

Managing Agricultural Production Risk

Innovations in Developing Countries

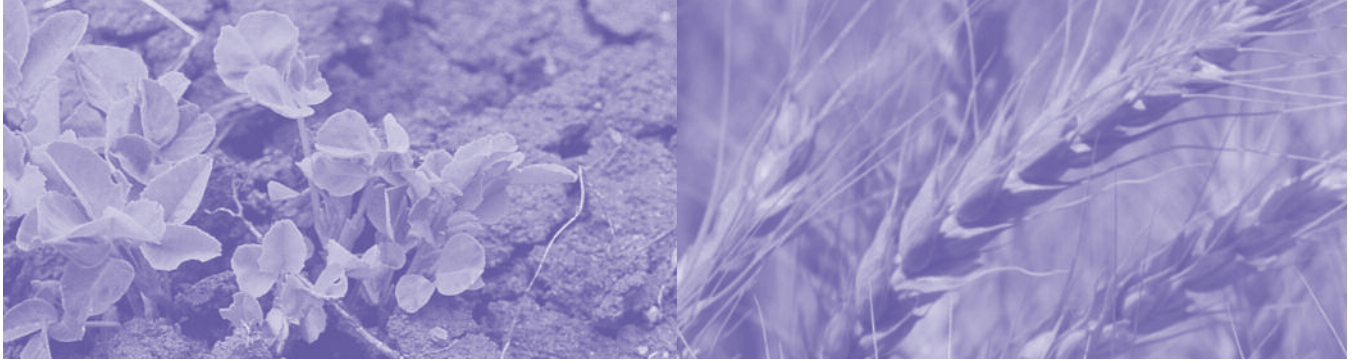
Agriculture and Rural Development Department



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THE WORLD BANK
AGRICULTURE AND RURAL DEVELOPMENT DEPARTMENT

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Acronyms and Abbreviations

ACP	Africa-Caribbean-Pacific
APF	Agricultural Policy Framework of Canada
APH	actual production history
ARD	Agriculture and Rural Development Department of the World Bank Group
BASIX	Livelihood Promotion and Microfinance entity of Andhra Pradesh
BIP	base insurance product
BSFL	Bhartiya Samruddhi Finance Limited (part of BASIX)
CAIS	Canadian Agricultural Income Stabilization
CAT	catastrophe
COFIDE	Corporación Financiera de Desarrollo S.A. (Development Finance Corporation located in Lima, Peru)
CRDB	Cooperative and Rural Development Bank Limited, a private commercial bank
CRMG	Commodity Risk Management Group (ARD, The World Bank)
DECRG	Development Economics Research Group of The World Bank
DOC	disaster option for CAT risk
DPPC	Disaster Prevention and Preparedness Commission (Ethiopia)
DRP	disaster response product
EC/ACP	European Commission/Africa-Caribbean-Pacific
EIC	Ethiopia Insurance Corporation
ENESA	Entidad Estatal de Seguros Agrarios, the National Agricultural Insurance Agency of Spain
ENSO	El Niño southern oscillation (sea surface temperatures)
ESDVP	Environmentally Sustainable Development Vice Presidency
ESSD	The World Bank Environmentally and Socially Sustainable Development Advisory Service
FAO	Food and Agriculture Organization of the United Nations
FCIP	Federal Crop Insurance Program
FSE	The Financial Sector Group of The World Bank
GDP	gross domestic product
GIIF	Global Index Insurance Facility (proposed by CRMG)

GMO	genetically modified organisms
IBLI	index-based livestock insurance
ICICI Lombard	A private general insurance company in India
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFC	International Finance Corporation of the World Bank Group
IFFCO-Tokio	A private general insurance company in India, a joint venture between Tokio-Marine and the Indian Fertilizer Association
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
INISER	Instituto Nicaraguense de Seguros y Reaseguros Nicaraguan Institute for Insurance and Reinsurance
ISMEA	Istituto di Servizi per il Mercato Agricolo Alimentare (Italian Institute for Services to Agricultural Food Markets)
KBS LAB	Krishna Bhima Samruddhi Local Area Bank
LIL	learning and innovation loan
MAMDA	Mutuelle Agricole Marocaine d'Assurance
MMPI	Malawi Maize Production Index
NASFAM	National Smallholders Association
NDVI	normalized difference vegetation index
NGO	nongovernmental organization
NMSA	National Meteorological Services Agency
OECD	Organization for Economic Cooperation and Development
OI	Opportunity International
PI	production insurance
RI	reinsurance
SADC	Southern African Development Community
SECO	State Secretariat for Economic Affairs, Swiss Trade Commission
SENAMHI	Servicio Nacional de Meteorología e Hidrología del Perú (National Meteorology and Hydrology Service of Peru)
SRA	Standard Reinsurance Agreement (U.S. crop insurance)
TCDAI	Technical Committee for the Development of Agriculture Insurance (Peru)
UNCTAD	United Nations Conference on Trade and Development
WFP	World Food Program of the United Nations



Preface and Acknowledgments

This document was produced by Ulrich Hess, as task manager, and by Jerry Skees, Andrea Stoppa, Barry Barnett, and John Nash, using background papers written by Robert Townsend; Paul Siegel; and Jerry Skees, Barry Barnett, and Jason Hartell. (These papers can be viewed at the Commodity Risk Management Group (CRMG) web site, www.itf-commrisk.org.) Panos Varangis led the work for this study during its conceptual stage. The two appendixes are shortened versions of contributions by CRMG authors Joanna Syroka and Hector Ibarra to a forthcoming ISMEA (Istituto di Servizi per il Mercato Agricolo Alimentare) publication on innovations in agricultural risk management.

Although motivated by the solid and growing literature on alternative risk management techniques, this paper is ultimately driven by empirical results that would have been impossible to obtain without the development community's support and demand for action.

At The World Bank, Karen Brooks and Richard Scobey, rural sector managers in the Africa Region, supported the conceptual work and instilled a sense of realism and purpose into the ideas expressed here. Jock Anderson and Derek Byerlee in the Agriculture and Rural Development department continuously refreshed our ideas in the areas of agricultural risk management and food security risk management. Kevin Cleaver and Sushma Ganguly, Sector Director and Sector Manager, respectively, in the Agriculture and Rural Development department, gave motivational advice and guidance. Ken Newcombe, ESDVP, encouraged this work and has become a champion of the Global Index Insurance Facility (GIIF). In his IFC days, Cesare Calari, FSE, was an early supporter of weather risk management concepts, and he continues to encourage this line of thinking in his various capacities. Rodney Lester, senior insurance expert in FSE, also contributed advice and support. Xavier Gine, DECRG, helped to shape our thinking on smallholder access to financial services. Our colleagues in the social development and social protection areas—notably Harold Alderman, Will Wiseman, and Elena Galliano—helped with the crossover to the social risk management realm, providing a better understanding of the needs of vulnerable populations and the relevance of insurance techniques for safety nets.

Development partners have continuously prompted quality leaps forward through their particular expertise. Richard Wilcox of the UN World Food Program (WFP) pushes the weather insur-

ance idea to new limits and has shaped our thinking at that level. Alexander Sarris, FAO, and Lamon Rutten, UNCTAD, supported CRMG in the areas of commodity risk management.

The key concepts espoused in this paper have been developed in the academic community as well. Ronald Duncan and his group at the World Bank systematically explored index insurance ideas in the early 1990s (Priovolos and Duncan 1991). Also in the early 1990s, Peter Hazell, IFPRI, and Jerry Skees analyzed the shortcomings of traditional crop insurance and suggested the weather index insurance alternative.

This ESW insists on market-based insurance techniques, the only sustainable way to transfer risk out of agriculture. At the same time, market gaps exist, and often markets fail the poor. CRMG and its partners—by “crowding in” the private sector—are building the bridges necessary to span these gaps. None of this would have been possible without the visionary thinking of leaders in the weather risk management markets. Ravi Nathan, ACE Insurance of North America, in particular, has helped to globalize the market beyond OECD countries thanks to creative partnership and risk-sharing structures that include marketing partners from developing countries. His vision continues to inspire the market and our work. Crucial advisors on the work and ideas of the CRMG as represented here are Brian Tobben and William Dick of Partner RE; Juerg Trueb, of Swiss RE; and Rick McConnell, formerly of the Agricultural Financial Services Corporation, Alberta. Bruce Tozer, at Rabobank, and Roy Leighton, at Carlyon, have advised and encouraged CRMG and the International Task Force for Commodity Risk Management, throughout their existence, with wisdom and passion.

The demand for systematic techniques of agricultural risk management in developing countries ultimately came from the people who deal with farmers and who partly make the farmers’ risks their own. The vision and inspiration of Nachiket Mor, of ICICI Bank, India, and Vijay Mahajan, of BASIX, India, are the real motivators behind the astounding success of weather insurance techniques. This paper and its proposals would be unthinkable without the ICICI Lombard and BASIX weather insurance pilots and their revelation that farmers understand and appreciate the transparency and timeliness of the product. Ramesh and Vasumathi in Mahahbubnagar, Ramana and Gunaranjan in Hyderabad and Mumbai, Virat Divyakirti at ICICI Lombard, and Bindu Ananth, also at ICICI, were the architects of a simple innovation that promises to change India’s rural landscape. Champions for pilot projects elsewhere are Rachid Guessous, MAMDA, in Morocco; Ramon Serrano, INISER, in Nicaragua; and Shadreck Mapfumo, OI, in Malawi.

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Executive Summary

The creation of risk transfer markets for weather events in developing and emerging economies is rapidly progressing. This document describes several sources of risk that create poverty traps for poor households and impede the development process, focusing on low-probability, high-consequence weather risk events as they relate to rural households. These types of risks are highly correlated and require special financing and access to global markets if they are to be pooled, rendered diversifiable, and improved in pricing. Thus, a significant contribution of this paper is the introduction of index insurance, highlighting its use at the micro-, meso-, and macrolevels for risk transfer. By using index insurance products, it is possible to organize systems that take advantage of global markets to transfer the correlated risks associated with low-probability, high-consequence events out of developing countries. This document presents both a conceptual backdrop for understanding this system and a progress report on several World Bank efforts to assist countries in using their limited government resources to facilitate market-based agricultural risk transfer when faced with natural disasters.

While global markets providing reinsurance for natural disasters are both large and growing, they are rarely interested in taking such risk from developing and emerging economies. In part, this is because developing countries have weak primary insurance markets. Before agreeing to provide reinsurance, global reinsurers engage in due diligence investigations of primary insurers and of the risks the primary insurers wish to transfer. Compared to traditional insurance products, index insurance has far fewer problems with hidden information and hidden action. This reduces the reinsurers' due diligence and underwriting costs and makes accepting natural disaster risk from new insurance providers in developing countries more attractive. Nonetheless, natural disaster losses can be significant, and carefully crafted ways to finance such losses are critical preconditions for shifting the risk into global markets. Innovation in pooling these risks globally may also facilitate the transfer of natural disaster risk from developing countries.

One global innovation currently being prepared by the World Bank and the European Commission involves a Global Index Insurance Facility (GIIF). The GIIF will have three functions targeted at helping insurance providers in developing countries build capacity: (1) supporting the technical assistance and infrastructure needed

to develop index insurance based on quality data; (2) aggregating and pooling risk from different developing countries to improve pricing and risk transfer into the global reinsurance and capital markets; and (3) cofinancing certain insurance products on a bilateral basis from donor to developing country. Importantly, the third function will be separate from the commercial activity represented in the first and second functions. A global effort to facilitate these three functions could represent a major breakthrough for those developing countries exposed to extreme natural disaster risk.

Another promising realm of innovation is the development of improved technology both to measure weather and to link it to farming systems to forecast crop yields. Improved and less costly systems for measuring weather events in developing countries will play a significant role in the potential success of many of the ideas presented here. Secure and accurate measurement will influence both the pricing of index insurance and the demand from end users. Improvements in developing countries first in measuring the vegetative cover using satellite images and then in forecasting the value of that vegetation in terms of crop yields or grazing value could lead to the availability of enhanced types of index insurance products. Additionally, more sophisticated crop models linking weather, management systems, and soil condition can be used to provide insurance products that protect against the dominant random variable affecting production—the weather.

Transferring risk out of developing countries is important for a number of reasons. Natural disasters impede development, push households into poverty, and drain fiscal resources. Many natural disasters are directly tied to extreme weather events that can have devastating impacts on agriculture. Nearly three-fourths of the 1.3 billion people worldwide living on less than US\$1 per day depend on agriculture for their livelihoods. In many countries around the world, agricultural development clears the way for overall economic development in the broader economy, forging a strong link between weather, the livelihoods of the poor, and development. Yet, no effective ex ante solutions for dealing with weather risks in developing countries exist. Rather, developing countries, the World Bank, and the donor community are currently heavily exposed to natural disaster risk via ex post responses such as financial bailouts, debt forgiveness, and emergency response.¹ None of these

responses are optimal. They fail to provide an effective safety net for the poor; they can be inequitable and untimely; and they create a dependency that has dire consequences.

If the planning for and financing of extreme weather events were to occur ex ante, access to both formal and informal lending should improve. As broader financial services become more accessible to the rural poor, newer technologies will be used, and improvements in productivity and incomes should follow.

Farmers around the world utilize various risk coping and risk management strategies, but many of these strategies are inefficient. The economic development literature is full of cases illustrating how poor, risk-averse farmers often forego potentially higher incomes to reduce their risk exposure. Both individual households and the larger society incur costs for smoothing consumption across income shocks. In many cases, following major income shocks, the poor must resort to high interest rate loans. Many argue that the poor cannot afford to purchase ex ante insurance protection against extreme weather events, but the widespread use of ex post loans suggests otherwise.

The challenge remains of how to make insurance against extreme weather events both more effective and more affordable. Two major considerations inhibit the development of risk transfer markets for agricultural losses caused by extreme weather events: First, organizing ex ante financing for highly correlated losses can result in extremely large financial exposure; and, second, asymmetric information problems, such as moral hazard and adverse selection, lead to high transaction costs. The latter also makes it nearly impossible to provide traditional agricultural insurance for small farmers, because the large fixed transaction costs greatly increase the average cost, per monetary unit, of insurance protection for smallholder agriculture. Unfortunately, there are few successful examples to consider; the heavily subsidized crop insurance provided by governments in developed countries is both costly and questionable in terms of net social welfare.

Researchers frequently find that economic decision makers underestimate the likelihood and/or magnitude of low-probability, high-consequence loss events, leading to a reduced willingness to pay for insurance to protect against these events. At the same time, because insurers have little empirical information about the likelihood and/or

magnitude of extreme events, they tend to add large extra costs to premium rates for insurance products protecting against them. This divergence between what potential purchasers will pay and what insurers will accept results in agricultural insurance markets that clear less than socially optimal quantities of risk transfer.

New conceptual models are being developed to facilitate the transfer of extreme weather risk out of developing countries. This document reports on the progress of several ongoing efforts by the Commodity Risk Management Group (CRMG) at the World Bank that have been motivated by these models. All of these efforts are built on the premise that index-based insurance products can effectively address the challenges of the ex ante financing of highly correlated losses and high transaction costs. Index insurance products pay indemnities based on an independent measure highly correlated with realized losses. Unlike traditional crop insurance, which attempts to measure individual farm yields, index insurance makes use of variables largely exogenous to the individual policyholder, including area yield or weather events such as temperature or rainfall. This feature greatly reduces the need for deductibles and copayments, since it results in very little exposure to asymmetric information problems, such as moral hazard and adverse selection. By eliminating farm-level loss adjustment, index insurance products achieve lower transaction costs than are possible with traditional agricultural insurance products.

Purchasers of index insurance products are exposed to basis risk. Since index insurance indemnities are triggered not by farm-level losses but rather by the value of an independent measure (the index), a policyholder can experience a loss and yet receive no indemnity. Conversely, the policyholder may not experience a loss and yet nonetheless receive an indemnity. The effectiveness of index insurance as a risk management tool depends on how positively correlated farm-level losses are with the underlying index. Importantly, since farmers have incentives to continue to produce or to try to save their crops and livestock even in the face of bad weather events, index insurance should provide for a more efficient allocation of resources.

Since they are standardized and transparent, index insurance products can also function as reinsurance instruments that transfer the risk of

widespread, correlated agricultural production losses. To the extent that institutions can be created to aggregate and pool the low-probability, high-consequence tail risk that results from writing insurance on these events, the divergence between insurers' willingness to accept and potential purchasers' willingness to pay should decrease, causing the market to clear at high quantities of risk transfer.

This paper was written to inform a broad range of decision makers about the progress being made in risk transfer for natural disaster risk. While the focus here is on agriculture, many of the same concepts can clearly also be used for other sectors exposed to natural disaster risk. Two basic innovations dominate the conceptual framework: (1) use of index-based insurance; and (2) layering risk to facilitate risk transfer. In many cases, individuals will self-insure against the layer of risk composed of high-probability, low-consequence losses. Some form of government intervention may be required to achieve higher levels of risk transfer in the layer of risk composed of low-probability, high-consequence losses. Between these two extremes lies a layer of risk that, with appropriate risk transfer and pooling structures, can be transferred using market mechanisms.

Since catastrophe risks (CAT risks) are one of the impediments to market development, a framework has been developed for government action in the management of agricultural risk that includes models for government intermediation of catastrophic risk through government disaster options for CAT risk, or DOC. This framework proposes that governments buy index-based catastrophic risk coverage in international markets and offer them at rates lower than global market rates to local insurers, who then pass the savings on to end users in developing countries. This system would mitigate large-loss/infrequent risks that are usually difficult and expensive to reinsure in traditional reinsurance markets and would ultimately allow local insurers to cover more people against the extreme risks in an ex ante fashion.

This paper includes several case studies illustrating the application of these concepts in countries around the world. While the specifics vary based on each country's needs, all of the cases involve the use of index insurance and/or the layering of risk to facilitate risk transfer. The final chapter of this document describes potential future roles for the World Bank in the area of agricultural risk management.

This document presents innovations in agricultural risk management for natural disaster risk, with the focus on defining practical roles for governments of developing countries and the World Bank in developing risk management strategies.² Recent success stories demonstrate that the World Bank can play a role in assisting countries in taking actions that effectively use limited government resources to facilitate market-based agricultural risk transfer. This is important, as developing countries, the World Bank, and the donor community are currently heavily exposed to natural disaster risk without the benefit of ex ante structures to finance losses. Instead, at each big drought or other natural disaster, those affected must appeal for financial support, leaving them vulnerable to the mercy of ad hoc responses from government, the international financial institutions, and donors. In most developing countries, livelihoods are not insured by international insurance/reinsurance providers, capital markets, or even government budgets. In addition, natural disasters and price risk in agriculture also impede development of both formal and informal banking. Without access to credit, risk-averse poor farmers are locked in poverty, burdened with old technology, and faced with an inefficient allocation of resources.

Advances in risk transfer in developed countries are leading the way to solutions to many social problems. Shiller (2003) documents progress and charts a course for far more innovation as the democratization of finance and technology spur global risk pooling. Financial and reinsurance markets in developed countries are rapidly devising index-based instruments that allow for the transfer of systemic risks and even of livelihood risks. Innovations in risk transfer for natural disasters have been well documented (Doherty 1997; Skees 1999b). The challenge is to make these innovations relevant in developing countries and to facilitate knowledge and access.

Is the absence of formal transfers of natural disaster risk inevitable in developing countries? Clearly not; formal global markets for offsetting natural disaster risks and weather risks are widely used in developed countries.³ This document demonstrates how these markets can be used to insure natural disaster risk in developing countries. Agricultural sectors in developing countries are much more exposed to the vagaries of weather than are those of richer countries, so this protection would be even more valuable to them.

