying weather index insurance to reduce ambiguity loads; 2) serve decision makers planning longer-term adaptation investments who want to hedge against extreme scenarios in future climate change effects; 3) improve pricing signals for public and private decision makers planning longer-term projects (e.g., infrastructure investments); and 4) provide additional, immediate economic incentives for research to improve the measurement and the ability to forecast and model climate change. We describe how creating a market that can hedge against climate change for short-term weather risks is a necessary first step toward creating a market to hedge against longer-term climate change effects. We also suggest creation of such a market based on ENSO (El Niño Southern Oscillation).³⁰

³⁰ ENSO cycles include warming (El Niño), cooling (La Niña), and neutral southern Pacific conditions (McPhaden, 2003).

5.1 Short-Term Climate Markets

Section 3.3 describes how insurance suppliers set insurance prices, based in part on their assumptions about the effects of climate change on the insured risk. Instead, if important risks thought to be affected by climate change could be traded on an exchange market, the interaction of buyers and sellers having their own views about weather patterns would converge on a price for weather risk.

Moving from an abstract “climate market” to the actual steps to create such a market is daunting and beyond the scope of this paper. Some basic preconditions for a climate market are that 1) there is a standardized index to be traded; 2) that the index has both negative and positive effects (e.g., in the vernacular of futures markets — that there are natural long and short positions); and 3) that there is enough volatility in the index to stimulate participation in the market among those exposed to the risks and speculators who provide liquidity in futures markets.³¹ An ENSO index potentially meets all these conditions.

Trading ENSO

El Niño — the part of the ENSO cycle with the highest impact — is a climatic event that affects weather conditions on a global scale. El Niño events occur roughly every three to seven years and last for twelve to eighteen months. El Niño results from the complex interaction of trade winds, atmospheric pressure, and sea surface temperatures (SSTs). It impacts global circulation patterns, resulting in a variety of effects including drought in Australia, Indonesia, southern Africa; heavy rains in Peru and equatorial East Africa; warmer temperatures in Canada, the U.S. Northeast and southern Brazil; and a reduced incidence of Atlantic hurricanes (McPhaden, 2003).

As expected, these changes have many economic consequences. Perhaps the impacts are most widespread in agricultural production, due to rainfall and temperature changes. Torrential rain destroys property and infrastructure and results in loss of life in northwestern South America (e.g., Peru and Ecuador). Pacific Ocean swells, sea surges, and intense rain cause significant property damage in highly-developed coastal regions of southern California. Additionally, fisheries in the equatorial Pacific are affected by rising SSTs — the Peruvian anchovy industry collapsed due to the 1972–1973 El Niño (McPhaden, 2003). By contrast, the likelihood of hurricanes off the eastern seaboard of the United States declines as ENSO measures increase (AIR, 2008; McPhaden, 2003). Additionally, the fact that winters are warmer in North America and some other regions provides a benefit to offset many of the negative effects from strong El Niño events (McPhaden, 2003). Much uncertainty remains regarding the climate risk of ENSO patterns, which is of great significance given the importance of the ENSO cycle to climate change effects and the substantial economic costs of El Niño events (see Box 3).

³¹ In a futures market this volatility can be framed as uncertainty regarding the outcome of the index. In a context of climate risk and uncertainty, the critical variables are those where information is available about the underlying risk. However, some uncertainty remains.

Box 3: Is Climate Change Affecting ENSO?

Because the occurrence of El Niño depends on SSTs and other climatological factors that are changing with much certainty due to climate change, the effects of climate change on ENSO cycles has been of some concern to researchers (Stevenson et al., 2005). However, the complexity of the ENSO cycle has limited researchers' understanding of the effects of climate change on ENSO patterns (Merryfield, 2006). Additionally, because ENSO is a leading source of climate variability, understanding ENSO patterns and how they might be affected by GHG emissions is very important for assessing climate change effects more generally (Guilyardi, 2006; Hulme et al., 2001).