Is it a luxury to offer insurance to poor people who lack proper roads or even safe drinking water? Every government must set its

own priorities. Careful consideration of the benefits and costs of different interventions is critical. Still, the poor are forced to make production decisions using the objective of minimizing risk, rather than maximizing profits, and thus they must forego more remunerative activities that could provide means of escape from their poverty. An effective and timely insurance mechanism might allow people to engage in higher risk, higher return activities without putting their livelihoods at risk. Spurring development via improved financial markets is important for developing countries.

Are there any effective precedents for agricultural insurance mechanisms in developing countries? While these innovations are just taking hold, progress has been made with weather insurance for farmers in India, Ukraine, Nicaragua, Malawi, Ethiopia, and Mexico. Several other experiments are also documented in this work. Weather insured farmers in India say they either have a good crop—in which case it does not matter if they do not recoup the insurance premium—or they have a monsoon failure, in which case they receive an insurance payout. This payout will at least cover the farmers' cash outlay and perhaps provide them with enough extra money to keep their children in school and to preserve assets they would otherwise be forced to liquidate, often at greatly reduced prices. These farmers will be likely to invest a little more in the right seeds and fertilizer at the right time. Quantifying this impact is difficult right now, but a large impact assessment will soon provide more information on the effectiveness of this program. It is clear already, however, that when offered the choice, many farmers in India will pay for fully priced weather insurance. Even farmers with access to the government-subsidized crop insurance product choose to buy the market-priced weather insurance product. They say they like the objective nature of the weather index; they can check the weather station measurements themselves. They also like the timely payout. Indeed, on this count, the new rainfall index insurance, which pays on a timely basis, compares favorably to the national crop insurance product, which might pay only after as much as eighteen months.

Is this insurance only suitable for large commercial farmers? One true advantage of weather insurance is that it can be targeted to small farmers, as no monitoring is needed to verify farm-level losses. The Indian experience clearly demonstrates that small farmers find value in weather insurance.

BASIX (a microfinance entity in Andhra Pradesh) estimates that all of the 427 farmers who bought weather insurance policies in 2003 have small- to medium-sized farms of between two and ten acres, providing an average yearly income of 15,000 to 30,000 Rupees, or between US\$1 and US\$2 per day. Currently, many farmers buying weather insurance in India are repeat customers. Clearly, these farmers were not too poor to buy the product. Early survey results demonstrate that more than half of those purchasing the insurance list managing risk as their primary reason. Some farmers might have chosen this new insurance option over the prospect of paying high interest to moneylenders when cash is needed after a harvest failure.

Is India's insurance program sustainable? With the pilot program now in its third year and other insurance companies replicating and selling the product, BASIX has mainstreamed the weather insurance product and automated delivery to an expected 8,000 clients for the 2005 season. Countries in sub-Saharan Africa and Latin America are starting their own weather insurance projects at micro- and macrolevels. Ethiopia is piloting a weather-insurance-based drought emergency response, for example. Furthermore, weather insurance seems to be a good business. The Indian weather insurance program has emerged without the support of government subsidies. The Commodity Risk Management Group (CRMG) of the World Bank has advised those who were ready to try these new approaches to agricultural risk management.

How can this process be operationalized in the World Bank and elsewhere? Task managers and practitioners may want to follow this work with potential projects, but how do they get started? This document presents ideas on how to structure a solid framework of action. Among the important public goods that governments and the World Bank might provide are, for example, weather stations and risk financing for catastrophic protection.

Governments in drought-prone countries and donors and relief agencies should also be aware of other kinds of projects that use risk management markets to improve the response to weather-related shocks. This document explores how current ad hoc disaster relief mechanisms can be modified and complemented by a more systematic response to recurrent droughts.

When assessing proper roles for government, the first factors to consider are the economic benefits that can be created by risk management tools,

the characteristics of the risks faced by farmers in a specific area, and the challenges associated with creating and maintaining risk management tools such as insurance. In general, agricultural risk management presents no “one-size-fits-all” policy recommendation for the role of government. Most governments consider at least four criteria when considering alternatives for addressing agricultural risk management needs: (1) fiscal constraint; (2) growth; (3) market-oriented risk-transfer; and (4) social goals of reducing poverty and vulnerability in rural areas.

Chapter 2 of this document begins with an overview of risk in agriculture, focusing on how decision makers currently cope with and manage risk in developing countries and on the impediments to developing effective risk transfer markets. High transaction costs, problems with correlated risk, and the classic problems of moral hazard and adverse selection clearly increase the cost of traditional insurance. Chapter 3 reviews in detail the experiences of some developed countries with agricultural risk transfer. A clear message emerges about the costs to governments and the inefficiencies of these systems, supporting the need to search for new solutions appropriate for developing countries. The stark contrast between what is possible in a developed country versus what is possible in a developing country further motivates a continuing

search for new solutions. Chapter 4 explores alternate solutions based on the concept of weather index insurance that covers farmers against weather events leading to serious agricultural losses, highlighting the advantages of such systems for developing countries. Chapter 5 brings together two core innovations: first, the use of index insurance to insure against detrimental weather events, a form with significantly lower monitoring costs; and second, the layering of insurance products to segment risk more efficiently, thus allowing for transfer of correlated risk. These innovations provide a rich framework for introducing new approaches to risk sharing and risk transfer in developing countries. Chapter 5 outlines an effective role for the World Bank and other donors in this important domain of natural hazard risk management. Chapter 6 provides an overview of a number of ongoing agricultural risk pilot programs and case studies for in various countries. Finally, Chapter 7 makes recommendations for the role of the World Bank and country governments in facilitating the development of innovation in agricultural risk management. Following the core chapters, the report includes two detailed appendixes: the first explains how to structure and price weather index insurance; the second provides more background to risk transfer programs and experiences in Ukraine, Mexico, Canada, and India.



2

Risk and Risk Management in Agriculture

Agricultural risk is associated with negative outcomes stemming from imperfectly predictable biological, climatic, and price variables. These variables include natural adversities (for example, pests and diseases), climatic factors not within the control of agricultural producers, and adverse changes in both input and output prices. To set the stage for the discussion on how to deal with risk in agriculture, we classify the different sources of that risk.⁴

Agriculture is often characterized by high variability of production outcomes, that is, by production risk. Unlike most other entrepreneurs, agricultural producers cannot predict with certainty the amount of output their production process will yield, due to external factors such as weather, pests, and diseases. Agricultural producers can also be hindered by adverse events during harvesting or collecting that may result in production losses.

Both input and output price volatility are important sources of market risk in agriculture. Prices of agricultural commodities are extremely volatile. Output price variability originates from both endogenous and exogenous market shocks. Segmented agricultural markets will be influenced mainly by local supply and demand conditions, while more globally integrated markets will be significantly affected by international production dynamics. In local markets, price risk is sometimes mitigated by the “natural hedge” effect, in which an increase (decrease) in annual production tends to decrease (increase) output price (though not necessarily farmers’ revenues). In integrated markets, a reduction in prices is generally not correlated with local supply conditions, and therefore price shocks may affect producers in a more significant way. Another kind of market risk arises in the process of delivering production to the marketplace. The inability to deliver perishable products to the right market at the right time can impair producers’ efforts. The lack of infrastructure and of well-developed markets makes this a significant source of risk in many developing countries.

The ways businesses finance their activities is a major concern for many economic enterprises. In this respect, agriculture has its own peculiarities. Many agricultural production cycles stretch over long periods, and farmers must anticipate expenses they will only be able to recuperate after marketing their product. This leads to potential cash flow problems, which are often exacerbated by lack of access to credit and the high cost of borrowing. These problems can be classified as financial risk.

Institutional risk, that is, risk generated by unexpected changes in regulations that affect producers' activities, constitutes another important source of uncertainty for agricultural producers. Changes in regulations can have significant impact on the profitability of farming activities. This is particularly true for import/export regimes and for dedicated support schemes, but sanitary and phytosanitary regulations too can restrict producers' activities and impose costs on households.

Like most other entrepreneurs, agricultural producers are responsible for all the consequences of their activities. Growing concern over the impact of agriculture on the environment, however, including the introduction of genetically modified organisms (GMO), may cause an increase in producer liability risk. Finally, agricultural households, along with other economic enterprises, are exposed to personal risks to the well-being of people who work on the farm and asset risks, including possible damage or theft of production equipment and assets. (See Box 2.1.)

In discussing how to design appropriate risk management policies, it is useful to understand strategies and mechanisms employed by producers to deal with risk, including the distinction between informal and formal risk management mechanisms and between *ex ante* and *ex post* strategies.⁵ As highlighted in the 2000/2001 World Development Report (World Bank, 2001), informal strategies are identified as "arrangements that involve individuals or households or such groups as communities or villages," while formal arrangements are "market-based activities and publicly provided mechanisms." The *ex ante* or *ex post* classification focuses on the point at which the reaction to risk takes place: *ex ante* responses take place before the potential harming event; *ex post* responses take place after the event. *Ex ante* reactions can be further divided into on-farm strategies and risk-sharing strategies (Anderson, 2001). Table 2.1 summarizes these classifications.

INFORMAL MECHANISMS⁶

Ex ante informal strategies are characterized by diversification of income sources and choice of agricultural production strategy. One strategy producers can employ is simply to avoid risk. In many cases, extreme poverty makes people very risk averse; producers facing these circumstances often avoid activities that entail significant risk, even though

the income gains might be larger than for less risky choices. This inability to accept and manage risk and accumulate and retain wealth is sometimes referred to as the "the poverty trap" (World Bank 2001).

Once producers have decided to engage in farming activities, the production strategy selected becomes an important means of mitigating the risk of crop failure. Traditional cropping systems in many places rely on crop and plot diversification. Crop diversification and intercropping systems reduce the risk of crop failure due to adverse weather events, crop pests, or insect attacks. Morduch (1995) presents evidence that households whose consumption levels are close to subsistence (and which are therefore highly vulnerable to income shocks) devote a larger share of land to safer, traditional varieties such as rice and castor than to riskier, high-yielding varieties. Morduch also finds that near-subsistence households diversify their plots spatially to reduce the impact of weather shocks that vary by location.

Apart from altering agricultural production strategies, households also smooth income by diversifying income sources, thus minimizing the effect of a negative shock to any one of them. According to Walker and Ryan (1990), most rural households in villages of semi-arid India surveyed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) generate income from at least two different sources; typically, crop income is accompanied by some livestock or dairy income. Off-farm seasonal labor, trade, and sale of handicrafts are also common income sources. The importance to risk management of income source diversification is emphasized by the Rosenzweig and Stark (1989), who find that households with high farm profit volatility are more likely to have a household member engaged in steady wage employment.

Buffer stock accumulation of crops or liquid assets and the use of credit present obvious means by which households can smooth consumption. Lim and Townsend (1998) show that currency and crop inventories function as buffers or precautionary savings.

Crop-sharing arrangements in renting land and hiring labor can also provide an effective means of sharing risk among individuals, thus reducing producer risk exposure (Hazell 1992). Other risk sharing mechanisms, such as community-level risk pooling, occur in specific communities or extended households where group members transfer resources among themselves to rebalance marginal

Box 2.1 Asset-Based Risk Management

Siegel (2005) broadens the risk discussion into an asset-based risk management framework. This comprehensive approach considers the dynamics of risks within a given context. The asset-based approach uses a “livelihood focus,” recognizing that rural households hold a portfolio of assets that they allocate among a range of welfare generating activities and that the particular livelihood activities pursued reflect explicit (or implicit) multidimensional objectives that include economic, social, cultural, and environmental outcomes (Chambers and Conway 1992; Carney et al. 1999). The asset-based approach helps clarify why and how households manage assets and risks to “select” certain livelihood strategies for achieving welfare outcomes given specific asset-context interface conditions.

The asset-based risk management approach focuses on the long-term implications of short-term decisions about the allocation of assets. Coping strategies used by poor rural households can lead to the degradation or decapitalization of assets, as when, for example, trees are cut down or children are removed from school, and these actions can contribute to a cycle of poverty. Alternatively, livelihood strategies that lead to improved asset portfolios, for example, investments in improved technology, training programs, and empowerment through social and political networks, can foster a virtuous cycle of sustainable growth. Asset accumulation and changes in livelihood strategies are thus important for sustained improvements in household well-being.

Improved management of rural risk is critical to achieve rural growth and reduce poverty. It is critical, however, to move beyond a narrow risk management focus to a more holistic rural development approach that focuses attention on building, enhancing, maintaining, and protecting household assets. The development of new rural risk management instruments offers

the potential to improve household livelihood options, yet their ultimate success will depend on the linkages among assets, context, behavior, and outcomes. Thus, the real question to be asked is what optimal risk management instruments will allow households to maximize their objectives in terms of expected income and variability of income?

The relationship between assets and productivity explains the poverty cycle and the difficulty the poor have in improving their livelihoods. A household’s portfolio of assets influences their risk attitude and their ability to respond to risk. Assets also determine the types of activities that can be undertaken. More productive activities are typically associated with greater risk, so how assets are utilized will impact productivity as a function of both expected income and variability of income. At the household level, agricultural risk management instruments reduce the variability of household incomes. The expectation is that by reducing risk and uncertainty, households will be able to accumulate assets and undertake more productive investments.

In the design of risk management instruments, it is important to account for the unique context presented in different situations. Risk management instruments must be tailored to specific constraints and objectives within the country, community, and household context.

In considering the potential applications of index insurance in developing countries, it is important to remember that index insurance is not necessarily applicable or replicable for every situation. Nor should it be inferred that index insurance is a substitute for other risk management strategies. Index insurance can, however, provide a starting point and, ideally, a springboard for the development of a variety of risk management mechanisms.

Note: A more detailed discussion of these issues can be found in “Looking at Rural Risk Management Using an Asset-Based Approach,” a background paper for this report by Paul Siegel. In particular, the reader is directed to Figure 1, which depicts the relationships among assets, context, behavior, and outcomes.

Source: Siegel 2005.

utilities (World Bank 2001). These arrangements, however, while effective for counterbalancing the consequences of events affecting only some members of the community, do not work well in cases of covariate income shocks (Hazell 1992).

Typical ex post informal income-smoothing mechanisms include the sale of assets, such as land or livestock (Rosenzweig and Wolpin 1993), or the reallocation of labor resources to off-farm labor activities. Gadgil, et al. (2002), argue that southern

Table 2.1 Risk Management Strategies in Agriculture

		Informal Mechanisms	Formal Mechanisms	
			Market Based	Publicly Provided
EX ANTE STRATEGIES	On-farm	Avoiding exposure to risk Crop diversification and intercropping Plot diversification Diversification of income source Buffer stock accumulation of crops or liquid assets Adoption of advanced cropping techniques (fertilization, irrigation, resistant varieties)		Agricultural extension Pest management systems Infrastructures (roads, dams, irrigation systems)
	Sharing risk with others	Crop sharing Informal risk pool	Contract marketing and futures contracts Insurance	
EX POST STRATEGIES	Coping with shocks	Sale of assets Reallocation of labor Mutual aid	Credit	Social assistance Social funds Cash transfer

Source: Anderson 2001; Townsend 2005; World Bank 2001.

Indian farmers who expect poor monsoon rains can quickly shift from 100 percent on-farm labor activities to mainly off-farm activities. Fafchamps (1993), in his analysis of rain-fed agriculture among West African farmers, emphasizes the importance of building labor flexibility into the production strategy.

As reported by Townsend (2005), in analyzing the cost of risk on ex ante agricultural production strategies, Rosenzweig and Binswanger (1993), Morduch (1995), and Kurosaki and Fafchamps (2002) all find considerable efficiency losses associated with risk mitigation, typically due to lack of specialization—in other words, farmers trade off income variability with profitability.

The need to smooth consumption not only against idiosyncratic shocks but also against correlated shocks comes at a serious cost in terms of production efficiency and reduced profits, thus lowering the overall level of household consumption. A major consideration for innovation would be to shift correlated risk from rural households (Skees 2003). One obvious solution would be for rural households to share risk with households or institutions from areas largely uncorrelated with the local risk condi-

tions. Examples of such extra-regional risk sharing systems are found in the literature, including, credit and transfers between distant relatives (Rosenzweig, 1988; Miller and Paulson 2000); migration and marriages (Rosenzweig and Stark 1989); or ethnic networks (Deaton and Grimard 1992). Although these studies find some degree of risk sharing and thus of insurance against weather, use of such systems is not so widespread as to cover all households, nor do they come even close to providing a fully efficient insurance mechanism. Most households are therefore still left with no insurance against correlated risks, the main source of which is weather.

FORMAL MECHANISMS

Formal risk management mechanisms can be classified as publicly provided or market based (Table 2.1). Government action plays an important role in agricultural risk management, both ex ante and ex post. Ex ante education and services provided by agricultural extension help familiarize producers with the consequences of risk and help them adopt strategies to deal with it. Governments also reduce the impacts of risk by developing relevant infra-

structure and by adopting social schemes and cash transfers for relief after shocks have occurred.⁷

As mentioned in the section on informal mechanisms, production and market risks are probably those with the largest impact on agricultural producers. Various market-based risk management solutions have been developed to address these sources of risk.

Price Risk Management

One way producers have traditionally managed price variability is by entering into preharvest agreements that set a specific price for future delivery. These arrangements, known as forward contracts, allow producers to lock in a certain price, thus reducing risk but also foregoing the possible benefits of positive price deviations. In specific markets, and for specific products, these arrangements have evolved into futures contracts, traded on regulated exchanges on the basis of specific trading rules and for specific standardized products. This reduces some of the risks associated with forward contracting (for example, default). A further evolution in hedging opportunities for agricultural producers has been the development of price options, a price guarantee that allows producers to benefit from a floor price while also allowing them to take advantage of positive price changes. With price options, agents pay a premium to purchase a contract that gives them the right (but not the obligation) to sell futures contracts at a specified price. Price options for commodities are regularly traded on exchanges, but they can also be traded in over-the-counter markets. Futures and options contracts can be effective price risk management tools as well as im-

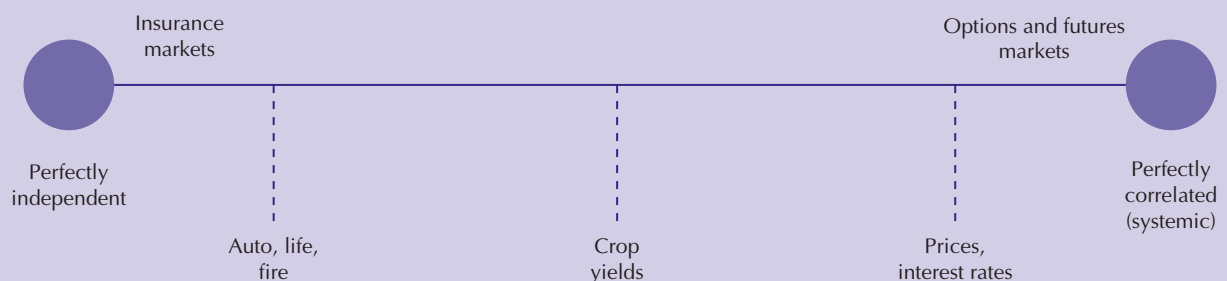
portant price discovery devices and market trend indicators.

For agricultural producers in developing countries, access to futures and options contracts is probably the exception rather than the rule. Futures and options markets in developed countries represent important price discovery references for international commodity markets, however, and indirect access to these exchange-traded instruments may be granted through the intermediation of collective action by producer groups such as farmer cooperatives or national authorities.⁸ While an important reality for some commodities, futures and options are not available for all agricultural products.

Production/Weather Risk Management

Insurance is another formal mechanism used in many countries to share production risks. Insurance does not as efficiently manage production risk, however, as derivative markets do price risks. Price risk is highly spatially correlated and, as illustrated in Figure 2.1, futures and options are appropriate instruments for dealing with spatially correlated risks. In contrast, insurance is an appropriate risk management solution for independent risks. Agricultural production risks typically lack sufficient spatial correlation to be effectively hedged using only exchange-traded futures or options instruments. At the same time, agricultural production risks are generally not perfectly spatially independent; therefore, insurance markets do not work at their best. Skees and Barnett (1999) refer to these risks as “in-between” risks. According to Ahsan, et al. (1982), “good or bad weather may have similar effects on all farmers in adjoining areas,”

Figure 2.1 Independent Versus Correlated Risk



Source: Miranda and Glauber 1997.

and, consequently, “the law of large numbers, on which premium and indemnity calculations are based, breaks down.” In fact, positive spatial correlation in losses limits the risk reduction obtainable by pooling risks from different geographical areas. This increases the variance in indemnities paid by insurers. In general, the more the losses are positively correlated, the less efficient traditional insurance is as a risk-transfer mechanism. For many ideas presented in this document, a precondition for success is a high degree of positive correlation of losses.

The lack of statistical independence is not the only problem with providing insurance in agriculture. Another set of problems relates to asymmetric information, the situation in which the insured has more knowledge about his or her own risk profile than does the insurer. Asymmetric information causes two problems: adverse selection and moral hazard. In the case of adverse selection, farmers have better knowledge than do the insurers about the probability distribution of losses. The farmers thus occupy the privileged situation of knowing whether or not the insurance premium accurately reflects the risk they face. Consequently, only farmers bearing greater risks will purchase the coverage, generating an imbalance between indemnities paid and premiums collected. Moral hazard similarly affects the incentive structure of the relationship between insurer and insured. After entering the contract, the farmer’s incentive to take proper care of the crop diminishes, while the insurer has limited effective means to monitor what may prove hazardous behavior by the farmer. Insurers may thus incur greater than anticipated losses.

Agricultural insurance is often characterized by high administrative costs, due, in part, to the risk classification and monitoring systems that insurers must put in place to forestall asymmetric information problems. Other costs include acquiring the data needed to establish accurate premium rates and conducting claims adjustments. As a percentage of the premium, the smaller the policy, typically, the larger the administrative costs.

Spatially correlated risk, moral hazard, adverse selection, and high administrative costs are all important reasons why agricultural insurance markets may fail. Cognitive failure among potential insurance purchasers and ambiguity loading on the part of insurance suppliers are other possible causes of agricultural insurance market failure.⁹

If consumers fail to recognize and plan for low-frequency, high-consequence events, the likelihood

that an insurance market will emerge diminishes. When considering an insurance purchase, the consumer may have difficulty determining the value of the contract or, more specifically, the probability and magnitude of loss relative to the premium (Kunreuther and Pauly 2001). Many decision makers tend to underestimate their exposure to low-frequency, high-consequence losses. Thus, they are unwilling to pay the full costs of an insurance product that protects against these losses. Low-frequency events, even when severe, are frequently discounted or ignored altogether by producers trying to determine the value of an insurance contract. This happens because the evaluation of probability assessments regarding future events is complex and often entails high search costs. Many people resort to various simplifying heuristics, but probability estimates based on these heuristics may differ greatly from the true probability distribution (Schade et al. 2002; Morgan and Henrion 1990). Evidence indicates that agricultural producers forget extreme low-yield events. The general finding regarding subjective crop-yield distributions is that agricultural producers tend to overestimate the mean yield and underestimate the variance (Buzby et al. 1994; Pease et al. 1993; Dismukes et al. 1989).

On the other side, insurers will typically load premium rates heavily for low-frequency, high-consequence events where considerable ambiguity surrounds the actual likelihood of the event (Schade et al. 2002; Kunreuther et al. 1995). Ambiguity is especially serious when considering highly skewed probability distributions with long tails, as is typical of crop yields. Uncertainty is further compounded when the historical data used to estimate probability distributions are incomplete or of poor quality, a very common problem in developing countries. Small sample size creates large measurement error, especially when the underlying probability distribution is heavily skewed. Kunreuther et al. (1993) demonstrate via experimental economics that when risk estimates are ambiguous, loads on insurance premiums can be 1.8 times higher than when insuring events with well specified probability and loss estimates.

Together, these effects create a wedge between the prices that farmers are willing to pay for catastrophic agricultural insurance and the prices that insurers are willing to accept. Thus, functioning private-sector markets may fail to materialize or, if they do materialize, they may cover only a small portion of the overall risk exposure (Pomareda 1986).

Approaches to Agricultural Risk in Developed Countries

To better understand agricultural risk management markets and government policies to facilitate access to risk management instruments, it is worthwhile to analyze critically the experiences of some developed countries. The experiences of the United States, Canada, and Spain are thus described for reference, but it is important to consider that these systems may not be replicable in or suitable for most developing countries. In addition, many developed countries have involved market support and income transfer programs that extend well beyond crop insurance. To the extent they are based on farm income, these programs involve levels of protection against severe crop failures. The European community has extensive policies focusing on income protection.

CROP INSURANCE PROGRAMS IN DEVELOPED COUNTRIES

This section presents overviews of agricultural risk management programs in three developed countries: the United States, Canada, and Spain. These countries have been able to implement substantial programs to reduce yield and revenue risk for agricultural producers. While these programs offer a variety of risk management products for farmers, the programs require levels of government support unfeasible for most countries.

The United States

In the United States, multiple peril yield and revenue insurance products are offered through the Federal Crop Insurance Program (FCIP), a public/private partnership between the federal government and various private sector insurance companies.¹⁰ The program seeks to address both social welfare and economic efficiency objectives. With regard to social welfare, private companies selling federal crop insurance policies may not refuse to sell to any eligible farmer, regardless of past loss history. At the same time, the program aims to be actuarially sound.

Policies are available for over one hundred commodities but in 2004 just four crops—corn, soybeans, wheat, and cotton—accounted for approximately 79 percent of the US\$4 billion in total premiums. Excluding pasture, rangeland, and forage, approximately 72 percent of the national crop acreage is currently insured under the FCIP.

About 73 percent of total premiums are for revenue insurance policies, while 25 percent are for yield insurance policies.¹¹

Most FCIP policies trigger indemnities at the farm (or even subfarm) level.¹² Yield insurance offers are based on a rolling four-to-ten-year average yield, known as the actual production history (APH) yield. The federal government provides farmers with a base catastrophic yield insurance policy, free of any premium costs.¹³ Farmers may then choose to purchase, at federally subsidized prices, additional insurance coverage beyond the catastrophic level. This additional coverage, often called “buy-up” coverage, may be either yield or revenue insurance. Farm-level revenue insurance offers are based on the product of the APH yield and a price index that reflects national price movements for the particular commodity.

For some crops and regions, defined along county barriers, area yield and/or area revenue buy-up insurance policies are offered through FCIP. On a per acre insured basis, area-level insurance products tend to be less expensive than farm-level insurance products. Thus, in 2004, area yield and area revenue policies accounted for 7.4 percent of total acreage insured but less than 3 percent of total premiums.

The federal government also provides a reinsurance mechanism that allows insurance companies to determine (within certain bounds) which policies they will retain and which they will cede to the government. This arrangement is referred to

as the standard reinsurance agreement (SRA). The SRA is quite complex, with both quota share reinsurance and stop losses by state and insurance pool; however, in essence, it allows the private insurance companies to adversely select against the government. This is considered necessary since the companies do not establish premium rates or underwriting guidelines but are required to sell policies to all eligible farmers.

The federal costs associated with the U.S. program have four components:

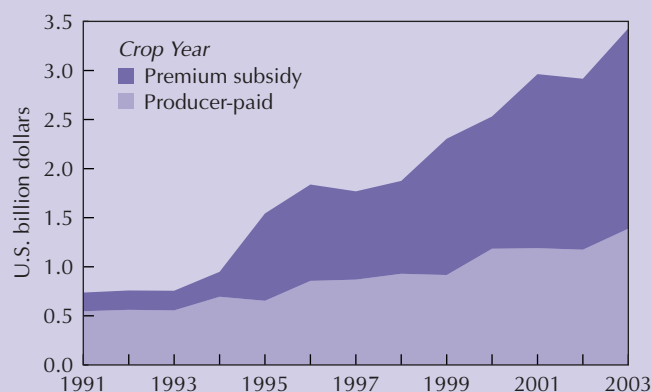
- Federal premium subsidies range from 100 percent of total premium for catastrophic (CAT) policies to 38 percent of premium for buy-up policies at the highest coverage levels. Across all FCIP products and coverage levels, the average premium subsidy in 2004 was 59 percent of total premiums.
- The federal government reimburses administrative and operating expenses for private insurance companies that sell and service FCIP policies. This reimbursement is approximately 22 percent of total premiums.
- The SRA has an embedded federal subsidy with an expected value of about 14 percent of total premiums.
- The program, by law, can be considered actuarially sound at a loss ratio of 1.075. This implies an additional federal subsidy of 7.5 percent of total premiums.

On average, the federal government pays approximately 70 percent of the total cost for the FCIP. Farmer-paid premiums account for only about 30 percent of the total cost. While the direct farmer subsidy varies by coverage level, the United States has consistently passed legislation increasing the subsidy level to farmers for crop and revenue insurance products. The rate of subsidy is one component that has influenced the growth in overall premium. Figure 3.1 clearly shows that the growth in premium subsidy is greater than the growth in farmer-paid premiums. The rate of subsidy increased in 1995 and 2001.

Canada¹⁴

In 2003, Canada revised its agricultural risk management programs. The “Business Risk Management” element of the new Agricultural Policy Framework (APF) is composed of two main schemes: Production Insurance and Income Stabilization.

Figure 3.1 Crop Insurance Premiums and Indemnities in the United States



Source: Babcock et al. 2004.

The Production Insurance (PI) scheme offers producers a variety of multiple peril production or production value loss products similar to many of those sold in the United States. One major distinction, however, is that the Canadian program is marketed, delivered, and serviced entirely and jointly by federal and provincial government entities, although it is the provincial authorities who are ultimately responsible for insurance provision. This allows provinces some leeway to tailor products to fit their regions and to offer additional products.

Production insurance plans are offered for over one hundred different crops, and provisions have been made to include plans covering livestock losses as well. Crop insurance plans are available based on either individual yields (or production value in the case of certain items, such as stone-fruits) or area based yields. Unlike the U.S. program, Canadian producers are not allowed to separately insure different parcels but rather must insure together all parcels of a given crop type. This means that low yields on one parcel may be offset by high yields on another parcel when determining whether or not an overall production loss has occurred. Insurance can also be purchased for loss of quality, unseeded acreage, replanting, spot loss, and emergency works. The latter coverage is a loss mitigation benefit meant to encourage producers to take actions that reduce the magnitude of crop damage caused by an insured peril.

Cost sharing between the federal government and each province for the entire insurance program is to be fixed at 60:40, respectively, by 2006. Federal subsidies as a percentage of premium costs vary, however, from 60 percent for catastrophic loss policies to 20 percent for low deductible production coverage. Combined, the federal and provincial governments cover approximately 66 percent of program costs, including administrative costs. This is roughly equivalent to the percentage of total program costs borne by the federal government in the U.S. program. Provincial authorities are responsible for the solvency of their insurance portfolio. In Canada, the federal government competes with private reinsurance firms in offering deficit financing agreements to provincial authorities.

Beginning in 2004, the Canadian Agricultural Income Stabilization (CAIS) scheme replaced and integrated former income stabilization programs. CAIS is based on the producer production margin, where a margin is "allowable farm income," including proceeds from production insurance minus "allowable (direct production) expenses." The pro-

gram generates a payment when a producer's current year production margin falls below that producer's reference margin, which is based on an average of the program's previous five-year margins, less the highest and lowest. One important feature of CAIS is that producers must participate in the program with their own resources. In particular, a producer is required to open a CAIS account at a participating financial institution and deposit an amount based on the level of protection chosen (coverage levels range from 70 percent to 100 percent of the "reference margin"). Once producers file their income tax returns, the CAIS program administration uses the tax information to calculate the producer's program year production margin. If the program year margin has declined below the reference margin, some of the funds from the producers' CAIS accounts will be available for withdrawal. Governments match the producers' withdrawals in different proportions for different coverage levels.

The total investment by federal and provincial governments for the "business risk management" programs is CAN\$1.8 billion per year. In 2004, approximately CAN\$600 million was provided by governments as insurance premium subsidies.

Spain

The Spanish agricultural insurance system is structured around an established public/private partnership. On the public side is the National Agricultural Insurance Agency (ENESA), which coordinates the system and manages resources for subsidizing insurance premiums, and the Insurance Compensation Agency (*Consortio de Compensación de Seguros*) that, together with private reinsurers, provides reinsurance for the agricultural insurance market. Local governments are involved only to the extent that they are allowed to augment premium subsidies offered at the national level. On the private side, insurance contracts are sold by *Agroseguro*, a coinsurance pool of companies that aggregates all insurance companies active in agriculture. Farmers, insurers, and institutional representatives are all part of a general commission hosted by ENESA that functions as the managing board of the Spanish agricultural insurance system.

Similar to programs in the United States and Canada, Spain's combined program offers insurance policies covering multiple perils. Policies are available for crops, livestock, and aquaculture activities, with risks being pooled across the country by

Agroseguro. Compared to the United States and Canada, however, farmers' associations are more actively involved in implementation and development of agricultural insurance. The government has reserves to cover extreme losses, and, as a final resort, the government treasury covers losses that occur beyond these reserves.

Total premiums for agriculture insurance policies purchased reached around US\$550 million (490 million) in 2003, of which approximately US\$225 million (200 million) have been provided by the government (Burgaz 2004). The rationale behind subsidizing agricultural insurance is that this outlay serves as a disincentive for the government to also provide free ad hoc disaster assistance. To reinforce the point, Spanish producers are ineligible for disaster payments for perils for which insurance is offered. For noncovered perils, ad hoc disaster payments are available, but only if the producer had already purchased agricultural insurance for covered perils.

WHY THE EXPERIENCE OF DEVELOPED COUNTRIES IS NOT A GOOD MODEL FOR DEVELOPING COUNTRIES

For various reasons, developing countries should avoid adopting approaches to risk management similar those adopted in developed countries. Clearly, developing countries have more limited fiscal resources than do developed countries. Even more importantly, the opportunity cost of those limited fiscal resources may be significantly greater than in a developed country. Thus, it is critical for a developing country to consider carefully how much risk management support is appropriate and how to leverage limited government dollars to spur insurance markets. In developed countries, government risk management programs are as much about income transfers as they are about risk management. Developing countries cannot afford to

facilitate similar income transfers, given the large segments of the population often engaged in farming. Nonetheless, since a larger percentage of the population in developing countries is typically involved in agricultural production or related industries, catastrophic agricultural losses will have a much greater impact on GDP than may occur in developed countries.

Policymakers should also carefully consider the varying structural characteristics of agriculture in different countries. In general, farms in developing countries are significantly smaller than are farms in countries like the United States and Canada. For traditional crop insurance products, smaller farms typically imply higher administrative costs as a percentage of total premiums. A portion of these costs are related to marketing and servicing (loss adjustment) insurance policies. Another portion is related to the lack of farm-level data and cost effective mechanisms for controlling moral hazard.

Developing countries also have far less access to global crop reinsurance markets than do developed countries. Reinsurance contracts typically involve high transaction costs related to due diligence. Reinsurers must understand every aspect of the specific insurance products being reinsured (for example, underwriting, contract design, rate making, and adverse selection and moral hazard controls). Some minimum volume of business, or the prospect for strong future business, must be present to rationalize incurring these largely fixed transaction costs. For a global reinsurer to be willing to enter a market, the enabling environment must foster confidence in contract enforcement and institutional regulations. An enabling environment is, in fact, a prerequisite for effective and efficient insurance markets, and these components are largely missing in developing countries. Setting rules assuring that premiums will be collected and that indemnities will be paid is not a trivial undertaking. The alternative risk management products discussed in Chapter 5 are structured to overcome many of these problems.

Innovation in Managing Production Risk

*Index Insurance*¹⁵

INDEX INSURANCE ALTERNATIVES¹⁶

Given the problems with some traditional crop insurance programs in developed countries, finding new solutions to help mitigate several aspects of the problems outlined above has become critical. Index insurance products offer some potential in this regard (Skees et al. 1999). These contingent claims contracts are less susceptible to some of the problems that plague multiple-peril farm-level crop insurance products. With index insurance products, payments are based on an independent measure highly correlated with farm-level yield or revenue outcomes. Unlike traditional crop insurance that attempts to measure individual farm yields or revenues, index insurance makes use of variables exogenous to the individual policyholder—such as area-level yield or some objective weather event or measure such as temperature or rainfall—but have a strong correlation to farm-level losses.

For most insurance products, a precondition for insurability is that the loss for each exposure unit be uncorrelated (Rejda 2001). For index insurance, a precondition is that risk be spatially correlated. When yield losses are spatially correlated, index insurance contracts can be an effective alternative to traditional farm-level crop insurance.

Index products also facilitate risk transfer into financial markets where investors acquire index contracts as another investment in a diversified portfolio. In fact, index contracts may offer significant diversification benefits, since the returns generally should be uncorrelated with returns from traditional debt and equity markets.

BASIC CHARACTERISTICS OF AN INDEX

The underlying index used for index insurance products must be correlated with yield or revenue outcomes for farms across a large geographic area. In addition, the index must satisfy a number of additional properties affecting the degree of confidence or trust that market participants have that the index is believable, reliable, and void of human manipulation; that is, the measurement risk for the index must be low (Ruck 1999). A suitable index required that the random variable measured meet the following criteria:

- observable and easily measured;
- objective;
- transparent;

- independently verifiable;
- reportable in a timely manner (Turvey 2002; Ramamurtie 1999); and
- stable and sustainable over time.

Publicly available measures of weather variables generally satisfy these properties.¹⁷

For weather indexes, the units of measurement should convey meaningful information about the state of the weather variable during the contract period, and they are often shaped by the needs and conventions of market participants. Indexes are frequently cumulative measures of precipitation or temperature during a specified time. In some applications, average precipitation or temperature measures are used instead of cumulative measures.

New innovations in technology, including the availability of low-cost weather monitoring stations that can be placed in many locations and sophisticated satellite imagery, will expand the number of areas in which weather variables can be measured as well as of the types of measurable variables. Measurement redundancy and automated instrument calibration further increase the credibility of an index.

The terminology used to describe features of index insurance contracts resembles that used for futures and options contracts rather than for other insurance contracts. Rather than referring to the point at which payments begin as a trigger, for example, index contracts typically refer to it as a strike. They also pay in increments called ticks.

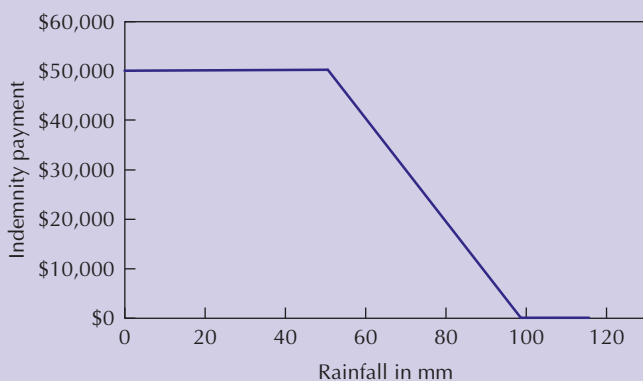
Consider a contract being written to protect against deficient cumulative rainfall during a cropping season (for example, see Figure 4.1). The writer of the contract may choose to make a fixed payment for every one millimeter of rainfall below the strike. If an individual purchases a contract where the strike is one hundred millimeters of rain and the limit is fifty millimeters, the amount of payment for each tick would be a function of how much liability is purchased. There are fifty ticks between the one hundred millimeter strike and fifty millimeter limit. Thus, if \$50,000 of liability were purchased, the payment for each one millimeter below one hundred millimeters would be equal to $\$50,000 / (100 - 50)$, or \$1,000.