Global circulation models produce differing conclusions regarding the effects of GHG emissions on ENSO: some project that ENSO patterns will remain the same over the next century, while others project a variety of changes in severity and/or frequency (Collins and CMIP Modelling Groups, 2005; Guilyardi, 2006; Merryfield, 2006; van Oldenborgh, Phillip, and Collins, 2005; Zelle et al., 2005). Differences in model outcomes depend on the many assumptions researchers must make regarding ENSO patterns and climate change. The ambiguity regarding ENSO reduces the precision of global circulation models (Hulme et al. 2001; Merryfield, 2006; van Oldenborgh, Phillip, and Collins, 2005; Zelle et al., 2006)

ENSO insurance could have a variety of applications and has already moved beyond the conceptual stages. Khalil et al. (2007) demonstrate how and why an ENSO insurance product could be useful for the northern regions of Peru. The insurance regulator of Peru approved the use of ENSO index insurance as a result of some of our work in 2006 (Skees, Hartell, and Murphy, 2007). Osgood et al. (2007) also demonstrate how ENSO-based seasonal forecasting could be incorporated into weather insurance for farmers in Malawi.

ENSO indexes are available in the form of Pacific SST data dating back to 1856. These are compiled and published monthly by the US National Oceanographic and Atmospheric Administration (NOAA). ENSO 1.2 is an index published by NOAA that measures SSTs off the coast of Peru, a particularly important location in ENSO patterns. Figure 2 plots a composite index of ENSO 1.2 anomalies from 1856 to 2005. Clearly, positive anomalies (El Niño) occur more frequently and are more severe than negative anomalies (La Niña). The El Niño events of 1983 and 1998 stand out as the strongest events in the last 150 years.

An active exchange market could trade the composite ENSO 1.2 index in a number of ways. For example, the index could be the three-month moving average as presented in Figure 2. Traders actively engaged in the market would bet on the index. Any active exchange market on such an index, either increasing or decreasing contracts, would converge on an aggregated market forecast of future

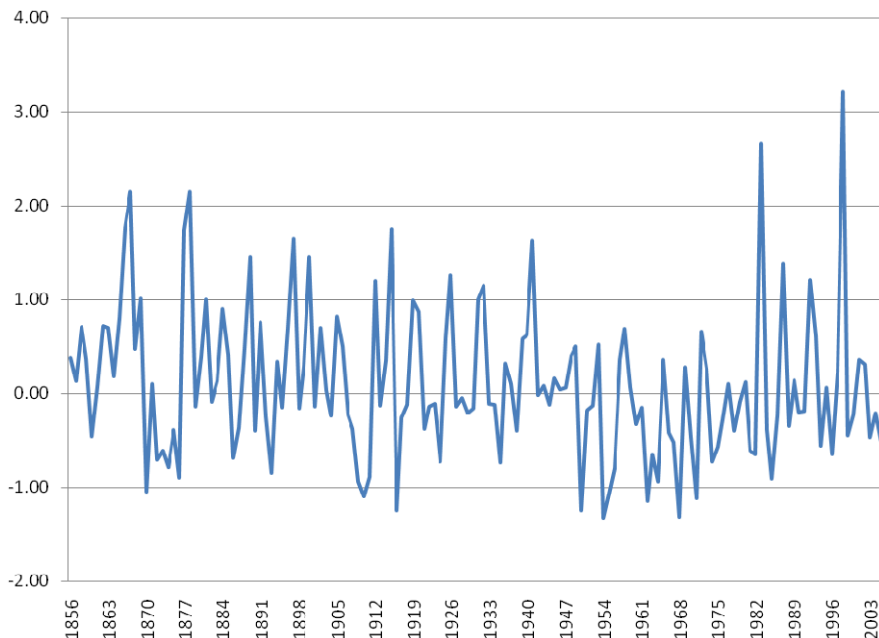


Fig. 2. Composite ENSO 1.2 Index from 1905–2004 [Refer Dates to Authors]

Source: Authors; based on NOAA data

conditions. This price would incorporate information from myriad sources including the effects of anthropogenic climate change on ENSO patterns over the life of the short-term (e.g., three-month) contract.³² Thus, an implicit market estimate of the climate risk for ENSO would “naturally” emerge. Such pricing would reduce the climate change ambiguity regarding ENSO. This is achieved by insurers by spreading the risk among the stakeholders taking different positions in the market. In this manner, climate markets are immediately relevant for hedging against current climate change effects.

Short-term markets act as the foundation for a longer-term climate market because they create volume and familiarity with the risk being traded. For longer-term products, the climate risk becomes a larger determinant of the price of the risk management product.

³² Roll (1984) found that the pricing of orange juice futures outperformed the US National Weather Service in predicting short-term Florida temperatures. Roll describes how orange juice futures pricing integrates many sources of information, including short- and long-term temperature forecasts from the National Weather Service.