Once the tick and the payment for each tick are known, the indemnity payments are easy to calculate. A realized rainfall of ninety millimeters, for example, results in ten payment ticks of \$1,000 each, for an indemnity payment of \$10,000. Figure 4.1 maps the payout structure for a hypothetical \$50,000 rainfall contract with a strike of one hundred millimeters and a limit of fifty millimeters.

In developed countries, index contracts that protect against unfavorable weather events are now sufficiently well developed that some standardized contracts are traded in exchange markets. These exchange-traded contracts are used primarily by firms in the energy sector, although the range of weather phenomena that might potentially be insured using index contracts appears to be limited only by imagination and the ability to parameterize the event. A few examples include excess or deficient precipitation during different times of the year, insufficient or damaging wind, tropical weather events such as typhoons, various measures of air temperature, measures of sea surface temperature, the El Niño southern oscillation (ENSO) tied to El Niño and La Niña, and even celestial weather events such as disruptive geomagnetic radiation from solar flare activity. Contracts are also designed for combinations of weather events, such as snow and temperature (Dischel 2001; Ruck 1999). The potential for the use of index insurance products in agriculture is significant (Skees 2001).

A major challenge in designing an index insurance product is minimizing basis risk. Basis risk refers to the potential mismatch between index-triggered payouts and actual losses. It occurs when an insured has a loss and does not receive an insurance payment sufficient to cover the loss (minus any deductible) or when an insured has a loss and receives a payment that exceeds the amount of loss.

Figure 4.1 Payout Structure for a Hypothetical Rainfall Contract



Source: Skees 2003.

Since index-insurance indemnities are triggered by exogenous random variables, such as area yields or weather events, an index-insurance policyholder can experience a yield or revenue loss and not receive an indemnity. The policyholder may also experience no yield or revenue loss and still receive an indemnity. The effectiveness of index insurance as a risk management tool depends on how positively correlated farm yield losses are with the underlying index. In general, the more homogeneous the area, the lower the basis risk and the more effective area-yield insurance will be as a farm-level risk management tool. Similarly, the more closely a given weather index actually represents weather events on the farm, the more effective the index will be as a farm-level risk management tool.¹⁸

RELATIVE ADVANTAGES AND DISADVANTAGES OF INDEX INSURANCE

Index insurance can sometimes offer superior risk protection compared to traditional farm-level, multiple-peril crop insurance. Deductibles, copayments, or other partial payments for loss are commonly used by farm-level, multiple-peril insurance providers to mitigate asymmetric information problems such as adverse selection and moral hazard. Asymmetric information problems are much lower with index insurance because, first, a producer has little more information than the insurer regarding the index value, and second, individual producers are generally unable to influence the index value. This characteristic of index insurance means that there is less need for deductibles and copayments. Similarly, unlike traditional insurance, few restrictions need be placed on the amount of coverage an individual purchases. As long as the individual farmer cannot influence the realized value of the index, liability need not be restricted. An exception occurs when governments offer premium subsidies as a percentage of total premiums. In this case, the government may want to restrict liability (and thus, premium) to limit the amount of subsidy paid to a given policyholder.

As more sophisticated systems (such as satellite imagery) are developed to measure events causing widespread losses, indexing major events should become straightforward and quite acceptable to international capital markets. Under these conditions, traditional reinsurers and primary providers may begin offering insurance in countries they

would never previously have considered. New risk management opportunities can develop if relevant, reliable, and trustworthy indexes can be constructed. A detailed technical overview of index insurance is presented in Appendix 1. Key advantages and challenges are summarized in Table 4.1.

THE TRADE-OFF BETWEEN BASIS RISK AND TRANSACTION COSTS

Among the most significant issues for any insurance product is the question of how much monitoring and administration is needed to keep moral hazard and adverse selection to a minimum. To accomplish this goal, coinsurance and deductibles are used so that the insured shares the risk and any mistakes in offering too generous coverage are mitigated. Considerable information is needed to tailor insurance products and to minimize the basis risk even for individual insurance contracts. Increased information gathering and monitoring involve higher transaction costs, which convert directly into the higher premiums needed to cover them. Index insurance significantly reduces these transaction costs and can be written with lower deductibles and without introducing coinsurance. When farm yields are highly correlated with the index being used to provide insurance, offering higher levels of protection can result in risk transfer superior even to individual multiple-peril crop insurance (Barnett et al. 2005).

The direct trade-off between basis risk and transaction costs has implications for achieving sustainable product designs and for outlining the role of governments and markets. Chapter 5 introduces the idea of layering risk. These concepts also greatly depend on understanding the trade-off between basis risk and transaction costs. At every level of risk transfer, someone must accept a certain degree of basis risk if the products are to be both sustainable and affordable. In short, extremely high transaction costs must be paid for. The social cost of having products with some basis risk may be significantly lower than the social cost associated with the high transaction cost entailed in attempting to design products that have no basis risk.

WHERE INDEX INSURANCE IS INAPPROPRIATE

Index insurance contracts will not work well for all agricultural producers. Many agricultural com-

Table 4.1 Advantages and Disadvantages of Index Insurance

Advantages	Challenges
<p><i>Less moral hazard</i> The indemnity does not depend on the individual producer's realized yield.</p>	<p><i>Basis risk</i> Without sufficient correlation between the index and actual losses, index insurance is not an effective risk management tool. This is mitigated by self-insurance of smaller basis risk by the farmer; supplemental products underwritten by private insurers; blending index insurance and rural finance; and offering coverage only for extreme events.</p>
<p><i>Less adverse selection</i> The indemnity is based on widely available information, so there are few informational asymmetries to be exploited.</p>	<p><i>Precise actuarial modeling</i> Insurers must understand the statistical properties of the underlying index.</p>
<p><i>Lower administrative costs</i> Underwriting and inspections of individual farms are not required.</p>	<p><i>Education</i> Users must be able to assess whether index insurance will provide effective risk management.</p>
<p><i>Standardized and transparent structure</i> Contracts can be uniformly structured.</p>	<p><i>Market size</i> The market is still in its infancy in developing countries and has some start-up costs.</p>
<p><i>Availability and negotiability</i> Standardized and transparent, the contracts may be traded in secondary markets.</p>	<p><i>Weather cycles</i> Actuarial soundness of the premium could be undermined by weather cycles that change the probability of the insured events, such as El Niño, for example.</p>
<p><i>Reinsurance function</i> Index insurance can be used to transfer the risk of wide-spread correlated agricultural production losses more easily.</p>	<p><i>Microclimates</i> These production conditions make rainfall or area-yield index based contracts difficult for frequent and localized events.</p>
<p><i>Versatility</i> Index contracts can be easily bundled with other financial services, facilitating basis risk management.</p>	<p><i>Forecasts</i> Asymmetric information about the likelihood of an event in the near future creates the potential for intertemporal adverse selection.</p>

Source: Authors.

modities are grown in microclimates. Coffee grows on certain mountainsides in various continents and countries, for example, and fruits such as apples and cherries also commonly grow in areas with very large differences in weather patterns within only a few miles. In highly spatially heterogeneous production areas, basis risk will likely be so high as to make index insurance problematic. Under these conditions, index insurance will work only if it is highly localized¹⁹ and/or can be written to protect only against the most extreme loss events. Even in these cases, it may be critical to tie index insurance to lending, since loans are one method of mitigating basis risk.

Overfitting the data is another concern with index insurance. If one has a limited amount of crop yield data, fitting the statistical relationship between the index and that limited data can become problematic. Small sample sizes and fitting regressions within the sample can lead to complex contract designs that may or may not be effective hedging mechanisms for individual farmers. Standard procedures that assume linear relationships between the index and realized farm-level losses may be inappropriate. While scientists are tempted to fit complex relationships to crop patterns, interviews with farmers may reveal more about the types of weather events of most concern. When designing

a weather index contract, one may be tempted to focus on the relationship between weather events and a single crop. When it fails to rain for an extended period of time, however, many crops will be adversely affected. Likewise, when it rains for an extended period of time, resulting in significant cloud cover during critical photosynthesis periods, a number of crops may suffer.

Finally, when designing index insurance contracts, significant care must be taken to assure that the insured has no better information about the likelihood and magnitude of loss than does the insurer. Farmers' weather forecasts are quite often highly accurate. Potato farmers in Peru, using celestial observations and other indicators in nature, are able to forecast El Niño at least as well as many climate experts (Orlove et al. 2002). In 1988, an insurer offered drought insurance in the U.S. Midwest. As the sales closing date neared, the company noted that farmers were significantly increasing their purchases of these contracts. Rather than recognize that these farmers had already made a conditional forecast that the summer was going to be very dry, the company

extended the sales closing date and sold even more rainfall insurance contracts. The company experienced very high losses and was unable to meet the full commitment of the contracts. Rainfall insurance for agriculture in the United States suffered a significant setback. The lesson learned is that when writing insurance based on weather events, it is crucial to be diligent in following and understanding weather forecasts and any relevant information available to farmers. Farmers have a vested interest in understanding the weather and climate. Insurance providers who venture into weather index insurance must know at least as much as farmers do about conditional weather forecasts. If not, intertemporal adverse selection will render the index insurance product unsustainable. These issues can be addressed; typically, the sales closing date must be established in advance of any potential forecasting information that would change the probability of a loss beyond the norm. But beyond simply setting a sales closing date, the insurance provider must have the discipline and the systems in place to ensure that no policies are sold beyond that date.

New Approaches to Agricultural Risk Management in Developing Countries

ROLE OF GOVERNMENT

Should the lack of effective private-sector agricultural insurance markets in developing countries be addressed through government intervention? High transactions costs preclude emergence of many markets, but this does not necessarily justify government intervention.

In the case of high-frequency, low-consequence losses, government intervention is likely to distort incentives and create rent-seeking opportunities, possibly to an extent that actually reduces net social welfare. Farmers can employ other risk management mechanisms to cover these losses. In fact, insurance products for high-frequency, low-consequence losses are seldom offered because the transaction costs associated with loss adjustment renders the insurance cost prohibitive for most potential purchasers.

Governments may have no inherent advantage over markets in trying to facilitate the provision of individual farm-level yield or revenue insurance products. The private sector typically does not provide these insurance products in part because of information asymmetries that cause moral hazard and adverse selection problems (Miranda and Glauber 1997); it is difficult to see how a government provider would have any advantage in addressing this problem.

In the case of low-frequency, high-consequence loss events, however, government intervention may be justified. As explained in the section on production/weather risk management, research suggests that many decision makers tend to underestimate their exposure to low-frequency, high-consequence losses, a tendency reinforced when the decision maker believes the government will provide assistance in the event of a disaster. Thus, producers thinking in this way will be unwilling to pay the full costs of insurance products that protect against these losses. Those who do buy insurance against low-frequency, high-consequence losses often cancel the policy if they do not receive an indemnity for an extended period. Thus, it seems that to be successful agricultural insurance products must be constructed so that they make indemnity payments with reasonable frequency, for example, once every seven or ten years.

On the supply side, insurers will typically load premium rates heavily for low-frequency, high-consequence loss events where considerable ambiguity surrounds the actual likelihood of the event. Together, these effects create a gap between the prices farmers will pay for catastrophic agricultural insurance and the prices insurers will accept. Thus functioning private sector markets fail to materialize, or,

if they do materialize, they cover only a small portion of the overall risk exposure. This type of market failure is commonly cited as justification for government interventions to facilitate provision of products or services not otherwise provided (or provided in sufficient quantity) by private markets.

Subsidies for catastrophic reinsurance (see Box 5.1) are a type of government intervention that can facilitate the provision of insurance for low-frequency, high-consequence loss events. Hardaker, et al. (2004), provide the following arguments for such an approach:

1. Governments already provide disaster relief; providing assistance through reinsurance might be more efficient.
2. The financial involvement of a government may address a moral hazard problem in its behavior: many catastrophes can either be prevented or magnified by government policies or lack thereof. Government financial re-

sponsible for some losses might be an incentive for putting in place appropriate hazard management and mitigation measures.

3. A government's financial involvement in reinsurance may reduce political pressure to provide distorting and often capricious ad hoc disaster relief.
4. Governments can potentially provide reinsurance more economically than can commercial reinsurers. A government's advantages, including its deep credit capacity and unique position as the country's largest entity, enable it to spread risks more broadly.

If governments are to intervene in agricultural insurance markets, the social benefits of reducing the inefficiencies brought on by risk must outweigh the social cost of making agricultural insurance work. This chapter presents a framework for government agricultural risk policy formulation that focuses on policy objectives, constraints on government

Box 5.1 Reinsurance

Reinsurance is insurance for insurers. Just like insurance, reinsurance is “fundamentally the promise to pay possible future claims against a premium today.” Insurers often hold undiversifiable or extreme risk in their portfolios, and since they do not wish to retain all of it, they transfer some risk to reinsurance companies, paying the reinsurers a premium to do so. Reinsurers also advise insurers on product development and more complex risk-taking.

Reinsurance agreements can be proportional or nonproportional. With proportional agreements, insurers and reinsurers divide premiums and losses in a contractually defined proportion; with nonproportional agreements, the insurer usually pays all losses up to a defined amount and the reinsurer indemnifies for losses above that limit. Quota-share and surplus reinsurance are examples of proportional reinsurance agreements. Excess-of-loss and stop-loss agreements are examples of nonproportional reinsurance.

Reinsurers seek to operate across boundaries in order to build globally diversified portfolios. More than 250 reinsurers in 50 countries wrote annual reinsurance premiums of approximately US\$176 billion in 2003.^a Nonlife reinsurance premiums accounted for US\$146 billion, or about 14 percent, of the global nonlife primary insurance industry. Only US\$25 billion of these premiums are written outside North America and Western Europe.^b The ten largest reinsurers write about 54 percent of reinsurance premiums, and the two giants in the business, Munich RE and Swiss RE, write around US\$49 billion of reinsurance premiums.^c

Securitization, an alternative to traditional reinsurance, transfers catastrophic risks to capital markets in the form of financial securities. Securitization has been used for exposure to natural catastrophes, such as earthquakes and hurricanes.

Notes:

a. Standard & Poor's Global Reinsurance Highlights, 2004 Edition.

b. Latin America: \$US4.7 billion; Asia: \$US13.8 billion; rest of the world: \$US6.7 billion. For comparison, the World Bank disburses approximately \$US0.5 billion per year in emergency assistance grants and loans to developing countries.

c. This premium volume includes life and health reinsurance premiums.

Source: Swiss Re 2004.

action, risk principles, and potential policy instruments (Figure 5.1). The framework is then used to consider alternative models for government intervention in agricultural insurance markets.

POLICY OBJECTIVES

Governments that seek to spur growth and eradicate poverty almost inevitably mix economic policies meant to enhance efficiency and growth with social policies meant to address poverty and vulnerability. Governments also often pursue equity or income redistribution objectives. Thus, government policies related to agriculture and rural areas tend to pursue the following objectives:

- *Growth.* Economic growth in rural areas—in particular higher agricultural yields and value-added processing as well as development of off-farm activities—is perceived to be the best way out of poverty in the medium term. While better incentives for market players and an enabling infrastructure are key drivers, better management of agricultural production risk is also critical for growth, as it enhances access to credit and adoption of new technologies.²⁰
- *Reduction of poverty and vulnerability in rural areas.* To achieve social and equity goals, governments directly intervene in a targeted manner, because free markets do not necessarily alleviate poverty for those in society who cannot effectively participate in them. Safety nets provide one tool for such government intervention.²¹

Given limited resources in developing countries and the existence of other sectors requiring government attention, these objectives are typically pursued within an environment of binding fiscal constraints. The two objectives target different segments of the rural population and different risk profiles. Growth objectives focus on increasing profitability so that less poor farmers can continue adopting production technologies even when high-frequency, low-consequence loss events occur. Poverty reduction policies seek to increase the average income of poor farmers, thus decreasing

the volatility of their income and the likelihood that a risk event will wipe out hard-won asset gains.

A precondition for achieving sustainable growth and poverty reduction is an ex ante system for disaster risk management. Disaster risk management covers severe and very infrequent events affecting mostly the poor, because the poor are more vulnerable and tend to live in marginal and more risk-exposed areas. Susceptibility to and the experience of major natural disasters tend to trap people in poverty, due to the lack of efficient risk management at the household level.²² Government disaster risk policies often entail some form of monetary compensation for victims of natural disaster. The

Figure 5.1 Framework for Governmental Agricultural Risk Management Policy Formulation

Objectives

- Agricultural and rural economic growth
- Poverty reduction

Constraints

- Underdeveloped financial sector
- Disaster risk
- Agricultural sector dominated by small farms
- Government fiscal limitations
- Underdeveloped regulatory framework

Principles

- Segment independent versus correlated risk
- Minimize rent seeking that creates market distortions
- Diversification of risk — risk management — risk layering
- Risk transfer cost optimization — reduce transaction costs

Policy Instruments

- Mechanisms for transferring catastrophic risk layers
- Limited government subsidies
- Contingent funding for disaster relief and enhanced social safety nets

Source: Authors.

challenge is to deliver timely and predictable aid in disaster situations. This requires *ex ante* planning rather than just *ex post* disaster responses. This also implies efforts to forestall political demands for *ex post*, *ad hoc* government disaster assistance. Indeed, a credible and reliable disaster risk management system can put farmers and countries on a higher growth path by making people more comfortable with taking calculated and protected risks.

Naturally growth and poverty-reduction objectives overlap, but this makes it even more important to identify clear objectives and to design effective and cost-efficient ways to achieve them. Mixing objectives can lead to suboptimal outcomes. Many government-facilitated crop insurance programs, for example, attempt to accomplish social welfare and economic efficiency objectives simultaneously.

CONSTRAINTS IN AGRICULTURAL RISK MANAGEMENT

When making decisions about agricultural risk management programs, policymakers face a number of constraints. They must consider whether the benefits of such programs outweigh the costs and if the benefits from putting resources into risk management programs are greater than the benefits of using these resources for other social needs. Governments must construct risk management programs that minimize distortions in resource allocation and reduce opportunities for rent-seeking behavior. They must take into consideration the status and development of financial and insurance institutions within the country, any regulatory constraints on the operations of those institutions, and the infrastructure for enforcing contracts. Finally, policymakers must consider the dichotomy, present in many countries, between smallholder farms and large farms producing for export markets.

Cost-Benefit Analyses of Agricultural Risk Management Projects

Traditional economic analyses of projects (or other sector interventions) weigh social benefits against social costs, usually in monetary terms. In theory, this procedure should make it possible to compare the net benefits from these projects with the net benefit of a government risk management program. Conducting such a comparison is not a trivial exercise, however, because numerous assumptions, not

always robust across different projects, are required to quantify risk management benefits. Still, it is worthwhile to compare the net benefits of government risk management programs with the net benefits from other projects, if only to get a sense of the orders of magnitude involved.

Fiscal Constraints

Government expenses for agricultural insurance programs can be quite high, a reality often masked by how the actuarial performance is presented. Governments typically report loss ratios, or cost to premium ratios, as indemnities paid divided by total premiums collected. This method presents two problems: first, due to government premium subsidies, farmers pay only a fraction of the total premium; second, governments typically absorb most administrative and operating costs. When calculating loss ratios for private sector insurance products, administrative costs are included in the numerator. When considering only indemnity relative to premiums (without noting that significant portions of premiums are paid by the public sector), both the U.S. and Canadian crop insurance programs have, in recent years, reported loss ratios around 1.0. These loss ratios are then cited as evidence that the programs are actuarially sound. But when administrative and operating costs are added to the numerator and government premium subsidies are subtracted from the denominator, so that the loss ratio is equivalent to the standard used for private sector insurance products, crop insurance loss ratios are about 3.6 for the United States and 2.9 for Canada.²³ Hazell (1992) estimates similar ratios for a number of government-based crop insurance programs. His estimates for programs in the Philippines, Japan, and Brazil, for example, show loss ratios (as defined in the private sector) exceeding 4.0.

Policymakers often suggest agricultural insurance programs as alternatives to free *ex post* disaster assistance. In principle, insurance programs have many advantages over *ex post* disaster assistance. Disaster assistance programs, it is often argued, for example, can generate perverse incentives that increase the magnitude of losses in subsequent disaster events (Barnett 1999; Rossi et al. 1982). But, in practice, agricultural insurance programs have often evolved into alternate vehicles for transferring wealth from the public sector to agricultural producers. Furthermore, not much evidence

indicates that agricultural insurance programs have been successful in forestalling free ex post government disaster assistance. In the United States, for example, more and more costly crop insurance programs have coexisted with disaster payments for well over twenty years (Glauber 2004).

Operational Constraints: Minimize Distortions/Rent-Seeking Opportunities

Governments should only invest public resources in developing agricultural insurance if the social costs of the inefficiencies resulting from the lack of such insurance products outweigh the social costs of government intervention. Social costs include not only the opportunity costs of public resources used to create and maintain the agricultural insurance products but also any resource allocation distortions that result when farmers and rural decision makers respond to the incentives created by the insurance products. This can include rent-seeking and regressive effects that benefit mostly large commercial farmers.

Contract Enforcement

Contract enforcement is critical to achieving effective and sustainable risk management programs. It is very difficult to develop insurance contracts if the legal and regulatory environment does not exist for contract enforcement. Purchasers will lose trust in the program if indemnity payments are not made on a timely basis or if they are frequently tied up in lengthy legal procedures.²⁴ Likewise, insurers will lose trust in the program if they are forced to pay indemnities for losses that the contract was not intended to cover.

Level of Financial Sector Development

Complex agricultural insurance programs are unlikely to be sustainable unless they are accompanied by adequate insurance capital and expertise. In developing countries, insurance sectors are often underdeveloped and concentrated in very few lines of business, for example, automobile, property, and casualty insurance. Insurance companies in developing countries also tend to be based in urban areas and to shy away from doing business in rural areas, where the insurance market is characterized by high transaction costs and small policies.

New products will be required if agricultural insurance is to take root in countries with underdeveloped traditional insurance sectors. Insurance products based on an index recognized and accepted by international reinsurers, for example, can provide opportunities to bypass in-country insurance capacity constraints. If the reinsurer accepts the index data and settlement procedures, the insurer's capital becomes somewhat less relevant than for traditional lines of insurance; this is because the reinsurer is not really accepting the insurer's underwriting risk but only the risk inherent in the index. Experience with reinsurance for weather index contracts reveals that reinsurers may even be willing to take 100 percent of the risk. For operational and regulatory reasons, however, international reinsurers prefer to deal with professionally-run companies to source the risk.

Structure of Agricultural Sectors

Agriculture dominated by smallholders imposes clear constraints on the large scale roll-out of sophisticated crop insurance programs or, indeed, of any agricultural risk management scheme. Farmers with one hectare of land or less will never offer an attractive marketing target for insurance companies. The challenge is to identify suitable aggregators of risk, such as microfinance institutions, banks or cooperatives, or even local authorities who can enroll farmers in group insurance programs. Agricultural sectors need to be segmented, with distribution channels tailor-made to specific needs and local customs.²⁵

Regulatory Constraints

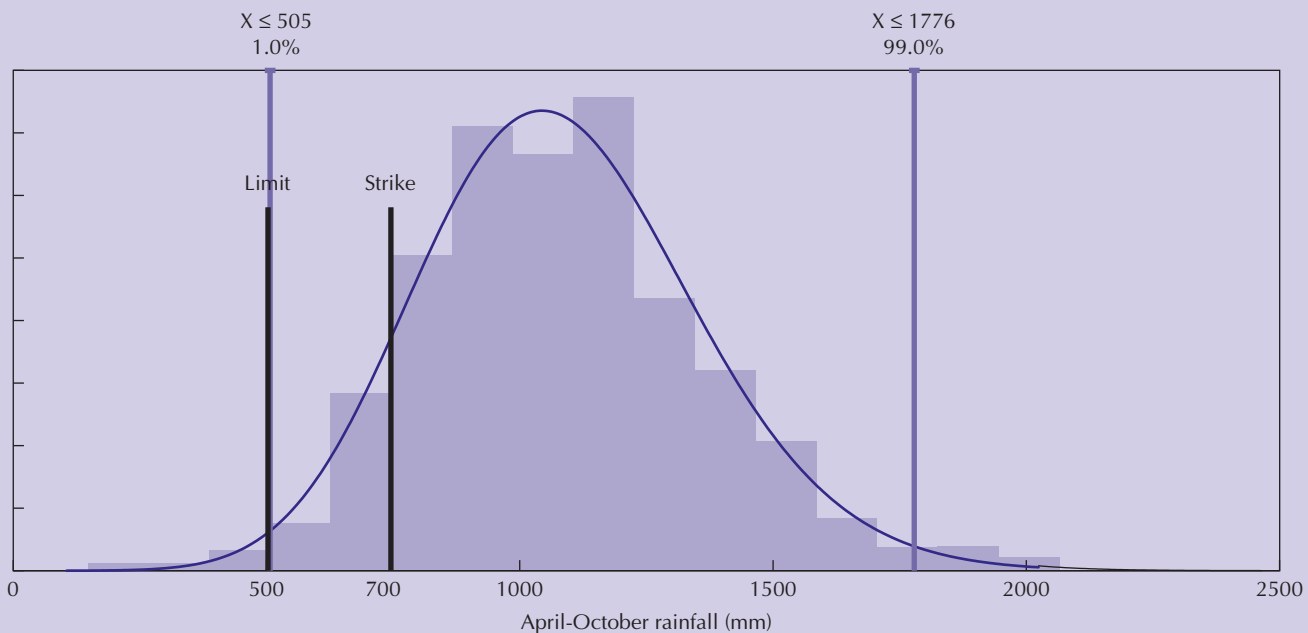
Agricultural risk transfer involves financial contracts that are regulated according to prudential principles. Insurance companies must organize the financing to pay for the possibility of the worst case scenario. This constrains the type and sophistication of contracts, which may also be constrained by limitations in the regulator's ability to understand and supervise new products.

RISK PRINCIPLES

Layering and the Role of Index Insurance

Segmenting risk into different "layers" is a key risk management principle. Consider, for example, Figure 5.2, which shows the probability distribution

Figure 5.2 Average April to October Rainfall for Thirteen Malawi Weather Stations



Source: Authors.

for average April to October rainfall at thirteen weather stations in Malawi.²⁶ Suppose that farmers start incurring production losses whenever rainfall is less than one thousand millimeters. The domain of losses might be segregated into three risk layers, with different entities holding each layer:

- For rainfall in excess of seven hundred millimeters, farmers would retain the loss risk, either individually or with financial service providers: the risk retention layer.
- For rainfall between five hundred and seven hundred millimeters, the risk would be transferred to an insurance company via a weather index insurance product: the market insurance layer.
- For rainfall levels below five hundred millimeters, the risk in this example would not be insured due to cognitive failure and ambiguity loading: the market failure layer.²⁷

Farmers would absorb losses in the risk retention layer using self-insurance strategies such as those described in Chapter 2. Strategies for effectively transferring the other risk layers are described below.

ADDRESSING THE MARKET INSURANCE RISK LAYER

Referring again to Figure 5.2, suppose that an insurance provider writes a rainfall index insurance contract with a strike of seven hundred millimeters and a limit of five hundred millimeters. Limits are commonly used by weather index insurance writers to avoid open-ended exposure to catastrophic weather events. The insured would select the amount of insurance (the liability) and the payment per tick would be calculated using this formula.

$$\text{Payment Per Tick} = \frac{\text{Liability}}{\text{Limit} - \text{Strike}}$$

Assume that a farmer has a crop with an expected value of \$15,000. At only five hundred millimeters of rainfall, the farmer is estimated to lose two-thirds of the value of the crop. Thus, the farmer purchases \$10,000 of liability, with a payment for each tick (each millimeter of rainfall) of fifty (\$10,000 divided by (700 – 500)). If the realized value for the rainfall index is six hundred millimeters, for example, the indemnity will be \$5,000 ((700 – 600) × \$50).²⁸

The limit of five hundred millimeters caps the insurance provider's loss exposure on the index insurance product. Without the limit, the contract would be extremely expensive, since it would protect against losses in the extreme lower tail of the probability distribution. Buyers would exhibit cognitive failure regarding the probability of events with less than five hundred millimeters of rainfall, while insurance providers would load the premium for ambiguity regarding these same events. Thus, even if insurance was available to protect against rainfall events of less than five hundred millimeters, few transactions would be likely, since the premium would exceed most buyer's willingness to pay.

Spatial Correlation of Risk

Weather events that cause agricultural losses are often highly spatially correlated. In the presence of such spatial correlation, index insurance products, such as the rainfall index insurance described above, can be effective risk transfer mechanisms. Once the risk is transferred from the farmer to a local insurance provider, however, spatial correlation makes it very difficult for the local insurance provider to generate much risk reduction through pooling. Unless some mechanism exists for transferring the spatially correlated loss risk out of the region or country, local insurance providers will be reluctant to offer insurance products, even if those products protect only against losses in the market insurance layer.

Risk Transfer Strategies

At least three strategies exist for transferring risk from index insurance contracts: (1) direct transfer of contracts into reinsurance markets; (2) packaged transfer of independent contracts; and (3) pooling of risk and subsequent transfer of the pool tail risk. (See Table 5.1.) Under the first two strategies, no basis risk occurs, insofar as every single contract is reinsured against payouts that exceed a defined level. Since no pooling occurs prior to the risk transfer, however, direct and packaged risk transfer strategies will likely have higher reinsurance premium rates than will the transfer of pooled risks, even if the reinsurer offers portfolio-adjusted pricing. Under the third strategy of pooling risk prior to transfer, insurers could be exposed to some basis risk, insofar as a pool of indexes does not perfectly reflect the payout likelihood of each individual contract, and only the excess risk of the overall pool

would be reinsured. If there are opportunities to diversify risks within the pool, however, this strategy could lead to lower reinsurance premiums relative to either of the other two strategies, since the risk of the overall pool (rather than each individual contract) would be reinsured. The first strategy does not involve the government in the transfer of risk. The other two strategies *may* involve government, either in facilitating risk transfer (for the second strategy) or in pooling risk and facilitating risk transfer (for the third strategy).

Pooling of Risk

The third risk transfer strategy identified above involves pooling risks within the country or region. Risk pooling is based on the statistical law of large numbers, which states that the more uncorrelated risks are added to a portfolio, the lower the variance in the outcomes of the overall portfolio. For an insurer, this results in lower capital needs and, therefore, lower capital costs.

Index-based insurance contracts can be pooled and transferred in a number of ways. In one method, the reinsurance contract can be based on a basket index that is a weighted average of the indexes contained in the pool. A risk management program being considered for Malawi would have private insurers sell rainfall-based index insurance contracts for various weather stations around the country. The government would purchase reinsurance protection and sell it to the insurers. For reinsurance coverage, the government could use the Malawi Maize Production Index (MMPI), a weighted average of weather station indexes with each station's contribution weighted by the corresponding expected maize production from that location. The more highly spatially correlated the risks on the underlying indexes, the better the basket index will perform as a reinsurance mechanism (that is, the lower the reinsurance basis risk). But, of course, the more highly spatially correlated the risks on the underlying indexes, the less advantage there is to pooling within the country as opposed to simply transferring the underlying weather station indexes to the reinsurance market using either of the first two strategies identified above.

A pool of index insurance risks can also be transferred using traditional stop-loss reinsurance. In this case, in exchange for a reinsurance premium, the reinsurer would simply cover all losses in excess of a predefined percentage (for example, 110 percent)

Table 5.1 Risk Transfer Strategies

Strategy	Advantages/Disadvantages	Role of Government
<p>Direct risk transfer Contracts are transferred directly from insurers to reinsurers.</p>	No basis risk. Pooling occurs at reinsurer level. If spatial diversification opportunities exist, reinsurance premium rates will likely be higher than if risks were pooled at insurer level (even if the reinsurer offers portfolio adjusted reinsurance premiums). Reinsurer will need to perform extensive due diligence on index but little due diligence on insurer.	Government is not involved in facilitating risk transfer.
<p>Packaged risk transfer Contracts are bundled among companies and transferred to one (syndicate) of reinsurers.</p>	Same as above, only may pay lower reinsurance premium rates because bundling reduces transactions costs for the reinsurer.	Either government or an association of insurers can facilitate the bundling and transfer of contracts to the reinsurance market.
<p>Pooling and transfer Contracts are pooled within the country and/or region with only the tail risk of the pool transferred to reinsurers.</p>	Some basis risk. If spatial diversification opportunities exist, reinsurance premium rates will be lower than with other strategies. In the case of pool reinsurance based on traditional stop-loss coverage ^a transactions costs may be higher, since the reinsurer will need to perform due diligence not only on the index but also on the pool. In case of reinsurance based on index insurance, pool due diligence is avoided, but basis risk would be higher. ^b	Either government or an association of insurers can facilitate the risk pooling and transfer of pool tail risk to the reinsurance market.

Notes:

a. For the agricultural insurance pool proposed by the Mongolian project of the World Bank, see the case study in Chapter 6.

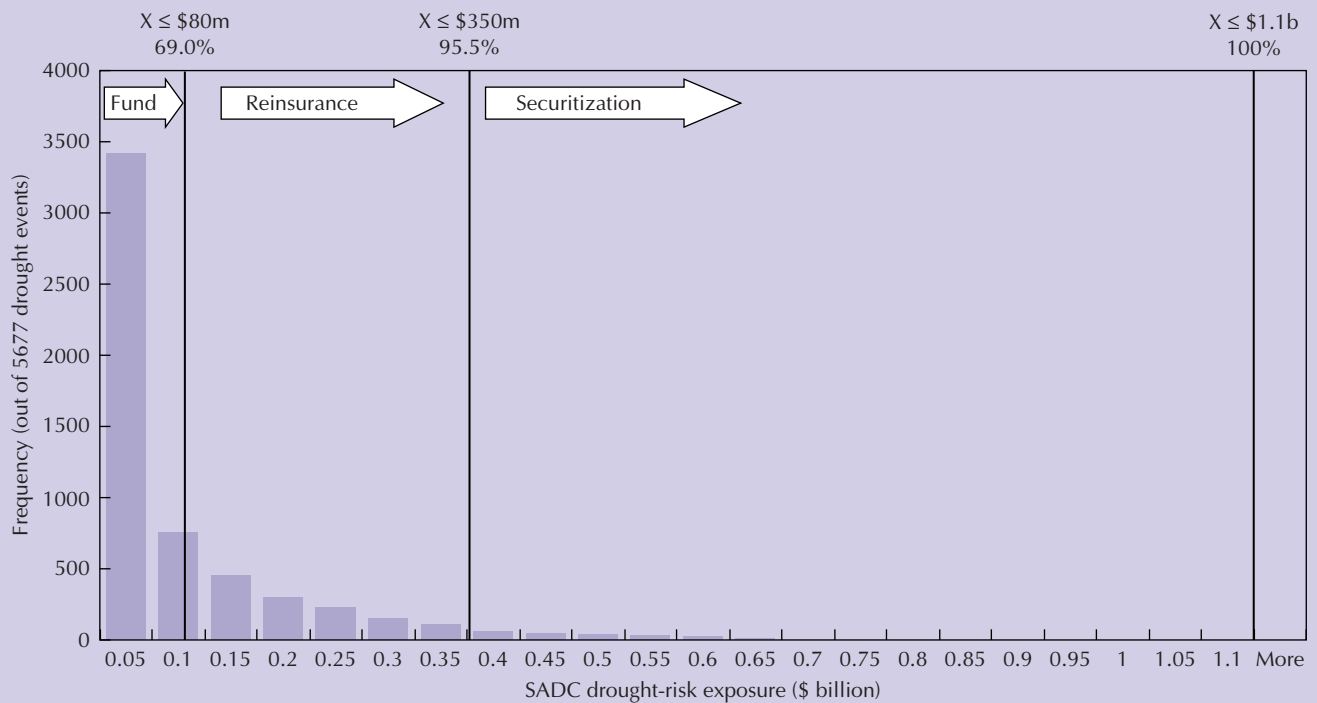
b. See the Agroasemex case in Appendix 2.

Source: Authors.

of the total premium dollars in the pool. With this type of reinsurance (and unlike reinsurance based on a basket index), the pool would not be exposed to basis risk. The transactions costs for the reinsurer will be much higher compared to the basket index based reinsurance, however, since the reinsurer will need to conduct due diligence on not only the underlying indexes but also the underwriting of the pool. All other things being equal, higher transactions costs will lead reinsurers to charge higher reinsurance premiums. Despite this, if spatial diversification opportunities are sufficiently high, pooling may reduce risk exposure to such an extent that reinsurance premium costs are reduced.

This concept can be extended to the pooling of multicountry risks within a region. Weather risk can be retained and managed internally if the areas under management are significantly diverse in their weather risk characteristics. This immediately suggests that the weather sensitivity of neighboring countries must be taken into account when considering a country's weather-risk profile and its need for outside reinsurance. Consider the example of the region of the Southern African Development Community (SADC; Figure 5.3). Analysis shows that, on average, two countries in the region suffer a drought each year. The distribution of drought events in SADC is extremely long-tailed, however,

Figure 5.3 Histogram of Simulated SADC Drought Events



Source: Hess and Syroka 2005.

with the possibility of widespread drought events that could potentially devastate the region.

A SADC pool of rainfall-based index insurance contracts could be constructed, with each member country being charged an actuarially fair assessment of the risk transferred to the pool. Suppose the financial impact to the pool of four SADC countries experiencing simultaneous droughts is about US\$80 million. The pool may wish to transfer the risk of losses beyond US\$80 million to the international reinsurance market. This could be done in layers with, for example, one layer of US\$80 to 350 million being transferred using reinsurance mechanisms.²⁹ Losses in excess of US\$350 million, as might occur with simultaneous droughts in ten SADC countries, occur with a frequency of about 1 percent. Instruments such as catastrophe (CAT) bonds might be used to transfer this extreme layer. CAT bonds allow the transference of very large exposures into financial markets and often have tenures of up to three years.

More efficient means of transferring risk imply that costs could be greatly reduced for the member

countries by transferring risk as part of a regional strategy rather than by transferring the risk one country at a time. The SADC pooling approach above, for example, would reduce insurance costs by 22 percent for one of the countries, Malawi, due to risk-pooling effects (Hess and Syroka 2005). Managing a pool requires a high degree of underwriting and actuarial sophistication, however. Reinsurers will conduct due diligence and will be very reluctant to write traditional excess of loss reinsurance unless they are convinced that the pool is being managed appropriately.