5.2 Toward a Longer-Term Climate Market

A short-term ENSO index market may be adequate for improved pricing of weather insurance products. However, creating complementary exchange-traded ENSO contracts could provide even more impetus for improved information about longer-term ENSO trends. For example, trading a ten-year moving average ENSO 1.2 index could have many benefits and may be possible after a short-term market develops. The trades could be actively rolled into the future and arbitrated with the short-term ENSO market to protect longer-term positions.

Improvements in our ability to forecast changing climate and the associated effects on economic activity are likely to create exchange markets such as this hypothetical ENSO market. It may also be possible to create climate markets for other regional sea surface oscillations. Active trading of global warming forecasts or possibly even sea levels may someday be possible.

6 Conclusions

Carbon and weather markets comprise a portfolio of mechanisms that address climate change. As carbon and weather market activity increases in developing countries, a key question remains: to what extent will the poor be included in these markets? Following is a summary and a look ahead examining several important factors that will affect how the poor can participate in these markets. This occurs as costs are reduced and as coverage is increased.

6.1 Improving Incentives to Mitigate Emissions

The logical priority for mitigation efforts is to motivate big polluters in developed countries and large firms in developing countries to reduce emissions through emissions taxes, emissions allowances, etc. But the aggregated emissions produced by the poor — through inefficient energy practices, deforestation, etc. — are also significant. With a troubled world economy and over 2 billion of the world's poor living on less than USD 2 a day (World Bank, 2007), it is also important to provide incentives for the poor to mitigate these effects, which should be designed to create new revenue and improve the quality of life for poor households. Efforts of UNFCCC and others are consistent with these conclusions.

Additional R&D investments in small-scale technology, especially in agriculture, would create more opportunities for the participation of the poor. The participation of donors and governments interested in improving incentives for the poor to mitigate emissions should 1) promote increased opportunities for the poor to participate in carbon offset projects, (perhaps through a streamlined CDM review process for carbon offset projects in the least developed countries; 2) advance new methodologies through the CDM approval process that are relevant to the poor (Chapple, 2008); and 3) invest in the development of emission-reducing technologies designed for poor households.

The price of carbon set by carbon markets is a critical factor in determining how the poor could actively participate in mitigation efforts. The successes of mitigation projects designed for the poor³³ provide anecdotal evidence that they can benefit from these markets at current prices when these efforts are supported by donor coordination. Future demand for carbon offsets depends on the level of growth in the world economy and political outcomes. Of special importance is whether the United States will develop a mandatory carbon trading market and the carbon regulation standards of the EU after Kyoto expires in 2012 (Capoor and Ambrosi, 2008). Higher carbon prices are more likely to attract finance and expand opportunities for the poor.

6.2 Seeding Credit for Mitigation and Adaptation

For mitigation and adaptation, credit is crucial for households in developing countries. Mitigation and adaptation funding to seed environmental credit markets for the poor could advance efforts to increase their participation. If new livelihood strategies can improve their income, the poor would have natural incentives to adapt. Likewise, if carbon offsets can create a new income source or contribute to their economic development, the poor would have incentives to mitigate. Information about climate change and mitigation and adaptation opportunities would improve household choices and increase participation.

A link between carbon markets and adaptation exists: two percent of payments for carbon offsets are paid into an Adaptation Fund. The intermediaries working between the poor and the carbon market have a strategic position to provide credit for mitigation and adaptation projects. Additionally, adaptation funds could foster weather index insurance markets by funding the start-up costs of offering access to data, financing product development research, etc. Donors and governments could provide seed funds designed to increase access to credit for these purposes.

6.3 Transferring Intermediation to the Private Sector

Because carbon and weather markets are organized on a global scale, the poor tend not to have access to these markets without an intermediary that can, for example, leverage carbon market funds to finance loans for household mitigation investments. Governments and donor organizations currently act as this intermediary (Chapple, 2008). In the future, private-sector intermediaries could emerge and improve the scalability and sustainability of these markets in developing countries. Profitable private sector services to the poor can be extended more expeditiously than those dependent on the relatively limited budgets of donor organizations. Microfinance is a powerful example.

³³ For examples, see 2.1. Clean Development Mechanisms: The Potential for Developing Countries.