MARKET FAILURE LAYER

At the catastrophic loss layer represented by market failure, private decision makers will likely not purchase adequate insurance due to cognitive failure, ambiguity loading of premiums rates, and perhaps, expectations of government or donor disaster relief. Some form of government intervention may be required to facilitate adequate transfer of the risk in this layer.

POLICY INSTRUMENTS

Risk layering provides an extremely helpful conceptual framework for thinking about government intervention in risk transfer markets. The discussion of the market insurance layer described situations in which government packaging or pooling of risk could potentially reduce the transaction costs associated with risk transfer and thus the premiums paid by end users. This section explores other possible government interventions, including government facilitation of risk transfer in the market failure layer, the role of government subsidies in risk transfer markets, and potential uses of index insurance instruments to finance government disaster relief and safety net policies.

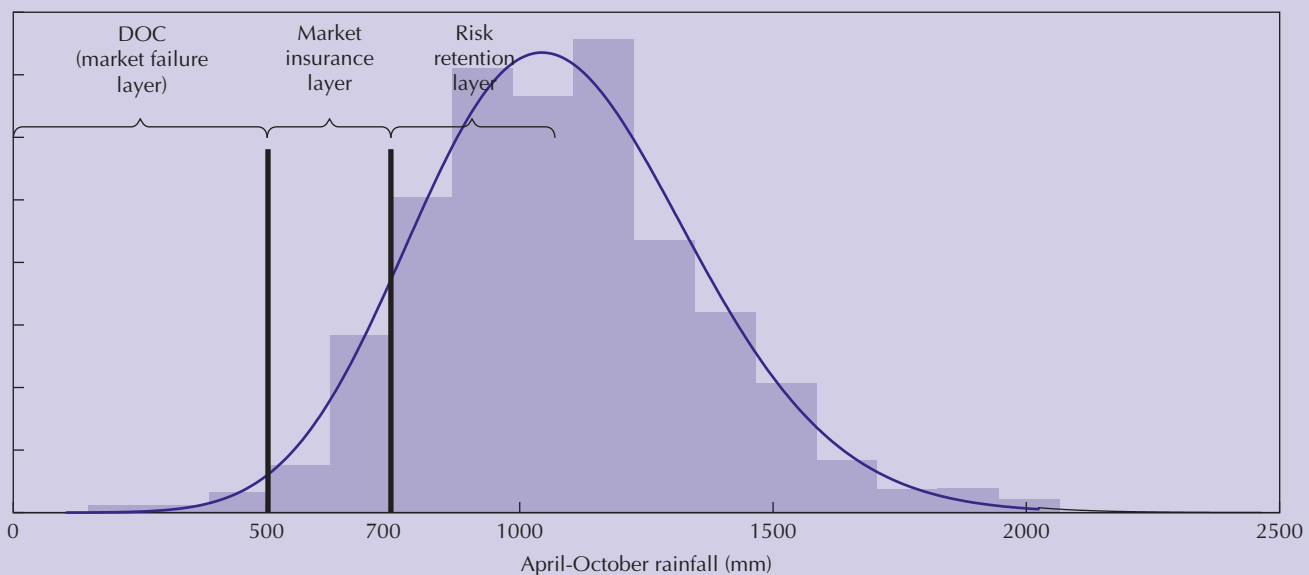
Government Disaster Option for CAT Risk: A Policy for the Market Failure Layer³⁰

Cognitive failure and ambiguity loading occur primarily with events in the extreme tail of the loss distribution, the area previously termed the market failure layer. For this reason, and as a substitute for ad hoc disaster relief payments, governments may decide to cofinance risk transfer mechanisms for these events. A government, for example, could de-

sign Disaster Option for CAT risk (DOC) index reinsurance contracts for catastrophic risks. Returning to the example in Figure 5.2, a DOC could insure against rainfall less than five hundred millimeters with a payment per tick of say, \$50. Primary insurers could then offer coverage beyond the earlier imposed limit of five hundred millimeters and transfer the catastrophic tail risk to the government using the DOC. Even if primary insurers are selling traditional crop insurance, they could use a DOC to transfer part of the catastrophic tail risk in their portfolio of crop insurance policies.³¹ DOCs could be offered for a variety of strikes and settlement weather stations, as long as the coverage is for catastrophic risk layers and can be offset in international weather risk markets. The government could even offer other DOC indexes (for example, excess rainfall or wind speed) to reinsure other lines of insurance, such as property and casualty (see Figure 5.4).

The government would reinsure DOCs in international reinsurance or capital markets using any of the three risk transfer strategies described earlier.³² Since DOCs would address only extreme catastrophic loss events, reinsurance premium rates would likely contain an ambiguity load. Premiums could be subsidized to offset part of this ambiguity load so that DOC purchasers would pay something

Figure 5.4 Government-Sponsored DOC as Risk Transfer Product between National and International Risk Markets



Source: Authors.

closer to a pure premium rate.³³ DOCs could be tailor-made to individual insurers' needs; for example, DOCs could be based on individual weather stations or written as regional weighted average baskets of weather stations. Strikes should be set so that the DOC covers only infrequent events (for example, events with an expected frequency of once every thirty years or less). This is the domain of the probability distribution over which potential insurance purchasers tend to experience cognitive failure and insurance providers engage in ambiguity loading. Primary insurers and ultimately insured parties would pay a premium for this catastrophic protection, but it would be significantly less than what the market would charge.

Those who reinsure DOC contracts will insist on verifying the credibility of the underlying indexes. The premium required to transfer the risk to international markets would provide a baseline for setting DOC premium rates.

The risk-layering approach proposed here would institutionalize the social role of government in subsidizing extreme risk events at the local level. Premium rates could be subsidized to offset ambiguity loading. Furthermore, by organizing DOC contracts at the local level, victims of isolated severe events that fail to capture national policymakers' attention could still receive some structured assistance.

The following list summarizes the major advantages of offering index-based DOCs:

- DOC contract provisions established ex ante allow for better planning than do ad hoc disaster payments.
- DOCs provide a structure that provides more spatial and temporal equity in government disaster assistance.
- DOCs facilitate commercial insurance product development by providing a means by which catastrophic risk layers can be effectively transferred into international markets.
- DOCs can be subsidized to address the market failure associated with ambiguity loading and cognitive failure.
- Governments can estimate their own DOC subsidy cost exposure based on actuarial estimates of the risk inherent in the index. Reinsurance coverage adds a market check on the credibility of the index and the adequacy of DOC premium rates.
- While DOCs may be partially subsidized, end users still pay part of the cost to transfer the

risk into international markets. This reduces the potential for perverse incentives that could encourage excessive risk taking.

Subsidies³⁴

Governments frequently subsidize agricultural insurance products. These subsidies take a variety of forms. The government may cofinance insurance purchasing with direct premium subsidies, reimburse primary insurers for administrative or product development costs, or provide reinsurance at below market premium rates. Regardless of the form, government subsidies are generally designed to increase insurance purchasing by lowering the premiums charged to agricultural insurance purchasers.

Such subsidies are extremely controversial. They tend to benefit operators of larger farms more than those of smaller farms. A wide range of stakeholders can and will engage in rent seeking once subsidies are introduced. Subsidies are costly to maintain and are subject to close scrutiny regarding social costs versus social benefits. Many times, subsidies are provided based on the rationalization that agricultural insurance markets are missing or incomplete, without careful consideration of the core reasons why such market limitations exist. This document has carefully considered why agricultural insurance is missing or incomplete in many settings: adverse selection and moral hazard, high transaction costs, cognitive failure and ambiguity loading, and exposure to highly correlated loss events. Any government subsidies should be carefully targeted to address one of these specific sources of market failure. Even then, however, the costs of addressing that market failure may simply be too high to justify use of limited government resources to that end.

The rents resulting from even the most carefully targeted subsidies can still be captured by politically powerful elites. Government insurance subsidies may crowd out demand for private sector risk transfer instruments. The World Bank supports the development of financial institutions that operate profitably on a commercial basis by offering products and services that meet the needs of a wide range of clients, including the poor. Thus, any World Bank efforts to facilitate the provision of risk transfer instruments should be based on careful consideration of whether subsidies or grants can be provided without distorting or inhibiting the growth of private sector financial markets.

Some types of subsidies are likely to be less distorting than others. Subsidies and grants for supporting financial intermediaries and financial infrastructure, such as technical assistance and data systems needed to develop effective index insurance products, generally create little distortion. Beyond distortions in the markets, legitimate reasons exist for supporting infrastructure to improve market access among the rural poor. Finally, some public support for product development may be justifiable because of the free rider problem. Innovative insurance products are costly to develop, yet it is difficult to recoup these costs in a competitive market. Any firm can simply copy and compete with the new product without the expense of recovering product development costs. Unfamiliarity with index insurance products can heighten these problems in many developing countries.

Examples of subsidies for financial intermediaries and infrastructure include:

- Providing technical assistance to financial intermediaries to improve systems that enhance efficiency, such as management information systems;
- Developing and introducing demand-driven products on a pilot basis;
- Helping to develop or improve service delivery mechanisms that enable greater outreach into rural areas;
- Covering a portion of the cost of establishing new branches in areas lacking financial intermediaries to serve the poor;
- Creating capacity within regulatory and supervisory bodies;
- Supporting the creation of industry associations;
- Developing training institutes and insurance information agencies;
- Supporting data for weather stations or other data to be used to develop effective indexes; and
- Providing technical assistance to develop new products in an emerging market in developing countries.

Premium Subsidies

While it is common for developed countries to cofinance premiums for farmers with direct premium subsidies, these types of subsidies are particularly problematic. Generally, direct premium subsidies reflect income enhancement objectives

as much or more than they do risk management objectives. Such subsidies are typically provided on a percentage basis. This clearly benefits higher risk areas relatively more than lower risk areas. Even attempts to subsidize to levels that represent a pure premium or expected loss basis may favor higher risk areas relatively more than lower risk areas, since in a commercial market, premium rates for higher risk areas would likely contain higher catastrophic loads. Thus, any attempt to introduce premium subsidies will likely be distorting.

In principle, if subsidies are targeted to the market failure layer, as described above, market distortions should be minimal. Given the ambiguity loading and cognitive failure that occur in this layer, carefully targeted subsidies (such as cofinancing of DOCs) may even be welfare enhancing. For the market insurance layer, however, subsidies should, in general, be avoided. Any subsidies in the market insurance layer should be targeted to reducing uncertainty loads in premium rates. Commercial insurers will tend to load premium rates based on the quantity and quality of data used to generate pure premium rates. The better (worse) the data used to generate the pure premium rates, the lower (higher) the premium load. These loads could be offset with cofinancing from donors. Here again, however, donors should be very clear about the level of these subsidies and the intent behind them.

INDEX INSURANCE AS A SOURCE OF CONTINGENT FUNDING FOR GOVERNMENT DISASTER ASSISTANCE AND SAFETY NET PROGRAMS

In addition to rural economic growth, governments also want to manage disaster assistance efforts more effectively and to combat poverty by pursuing social and equity objectives. Rather than listing the multitude of social policy responses to these objectives, this document focuses on the link between funding for social policy tools and risk. Specifically, index insurance is proposed as a source of contingent funding for government disaster assistance and safety net programs.

Ex Ante Disaster Risk Management

Disaster financing has generally focused on providing resources for ex post relief operations to

cope with shocks rather than on making dedicated resources available *ex ante*. This has often meant providing in-kind emergency resources rather than cash resources. Additional transient needs are met through emergency relief operations that often duplicate ongoing interventions: that is, through public works and assistance to the vulnerable. Moreover, due to delays in declaring emergencies and mobilizing and then distributing resources, relief often takes significant time to arrive and, indeed, can arrive too late.

Index insurance could be used to provide contingent *ex ante* funding for emergency relief operations. The relief could be distributed through normal emergency channels but would benefit from *ex ante* funding and timelier provision of assistance. Current funding for emergency activities in food-insecure countries is based on a protracted appeals-based system that delivers food aid well after crop failures and weather shocks. By this time, the people affected may have already had to sell productive assets and/or migrate. Additionally, the support that does come is not consistent; delivered as a result of appeals to individual donors subject to their own approval processes and budget cycles, deliveries are unpredictable. The use of index insurance as a means of contingent funding for emergency assistance may mitigate some of the shortcomings of the current system. Index insurance provides timely and predictable payouts during emergencies; by funding early relief they preserve livelihoods and to some extent preempt emergencies (Skees et al. 2005; Goes and Skees 2003).

Safety Nets

Safety nets respond to the needs of the poorest and most vulnerable by providing livelihood support and contributing to immediate food security, often through community-driven public works schemes and transfers to vulnerable labor-poor individuals. In times of adverse climatic shocks, the number of households in need of assistance dramatically

increases, necessitating the scale-up of the safety net. Because the emergency response capabilities of existing safety nets are currently limited, however, they could be complemented with index-based disaster insurance.

The scaled-up safety net is limited by two factors:

- *Design.* Safety nets often focus on addressing chronic poverty rather than transient poverty. Although efforts have been made to scale up safety nets in time of drought, for example, this has proved difficult due to delays in mobilizing financing and organizing activities.
- *Capacity.* Existing safety net operations have increasingly focused on implementation through local government structures. This is a positive development, as it will lead to enhanced local capacity in the long run, but capacity at the local level is limited, and scaling up rapidly and effectively in times of need requires substantial existing capacity.

Safety nets could be enhanced using index insurance. A rainfall index, for example, could be used to automatically trigger payments to districts in which the drought-affected population is concentrated, with the sums insured based on this population's likely size. Targeting to the household level would then be used to determine which individuals in the district should receive payments. Cash financing would be distributed to districts early (that is, immediately after the weather shock and before harvest) to scale up existing safety nets as rainfall measures indicate where production shortfalls will occur. This plan distributes cash during the critical coping period, several months earlier than under current emergency arrangements, and before the hungry period has set in.³⁵ This mechanism would not replace emergency operations but would instead provide timely contingent funding to scale up existing safety net structures. Providing assistance in the early stages of a disaster event may preempt the need for more extensive, long-term emergency responses.

From Theory to Practice

*Pilot Projects for Agricultural Risk Transfer in Developing Countries*³⁶

The previous chapter presented the conceptual foundations for developing risk transfers. This more pragmatic chapter offers concrete examples of the progress made in using index insurance for agricultural risk transfer in several developing countries. Index insurance is not a new concept. Chakravati in India was writing about this type of insurance as early as 1920. Sweden and Quebec, Canada, had area-yield insurance programs beginning in the 1950s and 1970s, respectively. The United States introduced the Group Risk Plan in 1992 (Skees et al. 1997). The concept of index insurance based on area rainfall follows many earlier efforts with area-yield insurance.

The World Bank and other donors were involved in crop insurance projects in the 1970s and 1980s. These efforts were soon abandoned, however, as many of the problems with introducing multiple-peril crop insurance in developing countries became insurmountable constraints. Hazell (1992) emphasized the problems with traditional crop insurance and recommended using rainfall insurance. Hazell and Skees (1998) participated in the World Bank's first efforts to return to crop insurance work, undertaken in Nicaragua. Skees and Miranda (1998) followed the work in Nicaragua, and this led to the development of the Skees, Hazell, and Miranda (1999) document. In 1999, a team of World Bank professionals and outside consultants obtained a Development Market Place award to work in Morocco, Nicaragua, Ethiopia, and Tunisia. Many of the efforts described in this chapter follow the conceptual development of that project.

As with any innovation, the adoption of this new insurance product went through various life cycle stages. Often an idea is largely ignored for decades before being slowly adopted. After the idea has been tested, the replication phase begins. The overall efforts described in this document are just entering the replication phase. Initial efforts to introduce the concepts in Nicaragua and Morocco have been slow to develop into projects. Nonetheless, these efforts and the experience of performing feasibility studies in these countries proved invaluable in the overall adoption process.

Table 6.1 lists the chapter's country case studies in the order in which they are presented. Nicaragua and Morocco are covered first, as they were the first two countries to undertake the work, followed by India and Ukraine, both countries in which weather index insurance has been used. Ethiopia, Malawi, and the SADC appear next, presented together because of the common elements in their experiences. The next listed countries, Peru and Mongolia, each demonstrate unique aspects. Finally, the current progress of the Global Index Insurance

Table 6.1 Summary of Case Studies

Country	Objectives					Conceptual Significance of Risk-Transfer Model
	Initial Work by the World Bank	Status	Growth	Better Disaster Risk Mgmt	Social and Poverty Reduction	
Nicaragua	1998	Pilot in 2005	■		■	Direct link to loans and reduction of interest rates when farmers purchase index insurance
Morocco	2000	No project	■		■	More efficient and effective drought risk management for cereal producers
India	2003	Three years of sales	■			Large scaling-up and mainstreaming of weather insurance for smallholders
Ukraine	2002	First sales in 2005	■			Regulatory approval under traditional insurance legislation and piloting of weather index insurance (first weather insurance contracts sold in April 2005)
Ethiopia, Micro	2003	Pilot in 2006	■	■	■	World Bank addressing rural risk in comprehensive manner; weather insurance for smallholders
Ethiopia, Macro	2003	Pilot 2006			■	WFP/WB jointly developed ex ante weather insurance based financing of early response to weather failure leading to negative coping strategies
Malawi	2004	Pilot 2005	■	■	■	Weather insurance for groundnut farmers
SADC	2004	Feasibility stage			■	Introduction of scaled-up safety nets; improved food security risk management comprehensively
Peru	2004	Pilot planned for 2006	■			Systematic approach to dealing with agricultural risk by government
Mongolia	2001	Pilot planned for 2006	■	■		World Bank pilot project mainstreaming designed to learn if herders will pay a commercial rate for mortality index insurance; prepaid indemnity pool coupled with a structure to completely protect the financial exposure
Global Index Insurance Facility		Concept note	■	■		Reinsurance intermediation for micro- and macrolevel insurance for insurers, governments, and banks

Source: Authors.

Facility is described; this effort, much broader in scope than the individual country efforts, could significantly facilitate risk transfer for all of the preceding programs as well as any future activity.

NICARAGUA

A Seven-Year Incubation Period

Country Context and Risk Profile

The contribution of agriculture to the Nicaraguan GDP has been in decline, but it still remains a sig-

nificant economic activity. In 2003, agriculture accounted for nearly 18 percent of the US\$4.1 billion GDP of Nicaragua, and thirty percent of population is involved in agricultural activities. The major commodities produced include coffee, meat, shrimp, corn, sugar, and beans. Since the 1990s, however, agriculture has had little or, often, negative growth. With its agricultural production hindered by exposure to drought and flood risks, Nicaragua has remained a net food importer of cereals and grains.

Nicaragua has provided the World Bank's first experience in recent history of serious consideration

of rainfall insurance. Hazell and Skees provided the first feasibility study in the spring of 1998. Subsequently, Skees and Miranda (1998) examined the issue in more detail and made specific recommendations about rainfall insurance in the major cereal production area of northwest Nicaragua, which suffers major risks to cereal production from insufficient or excess rainfall, concluding that the risk of both could be hedged using rainfall index insurance contracts sold to individual farmers. Nonetheless, Skees and Miranda also pointed to large hurdles blocking such an introduction in a developing country and offered four key recommendations for the development and sustainability of such an insurance scheme:

- *Analytical work and development of human capital.* Extensive data analysis and modeling would be necessary to design and price the insurance contracts. Training Nicaraguans in these methods would be equally important in developing capacity within the country for future efforts.
- *Pilot development for demonstration, education, and evaluation.* In its first year, the pilot should start small and target primarily learning and demonstration. Education, marketing, and sales would be primary goals. Only three stations should be used in the first year: Leon; San Antonio; and Chinandega. The market thus delineated would be contiguous and would cover no more area than eight hundred square kilometers. To obtain the most effective risk management, only producers within ten kilometers of the stations should purchase the rainfall contracts.
- *Infrastructure development and pilot expansion.* During year one of the pilot, investments in additional secure weather stations should be made to increase the density of stations within the original eight hundred square kilometer market area. By year two, sales and exposure should increase to about US\$10 million.
- *In-country project management and support.* It is essential to have a key person in Nicaragua to manage and support the pilot project. This person should know all aspects of the project and take an active role in every dimension of the project. Central goals for this individual would be monitoring the activity and providing international reinsurers with the confidence necessary to participate. Beyond the pilot test area, the key person should investigate new regions with the potential to stand on their own, with private support, in which to inaugurate additional pilot programs; fostering similar activity in other regions will help entice the international reinsurance community. Additional responsibilities for the key person would be facilitating an active education program and managing and deploying funds for advertising and promotion.

Discussion of these concepts was progressing in Nicaragua's public and private sectors when Hurricane Mitch arrived with its devastation in October 1998. After this event, the World Bank's technical assistance efforts in Nicaragua shifted to developing an aggregate weather index that would provide disaster financing to the government during severe weather events. This work developed to the point at which a specific set of weather stations were indexed into a single aggregate index to protect against catastrophic risk; the index was even priced in the global reinsurance markets. After the contract was priced, however, the government rejected the idea, maintaining that they did not need to purchase insurance because they could depend on the global community for assistance when major catastrophes occurred. Subsequent to this decision, no further activity on index insurance has been pursued in Nicaragua. Nevertheless, the Nicaraguan experience provides a number of significant lessons:

- *It takes time to develop innovation.* The literature on innovation emphasizes that it takes time, sometimes as much as a generation, for new ideas to gain acceptance. The Nicaraguan experience perfectly illustrates this observation. The original weather insurance idea was presented in Nicaragua seven years ago, but new products deriving from those ideas are only now being introduced. One reason Nicaragua may be proceeding now is because in the meantime other countries have ventured into this domain.
- *The expectation that countries will purchase catastrophic protection presents an inherent moral hazard.* The excellent work completed following Hurricane Mitch to develop a mechanism for the government of Nicaragua to indemnify catastrophic losses from extreme weather events met with a cool reception. The government was likely correct in its conclusion that

this type of protection was not needed, since the global community has been very responsive with free aid after major catastrophes.

- *Linking index insurance to banking in Nicaragua is an excellent addition to ongoing work elsewhere around the globe.* Early indications are that Nicaragua's banks have agreed to reduce interest rates for production loans for farmers who purchase the new weather index insurance products. Nicaragua may be the first country to forge an explicit tie between interest rates and the amount of index insurance purchased. This is an important development that should be evaluated and more fully understood.

Proposed Agricultural Risk Management Structure

In November 2004, CRMG responded to INISER's interest in developing a local weather index insurance market for agriculture. CRMG provided technical assistance to analyze potential markets for a pilot project in 2005 and decided to concentrate on developing a pilot project to secure lending for the groundnut sector. Banks have expressed interest in internalizing some part of the risk reduction by lowering interest rates and providing financing for farmers to pay premiums as incentives for a proactive financial risk management approach.

Armed with prototype contracts, INISER/CRMG has launched consultations with end users, financial intermediaries, and the insurance regulator. Final contracts have been designed and priced by reinsurers, although they still await approval from the regulator. The pilot project is expected to begin operations in the spring-summer of 2006.

The government of Nicaragua had adopted a "wait-and-see" strategy, based on several previous failures to launch either traditional or weather index insurance for agriculture. It was not until the most recent proposal was being developed and the government could clearly see the interest and participation of the international financial markets that it opened the door for serious policy dialogue on the issue. In particular, the government has offered to support INISER in the implementation phase with economic resources as well as guidance for scaling up the current pilot project. This has opened the door to work with several productive sectors, including small farmers, in a comprehensive context of economic development in which insurance

becomes a useful tool for facilitating investments in the agricultural sector.

MOROCCO

Country Context and Risk Profile

In Morocco, 47 percent of the total population and most of the poor live in rural areas. Agriculture plays a crucial role in rural livelihoods. On average, agriculture accounts for about 17 percent of the GDP, but this percentage fluctuates, mainly due to climatic—especially rainfall—variations. Moroccan agriculture is characterized by a dichotomy between the traditional and commercial sectors. The traditional sector consists of small farms in rain-fed areas involved predominantly in cereal, legume, and live-stock production; the commercial sector operates mainly in irrigated areas. Farm surveys indicate that about 70 percent of farms are small in size (under 5 hectares) and account for 23 percent of total land under cultivation. Farms less than 20 hectares (ha) in size represent 96 percent of farms in operation. Average farm size in Morocco is 5.7 ha. Almost 90 percent of Moroccan agriculture is nonirrigated, and the dependence of most crops on adequate rainfall translates into wide variations in yields and production. Drought caused cereal production, for example, to fall from 9.5 million tons in 1994 to 1.6 million tons in 1995.

Current Response

In 1995, the Moroccan government activated the Programme Secheresse (Drought Program), a state-sponsored insurance program managed by the local mutual agricultural insurance company (MAMDA) to address the drought problem by implementing a yield insurance scheme. The program, revised in 1999, is structured on the coverage of three revenue levels: 1,000, 2,000, and 3,000 Moroccan Dirhams (MAD) per hectare (ha). Payments are triggered by a ministerial declaration certifying the occurrence of drought. For the first revenue threshold, the payout is based on an area-yield base mechanism, while for the 2,000 and 3,000 MAD/ha levels, specific farm yield assessments are required. The program proved to be popular, but it also encountered typical yield insurance problems, such as high costs for supporting insurance premiums and severe management problems related to individual farm yield assessment (Hess et al. 2003).

Proposed Agricultural Risk Management Structure

Given the limitations of the Drought Program, the Moroccan government agreed to participate in a World Bank research project aimed at exploring the feasibility of weather-based insurance as an alternative to traditional yield insurance. The investigations led the team to conclude that a drought insurance program based on rainfall indexes could have potentially significant benefits over the current scheme, minimizing moral hazard and adverse selection risk and promoting a more rapid, streamlined pay-out process, in addition to increasing the potential interest of international reinsurers and capital markets in investing in the program. Based on analysis of rainfall and cereal-yield data across the country, the study determined that an index-based rainfall insurance product could be feasible in Morocco. Following the feasibility study, an international team sponsored by the IFC and the Italian Technical Assistance Trust Fund assisted MAMDA in structuring the insurance coverage to be launched as a pilot program in some cereal growing regions.

Products

The product proposed was a rainfall index insurance contract that would indemnify cereal producers when the rainfall index in a given area fell below a specified threshold.

The indexes, developed by local agronomists together with farmers' representatives, added important insights into the relationship of rainfall to yield. They were not just cumulative measures of rainfall but included specific weights for different plant growth phases and a "capping" procedure to take into account the loss of water in excess of storage capacity and hence unavailable to contribute to plant growth. This process allowed the indexes developed to reach correlation values of over 90 percent (Stoppa and Hess 2003), and they were greatly appreciated by the potential end users.

Constraints

Despite the wide consensus gained by the proposed rainfall index contracts among government officials, insurers, and producers, the implementation of the planned pilot programs in Morocco did not take place. The main reason for this failure

was that rainfall precipitation in the selected areas showed a downward trend, and the reinsurance company involved in the deal made the cost of the insurance prohibitive for producers. The experience developed through Morocco's feasibility study and planned implementation project, however, generated expertise that led to the realization of other WB-facilitated deals (for example, in India) and of other independent programs (for example, in Colombia).

INDIA

Private Sector Led Alternative Agricultural Risk Market Development

Country Context and Risk Profile

A 1991 household survey addressing rural access to finance in India revealed that barely one-sixth of rural households had loans from formal rural finance institutions and that only 35 to 37 percent of the actual credit needs of the rural poor were being met through these formal channels (Hess 2003). A survey based on the Economic Census of 1998 (Hess 2003) shows that Indian formal financial intermediaries reportedly met only 2.5 percent of the credit needs of the unorganized sector through commercial lending programs.³⁷

Current Response

Farmers, then as now, responded to the lack of formal financial services by turning to moneylenders; reducing farming inputs; overcapitalizing and internalizing risk; and/or by overdiversifying their activities, leading to suboptimal asset allocation. Smallholders cannot risk investing in fixed capital or concentrating on the most profitable activities and crops, because they cannot leverage the start-up capital and they face catastrophic risks, such as drought, that could wipe out their livelihoods at any time. The challenge for banks is to innovate low-cost ways to reach farmers and help them better manage risk.

Proposed Agricultural Risk Management Structure

An initial study explored the feasibility of weather insurance for Indian farmers to determine if it would be possible to extend the reach of financial services to the rural sector by reducing exposure to

weather risk (Hess, 2003). The study identified several potential project partners. In response to this study, CRMG, in collaboration with the Hyderabad-based microfinance institution BASIX and the Mumbai-based insurance company ICICI Lombard, a subsidiary of ICICI Bank, initiated a project to launch the first weather insurance initiative ever undertaken in India: a small weather insurance pilot program for groundnut and castor farmers in the Andhra Pradesh district of Mahabubnagar.

The insurance contracts were designed by ICICI Lombard, with technical support from CRMG and in consultation with BASIX, to protect farmers from drought during the groundnut growing season. The products were marketed and sold in the four villages selected by the extension officers of Krishna Bhima Samruddhi Local Area Bank (KBS LAB)³⁸ using workshops and meetings with the BASIX borrowers. In total, 230 farmers (154 groundnut and 76 castor farmers) bought the insurance for khariff, the monsoon season from June to September, 2003. Most purchasers fell into the small farmer category, with less than 2.5 acres of landholding. The entire portfolio of weather insurance contracts sold by BASIX was insured by ICICI Lombard, with reinsurance from one of the leading international reinsurance companies.

ICICI Lombard was also involved in another project in khariff 2003 in Aligarh, Uttar Pradesh, where 1,500 soya farmers bought protection against excessive rainfall. ICICI Lombard filed all the necessary forms and terms of insurance with the Indian insurance regulator, registering their products before the programs were launched.

A second pilot program was launched in khariff 2004 and introduced significant changes to the 2003 design following farmer feedback from the pilot program, with technical assistance from CRMG. The program was extended to four new weather station locations in two additional districts in Andhra Pradesh: Khammam and Anantapur. The weather insurance contracts were offered to both BASIX borrowers and nonborrowers and marketed and sold through KBS LAB in the Khammam and Mahabubnagar districts and through Bhartiya Samruddhi Finance Ltd. (BSFL)³⁹ in the Anantapur district using village meetings, farmer workshops, and feedback sessions during the month leading up to the groundnut and castor growing season. New contracts were also offered for cotton farmers in the Khammam district and an excess rainfall product for harvest was offered to all castor and groundnut

farmers. In total, over 400 farmers bought insurance through BASIX in 2004, and a further 320 groundnut farmers, members of a the Velugu self-help group organization in the Anantapur district, bought insurance directly from ICICI Lombard. Several farmers were repeat customers from the 2003 pilot. In contrast to 2003, ICICI Lombard did not seek reinsurance for the BASIX farmer/weather insurance portfolio in 2004.

In 2004, a number of other transactions also took place within the Indian private sector in response to the 2003 pilot program initiated by CRMG. In 2004, BASIX themselves bought a crop lending portfolio insurance policy based on weather indexes. For the first time, BASIX used this protection to cover their own risk and passed neither the cost nor the benefits to their farmers. The protection allowed BASIX to keep lending to drought-prone areas by mitigating default risk through the insurance policy claims in extreme drought years. BASIX bought a policy, insured by ICICI Lombard with structuring support from CRMG and reinsured into the international weather market, covering three business locations.

During 2004, not only did BASIX expand their weather insurance program, a number of other institutions, including the originator ICICI Lombard, began expanding the market for weather insurance in India. In 2004, IFFCO-Tokio, a joint venture insurance company, launched weather insurance contracts similar to the 2003 contracts, selling over 3000 policies to farmers throughout India. In conjunction with ICICI Lombard, the government of Rajasthan launched a weather insurance program for orange farmers, insuring 783 orange farmers from insufficient rainfall in khariff 2004; they also covered 1036 coriander farmers in rabi (the October to March growing season) 2004. The National Agricultural Insurance Company (NAIC), responsible for the government-sponsored area-yield indexed crop insurance scheme, also launched a pilot weather insurance scheme for twenty districts throughout the country in 2004, reaching nearly 13,000 farmers; the scheme was even mentioned in the Indian government's budget for the financial year 2004–2005. It is estimated that nearly 20,000 farmers bought weather insurance throughout India in 2004.

In 2005, BASIX/ICICI Lombard further improved its weather insurance product and automated underwriting and claims settlements. In 2005, BASIX sold area-specific weather insurance products in all of

its fifty branches, finally selling 7,685 policies to 6,703 customers in thirty-six locations in six Indian states. In addition, ICICI Lombard scaled up its agricultural weather insurance sales and expanded into other sectors, while NAIC and IFCCO-Tokio stepped up their efforts to sell weather insurance products and to develop better products for farmers. New insurance providers such as HDFC Chubb also entered the market. It is estimated that during 2005, 250,000 farmer bought weather insurance throughout the country. In partnership with ICICI Lombard, over seventy new automated weather stations were installed by private company Delhi-based National Collateral Management Services Limited, on which weather insurance contracts were written for the 2005 monsoon season. The company plans to scale-up their installations throughout the country with more insurance-provider partners in 2006.

Monitoring will be an important element of the new pilot programs. Ultimately, it will be necessary to learn not only if farmers are buying these products but how the purchases are changing their behavior and the lending behavior of local financial institutions. Box 6.1 describes the initial steps being taken to monitor the Indian weather insurance products. An early result of monitoring efforts—learning why farmers purchase the insurance—is reported in Table 6.2.

UKRAINE

Country Context and Risk Profile

Rural financial institutions in Ukraine increasingly use future harvests as collateral, since farm equipment is generally antiquated and of limited value. These lenders also tend to require harvest insurance to hedge against crop losses.⁴⁰ The major banks active in agricultural lending, such as Aval (with a total of 4600 loans and 30 percent market share), do not lend on the basis of uninsured collateral, so to obtain credit a farmer must have a proper insurance policy written by a preapproved insurer. To provide for the lending insurance needs of farmers, most banks set up their own insurance companies. Most farmers do not yet understand the particular nature of weather index insurance, but they are familiar with weather risk and would like to have protection against multiple natural perils.

Crop risk is diverse throughout Ukraine. Crop-yield data for five major crops (maize, sunflowers,

sugar beets, wheat, and barley) in all twenty-five oblasts in the 1970 to 2001 period show a substantial geographic spread of the agricultural values concentrated in central and southern Ukraine. The correlation of crop yields between eastern Ukraine and the southern region near Odessa is nearly zero, facilitating risk pooling and in-country retention of a large share of natural risks.

Current Response

In this market, the types of insurance policies currently offered are input cost insurance, generally linked to agricultural credit collateral requirements and limited to very low insured sums, and harvest insurance, covering hail, storm, excessive precipitation, frost, and fire risk. Drought insurance is offered by only a few companies and is not generally covered. Two crop insurance pools, one composed of five companies and the other of sixteen, were founded in 2003 as part of attempts to provide more secure crop insurance to Ukrainian farmers. The insurance companies agreed to pool their agricultural risks to improve their risk-bearing capacity and to obtain access to international reinsurance markets. Nevertheless, crop insurance policy sales were very limited (around eighty for both pools). Market participants cited the following reasons for the low uptake: inability to pay for the policy, unclear loss adjustment and underwriting procedures, mistrust of insurance companies, and insufficient information available to farmers. Moreover, by providing ad hoc disaster assistance to farmers in 2003 and 2004, the government of Ukraine (GoU) lowered incentives for farmers to pay for commercial insurance premiums. According to recent market information, by the end of 2004, the biggest agricultural insurance pool had shrunk to six companies.

Policy Objectives

The GoU has experimented with compulsory crop insurance and is now establishing a crop insurance subsidization scheme. The regulator has approved weather index insurance as an insurance product, and a few weather insurance policies were sold to farmers in the first pilot sales season of 2005.

A feasibility study by CRMG presents a risk management framework and considers several options for government intervention in the sector. An investment phase would consist of the acquisition and installation of automated weather stations, includ-

Box 6.1 India Impact Assessment

CRMG and DECRG designed a baseline survey^a that was implemented by the International Crop Research Institute (ICRISAT). The survey was conducted to study the introduction of the rainfall insurance products designed by ICICI Lombard and marketed through BASIX. The main objectives were to assess, first, the take-up rate, that is, the factors influencing the decision to purchase the insurance product, and, second, the impact of the insurance product in the treated villages as compared to the control villages. A sample was drawn from Hindupur, Anantapur district, and Narayanpet, Mahabubnagar district, of 1,052 farming households, including 267 buyers, 186 nonbuyers who attended a marketing meeting, and 299 nonattendees in the treated villages. In addition, 300 farming households were interviewed in control villages.

Anantapur and Mahabubnagar are characterized by low and uncertain rainfall, low levels of irrigation, and shallow and infertile soils. Anantapur has virtually a groundnut monoculture, while Mahabubnagar has castor bean, groundnut, sorghum, pigeon pea, maize, cotton, paddy, and finger millet crops. Crop failure is very frequent in these districts, mostly triggered by droughts. Indeed, 80 percent of farmers considered drought their main risk. In a drought year, farmers can lose about 25 percent of income. Drought affects most villagers at the same time, rendering informal insurance networks useless. Instead, in bad years, farmers sell livestock or their few assets and migrate to urban areas or other states. In addition, they borrow from formal and informal rural financial institutions. The union and state governments offer employment generation schemes, watershed development programs, and other welfare schemes to stem migration and assuage the misery of the people.

The rainfall insurance product was explained by BASIX and ICICI in village meetings. Most people who heard about the meeting decided to attend; of those, 35 percent attended because they trusted BASIX and another 35 percent because friends and neighbors attended. Only 27 percent of the buyers purchased the insurance during the marketing meeting, because the product was new and meeting attendees lacked the requisite funds. Meeting participants well understood

the crop to which the rainfall insurance was linked and the premium and payouts, but not the trigger levels. In fact, insurance trigger levels are expressed in millimeters of cumulative rainfall, but most farmers do not understand the concept of a millimeter. Most farmers determine when to sow by analyzing the moisture in the ground, and, indeed, only 10 percent were able to make an estimate in millimeters of the minimum accumulated rainfall required to sow.

Nonetheless, take-up was high. Buyers said they purchased the insurance for security reasons (exposure to rain, large cultivation of castor or groundnut, etc.) and because they were advised to do so by others. Yet initially, many buyers thought of the insurance policy as a gamble. They put money at risk in the hope of making a profit if the accumulated rainfall was below a certain threshold. To support this claim, we find that risk-loving people are more likely to buy the policy as well as those that believe that the monsoon rains will start later, for whom the gamble has favorable odds. In addition, buyers are generally more educated, farm more land (total and irrigated), have more savings at the time of purchase, and are more likely to trust the insurance product and BASIX, as compared to nonbuyers. At the time of the survey, most farmers in treatment villages reported that they would like to purchase the insurance for the next khariff (main monsoon) in June 2005. In addition, 14 percent of poorer farmers said they would like to open savings accounts in November to save for the premium. Again, when asked why they would like to buy the insurance in 2005 (see Table 6.2), 60 percent cited security reasons, but a full 30 percent cited the experience of a payout in 2004.