Education and capacity building are central to the creation of suitable intermediaries in the private sector. In carbon markets, multilateral organizations (e.g., the UNFCCC, World Bank) are already engaged in capacity building and carbon offset projects in developing countries (UNFCCC, 2007). As local stakeholders gain increased experience with carbon markets through donor- and government-supported projects, the private sector is likely to play a larger intermediary role, organizing families for mitigation projects and packaging these projects for carbon markets. Some of this is already occurring. Education for carbon market opportunities to help the environment, improve the quality of life, and/or earn additional income are likely to increase demand and energize the private sector. Educating households and building private sector capacity to manage carbon offset projects could be effective for governments and donors interested in increasing the participation of the poor in carbon markets.

Increasing the links among the poor in weather markets is more complex. It is a goal of reinsurers, governments, multilateral organizations, and donors. Many insurers in developing countries lack the technical capacity to design these complex programs. Strategies that simplify the design process — such as more generic weather index insurance contracts — may be effective in transferring the ownership of weather index insurance programs from governments and donors to the private sector.

The complexities created by climate change may discourage insurers. Insurers understand that climate change increases risk in a general sense, while pricing the effects of climate change on a specific weather risk in a specific region is more difficult. Climate change research does not currently provide sub-regional and local projections that are satisfactory to insurers. But even as climate change projections improve, insurers are not generally trained to evaluate new findings and their design implications. Climate markets can help address this constraint by pricing major climate risks.

Donors and governments interested in increasing the scalability and sustainability of mitigation and adaptation efforts for the poor should consider capacity building among private-sector stakeholders. Experience with weather index insurance shows that capacity building can lead to local ownership of these projects and to market competition as successful programs expand over time in ways that help the poor can gain access to these markets.

6.4 Creating Climate Markets to Facilitate Adaptation

Short- and longer-term climate markets could address the capacity constraints of insurers planning for climate change, improving the competitiveness of their pricing. While we have puzzled through an example of a short-term climate market for ENSO, it would be significantly more difficult to create longer-term climate markets. The motivation for creating active trading of important climate variables is to lower the price of weather insurance via more efficient and competitive price discovery that would improve access by the poor. Donors, governments, and the

private sector could use climate markets to hedge against large climate change effects. If these impacts were to occur, climate market payouts could fund investments to adapt to large climate change effects. Donors and governments interested in facilitating adaptation through climate market development can invest in R&D for products such as financial-exchange traded ENSO insurance. This would increase access to weather insurance and improve the capacity of governments and donors to manage longer-term climate risks. These products insure against potential climate risks that would have significant impacts on the poor

The activities we describe include increasing household access and incentives to participate in carbon markets, creating weather markets in developing countries, increasing the role of private sector intermediaries, and potentially creating both short-term and long-term climate markets. These factors should increase the participation of the poor in carbon and weather markets and improve their ability to address climate change.

APPENDIX: Summary of Index-Based Risk Transfer Products in Developing Countries

Country	Risk Event	Contract Structure	Index Measure	Target User	Status	Source
Bangladesh	Drought	Index insurance linked to lending	Rainfall	Smallholder rice farmers	In development; pilot launch planned for 2008	Barnett and Mahul 2007
Caribbean Catastrophe Risk Insurance Facility	Hurricanes and earthquakes	Index insurance contracts with risk pooling	Indexed data from NOAA and USGS	Caribbean country governments	Implemented in 2007	Barnett and Mahul 2007 Isom 2007
China	Low, intermittent rainfall	Index insurance	Rainfall and storm day count	Smallholder watermelon farmers	Implemented June 2007 in Shanghai only; includes a 40% premium subsidy	Barnett and Mahul 2007
Ethiopia	Drought	Index insurance	Rainfall	WFP operations in Ethiopia	USD 7 million insured for 2006; policy not renewed for 2007 due to lack of donor support	Skees et al. 2006, Syroka and Wilcox 2006

Country	Risk Event	Contract Structure	Index Measure	Target User	Status	Source
Ethiopia	Drought	Index insurance	Rainfall	Smallholder grain farmers	2006 pilot; Implemented 2008, sold by private insurer	Barnett, Barrett, and Skees 2008, Ethiopian Insurance Corporation 2008, Shewareged 2008
	Drought	Weather derivative	Satellite and weather data	NGO	Implemented in 2007	Swiss Re 2007
Honduras	Drought		Rainfall		In development	Syroka 2007
India	Drought and flood	Index insurance linked to lending; offered directly to farmers	Rainfall	Smallholder farmers	Began with pilot in 2003; index insurance products now offered by private sector and government; As of March 2008, close to 1 million contracts were sold ³⁴	Manuamorn 2007, Ibarra and Syroka 2006
Kazakhstan	Drought	Index insurance linked to MPCPI program	Rainfall	Medium and large farms	In development	Barnett and Mahul 2007
Kenya	Drought	Weather derivative	Satellite and weather data	NGO	Implemented in 2007	O'Hearne 2007
Mali	Drought	Weather derivative	Satellite and weather data	NGO	Implemented in 2007	Swiss Re 2007
Malawi	Drought	Index insurance linked to lending	Rainfall	Groundnut and maize farmers who are members of NASFAM	Pilot began in 2005; 1710 policies sold in 2006/2007 pilot season; USD5238 premium volume	Alderman and Haque 2007, Leftley and Mapfumo 2006, Micro Insurance Agency 2008

³⁴ Estimate based on Manuamorn (2007) and personal communication between Jerry Skees and Kolli Rao of AICI, 29 March 2008.

Country	Risk Event	Contract Structure	Index Measure	Target User	Status	Source
Mexico	Natural disasters impacting smallholder farmers, primarily drought	Index insurance	Rainfall, windspeed, and temperature	State governments for disaster relief; Supports the FONDEN program	Pilot began in 2002; available in 26 of 32 states; currently 28% (2.3 million ha) of dryland cropland is covered	Agroasemex 2006a, Skees et al. 2006
	Major earthquakes	Index-linked CAT bond and index insurance contracts	Richter scale readings	Mexican government to support FONDEN	Introduced in 2006; CAT bond provides up to USD 160 million; index insurance coverage up to USD 290 million	Wenner 2007, Cárdenas 2006
	Drought affecting livestock	Index insurance	Normalized Difference Vegetation Index	Livestock breeders	Launched in 2007, sum insured USD 22.5 million across 7 states, insured 913,000 cattle	Agroasemex 2006b
	Insufficient irrigation supply	Index insurance	Reservoir levels	Water user groups in the Rio Mayo area	Feasibility assessment conducted	Skees and Leiva 2005
Mongolia	Large livestock losses due to severe weather	Index insurance with direct sales to herders	Area livestock mortality rate	Nomadic herders	Third sales season of pilot completed in 2008; offered in 3 provinces; 17% of eligible herders participated; about 4,000 policies sold	Mahul and Skees 2005, Skees and Enkh-Amgalan 2002
Morocco	Drought	Index insurance	Rainfall	Smallholder farmers	No interest from market due to declining trend in rainfall	Barnett and Mahul 2007, Skees et al. 2001, Stoppa and Hess 2003

Country	Risk Event	Contract Structure	Index Measure	Target User	Status	Source
Nicaragua	Drought, excess rain, and excess humidity	Index insurance	Rainfall	Groundnut farmers	Launched in 2006	Barnett and Mahul 2007, Syroka 2007
Peru	Flooding, torrential rainfall from El Niño	Index insurance	ENSO anomalies in Pacific Ocean	Rural financial institutions	Feasibility assessment and preliminary market development work conducted	USAID 2006 Skees, Hartell, and Murphy 2007
	Drought	Index insurance linked to lending	Area-yield production index	Cotton farmers	First sales season launched in 2008	Carter, Boucher, and Trivelli 2007.
Senegal	Drought	Index insurance linked to area-yield insurance	Rainfall and crop yield	Smallholder farmers	Proposed	Barnett and Mahul 2007 Swiss Re 2007
Tanzania	Drought	Index insurance linked to lending	Rainfall	Smallholder maize farmers	Pilot implementation in 2007	Barnett and Mahul 2007, Swiss Re 2007
Thailand	Drought	Index insurance linked to lending	Rainfall	Smallholder maize farmers	Pilot implementation in 2007	Barnett and Mahul 2007, Manuamorn 2006
	Flood	Index insurance	River level or rainfall	Smallholder rice farmers	Proposed	Manuamorn 2006
Ukraine	Drought	Index insurance	Rainfall	Smallholders	Implemented in 2005; currently closed due to limited sales	Barnett and Mahul 2007, Skees, Hess, and Ibarra 2002
Vietnam	Flooding during rice harvest	Index insurance linked to lending	River level	The state agricultural bank and, ultimately, smallholder rice farmers	In development; a draft business interruption insurance contract is being considered by the state agricultural bank	Skees, Hartell, and Murphy 2007

Source: Authors (updated from Barnett, Barrett, and Skees, 2008)

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Glossary

- Adaptation** Efforts to adjust to the physical impacts of climate change, as related to increasing weather risk affecting agriculture, behavioral changes that reduce household vulnerability and/or exposure resulting in fewer farm losses.
- Adverse Selection** Occurs when potential insurance purchasers know more about their risk exposure than the insurer, leading to participation by high-risk individuals and non-participation by low-risk individuals. Insurers react either by charging higher premiums or not insuring at all, as in the case of floods. Adverse selection is also referred to as anti-selection. *See also Asymmetric Information.*
- Ambiguity Loads** An additional cost added to the premium to reflect the possibility that insurers may underestimate future losses.
- Basis Risk** A term generally used to reflect variance around a futures exchange price and a local cash price. In the context of index insurance, it refers to the difference between the loss as reflected

in the index versus the individual loss. Indexes rarely perfectly match individual losses. Some households experiencing loss do not receive indemnity payments and/or households that experience no loss receive indemnity payments. Basis risk increases as the geographical area covered by the index expands.

Asymmetric Information	An information imbalance in a transaction in which one party possesses more or better information than another party or parties, such as knowledge of hidden costs or risky behavior. Buyers of insurance products typically have better information about their level of risk exposure than do the sellers of insurance. Thus these buyers have incentives to hide information to gain better terms for insurance in a way that will increase the probability of payout. <i>See also Adverse Selection and Moral Hazard.</i>
Catastrophe Loading	A component of the price of weather index insurance that accounts for the possibility of an extreme weather event occurring in the early years in which the product is offered.
Central Tendency	The median or most frequently occurring value used by term insurers to describe a weather event.
Climate Change	Theory that overall weather patterns are changing on a global scale for the long-term due to human contributions to greenhouse gases.
Correlated Risk	A risk or risks affecting many individuals or households in the same area at the same time, such as drought, which can damage agricultural production over an entire region, or a fall in a commodity price that simultaneously affects all producers of the commodity within the same market. Correlated risk is also referred to as covariant risk and systemic risk.
Derivative	A financial instrument, traded on or off an exchange, having a price that is directly dependent upon or “derived” from the value of one or more underlying instruments. Examples include debt instruments, commodities, or any established pricing index. Derivatives involve the trading of rights or obligations based on an underlying product, but they do not directly transfer underlying property. The derivative is merely a contract between two or more parties. Its value is determined by fluctuations in the underlying asset. Derivatives can hedge risk or lock in a fixed rate of return. Derivatives are generally used to hedge risk, but they may be used for speculative purposes. <i>See also Hedging.</i>

- El Niño A warming of sea surface temperatures in the equatorial Pacific Ocean associated with dramatic changes in the weather patterns of the region and worldwide.
- El Niño Southern Oscillation (ENSO) ENSO is an oceanic-atmospheric process that results from interaction between the temperature of the equatorial Pacific Ocean and the atmosphere. Changes in the ocean affect the atmosphere and climate patterns around the globe. In turn, changes in the atmosphere impact the ocean temperatures and currents. The system oscillates between warmer than average (El Niño) and cooler than average (La Niña) conditions.
- Futures Contract A standardized agreement or the deferred delivery of a commodity, or its equivalent, traded through organized futures exchanges. The holder of the contract has the right and obligation to buy or sell a commodity at a certain date for a price determined in advance. Most agricultural futures contracts require physical delivery, but some contracts such as feeder cattle futures contracts call for cash settlement at contract maturity. In fact, contracts are usually liquidated before delivery. Traders are classified as hedgers or speculators. Futures contracts have standard delivery dates, trading units, terms, and conditions.
- Index Insurance Index insurance makes indemnity payments that are not based on an assessment of the policyholder's individual loss, but rather on measures of an index that is correlated with losses and serves as a proxy for actual losses. Agricultural index insurance products are based on area yields (where the area is some unit of geographical aggregation larger than the farm) and on products based on measurable weather events. *See also Weather Index Insurance.*
- Loss Adjustment The process of estimating actual losses after an insured party has filed a claim.
- Mitigation Efforts aimed at reducing anthropogenic contributions to climate change.
- Moral Hazard A change of behavior that increases the chance of loss because of the existence of insurance. Examples of moral hazard can range from poor management or carelessness to fraud, in the latter case specifically targeted at creating losses and collecting the insurance. *See also Asymmetric Information.*

Multiple Peril Crop Insurance	MPCI is a form of traditional agricultural insurance, designed to insure against multiple crop perils. Most of the risks covered are weather perils (excess moisture, drought, freeze, etc.), and other perils such as fire can be included. Two forms of MPCI are dominant: 1) coverage is set based on expectations of the average farm yield, and payments are made if the individual farm yield falls below some percentage of that average farm yield; and 2) losses are established based on an assessment of the portion of damage to the crop. In either case, it is difficult to prove whether losses are from an insured weather peril or if they are the result of poor farm management practices. <i>See also Traditional Agricultural Insurance.</i>
Over-the-Counter (OTC)	The trading of financial instruments such as securities or derivatives directly between dealers or their counterparties. OTC trading operates outside organized market exchanges.
Premium	The monetary sum payable by the insured to the insurer for the period (or term) of insurance granted by the policy.
Probability Distribution	<p>(i) A function of a discrete random variable yielding the probability that the variable will have a given value.</p> <p>(ii) Outcomes of an experiment and their probabilities of occurrence. If the experiment were repeated a large number of times, the same probabilities should also repeat.</p> <p>(iii) A statistical function that describes all the possible values and likelihoods that a random variable can take within a given range. This range will be between the minimum and maximum statistically possible values, but where the possible value is likely to be plotted on the probability distribution depends on a number of factors, including the distribution's mean, standard deviation, skewness, and kurtosis.</p>
Pure Risk	A component of the price of weather index insurance that estimates weather risk based upon the probability distribution.
Reinsurance	The shifting of part or all of the insurance originally written by one insurer to another insurer who is known as a reinsurer. When the total exposure of a risk or group of risks presents the potential for losses beyond a limit that is prudent for an insurance company to carry, the insurance company may purchase reinsurance, i.e., insurance of the insurance. Reinsurance has many advantages, including (i) stabilizing

or evening out the financial performance of the insurance company over a period of time; (ii) limiting the exposure of individual risks and restricting or reducing losses paid out by the insurance company; (iii) the possibility of increasing an insurance company's solvency margin (percent of capital and reserves to net premium income) and hence the company's financial strength.

- Reinsurer A company that sells reinsurance. Commercial reinsurers often operate on a global scale, making them able to pool a diverse portfolio of large risks to reduce their overall risk exposure. *See also Reinsurance.*
- Risk Financing The process of managing the financial consequences of risk through instruments such as insurance contracts, CAT (catastrophe) bonds, reinsurance, or options contracts. In this context the authors use risk financing to describe the methods insurers must use to manage correlated risk in their insurance portfolio.
- Sea Surface
Temperature The surface temperature of the ocean. These temperature readings are predictive of atmospheric pressure patterns. For example, El Niño Southern Oscillation is associated with increasing sea surface temperatures in Peru several months prior to the atmospheric change.
- Stakeholder A party who has a vested interest in the topic being discussed. For example, insurers, reinsurers, insurance regulators, delivery agents, households, etc., involved in an insurance program are stakeholders.
- Subsidy A direct or indirect benefit granted by a government (or donor) for the production or distribution of a good or to supplement other services. Thus, the term has a wide range of applications. In insurance for agriculture, premium subsidies occur when a government pays a portion of insurance premiums for farmers. Premium subsidies, for example, often have unintended consequences, motivating farmers to take more risk at the government's expense, resulting in larger and larger losses by the government.
- Traditional
Agricultural
Insurance Insurance in agriculture has historically underwritten a specific crop on a specific plot of land. This insurance is priced by using historical farm yield data. In the event of a loss from an insured event, a trained claim agent will visit the

plot of land and assess the amount of damage incurred. One of the most common forms of traditional agricultural insurance is multiple peril crop insurance. *See also Multiple Peril Crop Insurance.*

Transaction Costs	The financial or in-kind costs of business transactions, such as the cost or time spent obtaining information or permits. Transaction costs associated with insurance include those associated with underwriting, contract design, rate making, and monitoring to control adverse selection and moral hazard.
Underwriting	Process of selecting risks for insurance and determining the amounts and terms the insurance company (the underwriter) will accept the risk.
Weather Index Insurance	Contingent claims contracts for which payouts are determined by an objective weather parameter that is highly correlated with farm-level yields or revenue outcomes, such as rainfall levels, temperature, or soil moisture. <i>See also Index Insurance.</i>

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