This willingness to purchase the policy as a result of a payout is particularly telling in the context of the introduction of a new product. Farmers may be uncertain that BASIX will honor its promise and thus may decide to wait and see and not change behavior. Indeed, the preliminary analysis conducted suggest that while there are no differences in input usage or area devoted to cash crops for farmers that do not trust Basix or the product, it does seem that trust in BASIX allows buyers to use the insurance policy as a hedging instrument.

Note:

a. Financed by Swiss Trade Commission, SECO.

Source: This information is based on preliminary findings by economist Xavier Giné (DECRG, World Bank), working in collaboration with Don Larson (DECRG, World Bank), Robert Townsend, professor at the University of Chicago, and James Vickery, an economist at the Federal Reserve Bank of New York.

Table 6.2 Reasons for Buying Weather Index Insurance in India

Reasons for Buying Insurance ^a	Khariff 2004		Khariff 2005	
	Freq.	%	Freq.	%
Security/risk reduction	144	54.8	181	53.2
Could not afford to lose harvest income	25	9.5	11	3.2
Low premium	19	7.2	1	0.3
Advice from progressive farmers	18	6.8	0	n/a
Other trusted farmers bought insurance	7	6.5	5	1.5
Advice from village officials	10	3.8	1	.3
High payout	10	3.8	10	.9
Concentration on castor crop	7	2.7	4	1.2
Product was well explained	5	1.9	0	n/a
Concentration on groundnut crop	4	1.5	0	n/a
Luck	4	1.5	5	1.5
Paid out for previous year	0	n/a	107	31.5
Advice from BUA members	0	n/a	11	3.2
TOTAL	263	100	340	100

Note:

a. The categories listed were created from open-ended survey responses to the question, "Why did you buy the insurance product for the last khariff?" The same categories may not apply for both years.

Source: ICRISAT survey, courtesy Xavier Gine.

ing analysis of the density of the network required to cover Ukraine's weather exposure and design of an adequate maintenance program to ensure the quality of observations across time.

In addition, the GoU could consider a backstop facility for weather risk insurance retention. Ukrainian insurance companies would need international reinsurance for insuring against systemic risks. A risk pool "facility" in Ukraine would allow for the underwriting of agricultural reinsurance based on preestablished guidelines to retain as much risk inside the country as possible. This pool would then reinsure itself through a GoU fund. Extreme or catastrophic risk would be reinsured on the international reinsurance market based on transparent and competitive premium ratemaking principles; that is, once the pool and the GoU fund are depleted, international reinsurers would pay the remaining claims. Aggregation and layering of risk would help interest reinsurers in reinsuring risk in Ukraine, causing them to price risk competitively. Individual insurance companies sometimes face insurmountable difficulties even accessing international reinsurance markets, let alone obtaining competitive prices. The combination of introducing a transparent index insurance product and

an efficient and well-regulated risk pool can overcome this market failure. Risk layers representing relatively frequent (but mild) adverse events would be insured by the GoU risk fund. Intermediate risk layers (for example, events occurring once in twenty years to once in one hundred years) could be transferred to the GoU Backstop Facility. The catastrophic risk layer (the once in one hundred year event) could be transferred to international reinsurance markets.

ETHIOPIA

Ethiopian Insurance Corporation and Donor Led Ex Ante Disaster Risk Management

Country Context and Risk Profile

Ethiopia is one of the poorest and least developed countries in the world, ranking 169 of the 175 countries in the Human Development Index. More than 85 percent of the population make their living in the agricultural sector, which accounts for 39 percent of Ethiopia's GDP (2002/2003) and 78 percent of foreign earnings. In Ethiopia, agriculture is predominantly rain-fed, and more than 95 percent of its output comes from subsistence and

smallholder farmers. The staple diet for the majority of Ethiopians consists of coarse grains, including maize, teff (a cereal grain), and sorghum. Production of coarse grains is valued at around US\$380 million and cereals at US\$585 million.

At the household level, adverse weather patterns, primarily lack of rain, are detrimental to yields and outputs and result in significant income losses and negative impacts on farmers' livelihoods. Ethiopia faces highly variable rainfall and suffers from both national and regional droughts that can have extreme impacts on farmers who utilize traditional agricultural practices with little irrigation and who rely on the country's thirty-five million head of livestock. This rainfall variability, in addition to limiting the ability and motivation of farmers to invest in agricultural technology and yield-increasing assets, reduces overall production, which can decrease both household consumption and income. At the national level, average grain production in the country is 8.9 million metric tons (MT) and is subject to recurrent drought. The Ethiopian ministry of agriculture has indicated that the level of production is too low to feed the whole population even in good rainfall years.

Current Response

With 10 percent of the population of seventy-two million requiring food aid assistance each year, food insecurity is a chronic issue. Emergency responses have been frequent if not constant, accounting for an annual average of 870,000 MT of food aid between 1994 and 2003. In 2003, a record thirteen million Ethiopians required emergency assistance as a result of drought and the consequent failed harvest in 2002. These emergency responses have saved millions of lives in the short term, but destitution has worsened, assets have eroded, and vulnerability has increased. The uninsured loss of income and assets caused by natural disasters, primarily droughts, in developing countries such as Ethiopia threatens the lives and livelihoods of vulnerable populations. Insurance is a critical requirement for development, as uninsured losses lock entire populations in vicious cycles of deepening destitution. It is estimated that in sub-Saharan Africa approximately 120 million people are at risk from natural disasters and that, for these populations, humanitarian aid provides the only insurance protecting their lives and livelihoods. But humanitarian aid is often too unreliable, unpre-

dictable, and untimely to provide an effective insurance function.

In 2003, in part to address this issue, the government of Ethiopia (GoE), donors, United Nations agencies, and nongovernmental organizations (NGOs), launched the New Coalition for Food Security with the goal of achieving food security for the part of the Ethiopian population categorized as "chronically food-insecure" and to improve significantly the food security for the additional ten million people vulnerable to becoming so in the next five years. To achieve these goals, starting in January 2005, the organizations began working through the government to introduce a productive safety net for five to six million people. The safety net is not meant to serve as an emergency activity but to change the vulnerability and risk profile of the chronically food-insecure. Responses to chronic and to emergency food shortages began to be addressed through different channels: the former, essentially a development activity, fell to the productive safety net program coordinated by the Food Security Coordination Bureau, and the latter, a response mechanism to unpredictable humanitarian needs, to the Disaster Prevention and Preparedness Commission (DPPC). Accordingly, those households not covered by the safety net program but still considered in need of government relief assistance will fall under the emergency program through early warning and annual needs assessments.

Proposed Agricultural Risk Management Structures

To address the current situation in Ethiopia, two agricultural risk management structures are currently being considered, one at the farmer or microlevel and the other at the government or macrolevel.

Microlevel Weather Insurance

The state-owned Ethiopia Insurance Corporation (EIC) plans to launch a small pilot weather insurance program for wheat and pepper farmers in southern Ethiopia in the wereda (district) of Alaba, SNNPR. The EIC has previously experimented with agricultural insurance for farmers, but it met with little success. The EIC is keen to explore new potential products to address the risks of larger, commercial farmers. A pilot program, for which it receives technical support from CRMG, is due to start in April 2006. Part of the work includes the

demand assessment and participatory design of contracts with Alaba farmers

Macrolevel Ex Ante Funding of Emergency Relief Operations

The World Bank and the United Nations World Food Programme (WFP) have launched a pilot to investigate the feasibility of index-based weather insurance as a reliable, timely, and cost-effective way of funding emergency operations in Ethiopia. The intention is to address the extreme emergency drought situations that put pressure on donor budgets and GoE strategic grain and cash reserves. The pilot is designed to serve vulnerable populations who are neither food-insecure nor included in the country's new safety net program but who are "at risk" to income and asset losses and consumption shocks resulting from the more severe natural disasters. It is estimated that at least a further 35 percent of the population, above those considered chronically food-insecure and covered by the safety net, is at risk from hunger in the event of an extreme drought such as that in 1984. A traditional food aid response to a catastrophic drought in today's prices would be estimated to cost about US\$1.6 billion for all beneficiaries, chronic and nonchronic.⁴¹ In preparing for a future drought, rather than rely on traditional funding approaches based on protracted appeals to international donors, the insurance approach focuses on transferring the risk to the reinsurance and capital markets. Such a mechanism will ensure predictable and timely availability of funds with which the DPPC can launch emergency relief operations and appropriate interventions in the event of a well-defined rainfall deficit at harvest time. Some of the benefits of this type of insurance-based emergency funding include objective payouts, timely delivery, and funding in cash. In the case of Ethiopia, the insurance approach would allow intervention four to six months earlier than does the traditional appeals-based system.

Policy Objectives

Both proposed agricultural risk management structures are in line with the GoE current poverty reduction strategy, which focuses on (1) agricultural-led, rural-based growth, recognizing the importance of improving the environment for exports, private sector growth, and rural finance; and, linked to this, (2) food security. Clearly the microlevel weather insurance initiatives are complementary to the government's primary focus on agricultural development.

The poverty reduction strategy is characterized by strong country ownership and focuses on a broad-based participatory process. In particular, the GoE favors a gradual shift from food assistance, assistance in kind, toward financial assistance that could be used to purchase food from the domestic market. The New Coalition for Food Security attests to the government's ambitious poverty reduction strategy: the main features of the safety net are multiannual funding, transition toward cash-based programming, scaled-up public/community works, linkages with broader food security programs, harmonized budgeting, and monitoring and evaluation. The Food Security Coordination Bureau has been created, under the Ministry of Agriculture and Rural Development, to coordinate all food security programming, including the safety net. Targeting the nonchronically hungry but food-insecure or vulnerable populations, an index-based weather insurance approach for Ethiopia aiming to provide contingency cash funding for responses to severe and catastrophic drought clearly aligns with the government's strategy and complements the safety net initiative.

The objective of the macrolevel pilot project is to contribute to an ex-ante risk-management system to protect the livelihoods of Ethiopians vulnerable to severe and catastrophic weather risks. The pilot will use a weather derivative to demonstrate the feasibility of establishing contingency funding for an effective aid response in the event of contractually specified severe and catastrophic shortfalls in precipitation. WFP will put in place a small hedge for Ethiopia's 2006 agricultural season from March to October 2006, demonstrating the possibility of indexing and transferring the weather risks of least-developed countries and facilitating price discovery for Ethiopian drought risk in international financial markets. In effect, in the pilot stage of the initiative, the WFP will be the counterparty to a commercial transaction with the international risk market. Donors will pay for the premium associated with this risk transfer. Ideally, however, the ultimate aim of the initiative would be for the GoE to take responsibility for the risk management program as part of its overall long-term poverty reduction strategy.

Constraints

Two major constraints might, in the short term, limit the proposed risk management frameworks. The first involves the weather-observing network and

the weather data available in Ethiopia. The National Meteorological Services Agency (NMSA) is responsible for a network of over five hundred weather stations and rain gauges throughout Ethiopia. Not all of these weather stations, however, offer reporting capabilities or historical data of a quality sufficient to transfer risk to the international markets or even to perform an actuarial analysis of the weather risks involved. Furthermore, given the large size and challenging topography of the country, the spatial distribution of the network is inadequate to protect the entire country from weather risk. These issues will hamper both micro- and macrolevel efforts. On the microlevel, initially, only farmers who live near good weather stations will benefit from the availability of weather insurance. Furthermore, the EIC may find it difficult to secure reinsurance for this risk until the quality and security of the NMSA network improves. On the macrolevel scale, the weather protection can only be designed using weather stations that adhere to the strict quality requirements of the international weather market. This will naturally limit the scope of the project in its first years.

The second constraint, more relevant for the macrolevel weather-risk transfer, involves fiscal issues: namely, the ability of the government of Ethiopia eventually to take over the ex ante funding of the emergency relief operations program and to take responsibility for the premium payments necessary to establish and maintain this funding mechanism.

Products and Risk Transfer Structure

Both micro- and macrolevel proposals focus on index-based weather risk management solutions.

At the microlevel, the EIC will market and sell weather insurance contracts to kebeles (small groups of farmers) and/or farming cooperatives to protect their farmer members from the financial costs associated with crop failure as a result of adverse weather. The products will be similar in concept to the products offered to farmers in India (see Appendix 2), but it will be sold at the group rather than individual level in line with farmer preferences identified during discussions and focus groups in Alaba. The EIC will then seek international reinsurance for their portfolio of weather risk.

At the macrolevel, lack of rainfall is the dominant, immediate cause triggering emergency relief

operations in Ethiopia. It is therefore an appropriate proxy for representing economic loss due to drought and also a simple, objective basis for index insurance. The appropriate index must be based on a weighted average, or “basket,” of as many stations as possible to capture the macrolevel nature of the risk the GoE faces. The government may be able to cope with small, localized droughts by transporting food supplies from other regions of the country and by sourcing government budget reserves. Retaining such risks will most probably be a more cost-effective solution than would seeking insurance, and Ethiopia should be able to take advantage of any natural diversification of the country to reduce its insurance costs. In situations where drought severely affects a single region or affects several regions or the entire nation, however, the government may find this reallocation of resources unmanageable, making it appropriate to utilize the basket-based insurance product to fund the expected emergency relief operations in a predictable and timely manner. The basket approach also reduces the risk of reliance on one weather station and the associated issues of moral hazard and basis risk. On this note, including more stations in the basket not only provides better national coverage and, hence, enhances the representation of the index, it also increases the placement potential of the structure in the international reinsurance markets. In 2006, the index to be piloted is based on a basket of 26 weather stations distributed throughout the agricultural producing areas of the country.

In the pilot stage of the program, the WFP will be the counterparty to any commercial transaction with the international risk market and donors will pay for the premium associated with this risk transfer. In the event of an extreme and catastrophic drought, however, any payment triggered by the insurance would be made available to the GoE DPPC. This would allow the early provision of resources to the GoE and thus to the beneficiaries to ensure appropriate consumption smoothing and to avoid distressed sales of assets, a vital outcome if the intervention is to play an effective and protective role. With the availability of cash, the intervention can also be used to fund activities other than food aid that have already been established in other parts of the country, such as cash-transfers, food-for-work, or cash-for-work schemes. Ultimately, the long-term objective of these insurance plans would be for the GoE to go directly to the market and take

responsibility for the program rather than having it continue to operate through the intermediary WFP.

MALAWI AND SADC

Weather Risk Transfer to Strengthen Livelihoods and Food Security⁴²

Country Context and Risk Profile

Malawi is dominated by smallholder agriculture, with farmers cultivating mostly maize, the staple food. Maize is very weather sensitive and requires a series of inputs. The economy and farm livelihoods are affected by rainfall risk (and resulting food insecurity), soil depletion, lack of credit, and limited access to inputs. Malawi suffers serious capacity constraints because it is ravaged by poverty and AIDS. Very few people have the energy and skills to build financial service programs.

Current Response

Malawi once had a paternalistic state culture. The role of the state in agricultural marketing (mainly tobacco but also maize) is still strong. Prices are not free, and smallholder incentives are distorted due to food aid and sales of subsidized maize by the state marketing board. The state and donors respond to recurrent drought-induced food crises by ad hoc disaster relief programs.

Proposed Agricultural Risk Management Structures

At the micro- or farm-level, weather-based index insurance allows for more stable income streams and could thus protect peoples' livelihoods and improve their access to finance. An insurance product can be based on a crop production index constructed from weather data recorded at the airport weather station in Lilongwe (Malawi's capital). Analysis and simulations conducted for the Lilongwe area indicate that the match between potential insurance payouts and farm-yield losses would be adequate. All that is needed is for demand to be aggregated at product distribution channels such as the National Smallholders Association (NASFAM). Rural financial institutions could finance the insurance premiums and lower interest rates to borrowers, since the financial institutions stand to benefit from reduced default risk.

At the intermediary level, banks can package loans and weather insurance into a single product, a weather-indexed crop production loan. Farmers would enter into higher interest rate loan agreements that include weather insurance premiums that the bank would then pay to the insurer. In case of a severe drought impacting crop yields, the borrower would pay only a fraction of the usual loan due and would thus be less likely to default, strengthening the bank's portfolio and risk profile. Historical simulations in Malawi of such products from maize demonstrated that the years of reduced loan payments coincided with the drought years in which farmers suffered from much lower yields, mainly 1992 and 1994. Recently, CRMG partnered with Opportunity International (OI) to develop weather insurance products to secure credit for groundnut farmers. Nearly 1000 policies were sold in October 2005 for the 2005/2006 groundnut growing season.

At the macrolevel, a specific nationwide maize production index for the entire country could form the basis of an index-based insurance policy or operate as an objective trigger to a contingent credit line for the government in the event of food emergencies that put pressure on government budgets. Applying the Lilongwe maize farmer index approach to the macrolevel situation, a Malawi Maize Production Index (MMPI) can be defined as the weighted average of farmer maize indexes measured at weather stations located throughout the country, with each station's contribution weighted by the corresponding average or expected maize production in that location. Given the objective nature of the MMPI and the quality of weather data from the Malawi Meteorological Office, such a structure could be placed in the weather risk reinsurance market. Analysis shows that Malawi could need up to US\$70 million per year to financially compensate the government in case of an extreme food emergency. Given the size of this figure, such a transaction would be treated on a stand-alone basis, with an estimated premium of approximately three times the expected loss for the reinsurer. In this case, the expected loss—given forty years of historical rainfall data and assuming the government retains the cost associated with deviations in maize production up to 25 percent away from normal—would be US\$2.32 million, implying a premium of US\$6.96 million or an insurance rate of 10 percent for such a product.

The weather index/drought risk management approach suggested for Malawi could be extended to a regional level to include all members of SADC at some future point. Weather risk can be retained and managed internally if the areas under management are significantly diverse in their weather risk characteristics. This immediately suggests that the weather sensitivity of neighboring countries, the SADC members, must be taken into account when considering Malawi's weather risk profile and its need for outside insurance. Analysis of the SADC region shows that, on average, two countries suffer drought each year. The distribution of drought events in SADC is extremely long-tailed, however, with the possibility of widespread drought events that could potentially devastate the region. This indicates that the most efficient way to layer and thus manage the risk is as follows:

- *SADC Fund*: The size of the SADC fund could be set at US\$80 million, the average financial impact of four average droughts in the region, with each member contributing its share according to an actuarially fair assessment of the expected claim of each country.
- *Reinsurance and/or contingent credit lines*: SADC-wide events incurring a financial loss of, say, US\$80 million to \$350 million could be transferred to the weather-risk reinsurance/professional investor market. Alternatively, in such situations, the SADC members could have access to a World Bank contingent credit line.
- *Securitization*: The final and extreme layer of risk, such as drought in ten countries, occurring 1 percent of the time, could be securitized and issued as a CAT bond (investors lose the principal if the event occurs in exchange for a higher coupon) in the capital markets. The advantage of capital markets for this risk transfer is the immense financial capacity of these markets and also the longer tenure of CAT bonds: up to three years and possibly longer.

A more efficient means of transferring risk implies that costs could be greatly reduced for the member countries by transferring risk as part of a regional strategy rather than by transferring that risk one country at a time. The SADC fund approach outlined above, for example, would reduce insurance costs by 22 percent for Malawi due to risk pooling effects.

PERU

Government Led Systemic Approach to Agricultural Risk Management

Country Context and Risk Profile

Peru is currently negotiating a Free Trade Agreement with the United States. Agriculture, because of its lack of competitiveness, is one of the most vulnerable sectors when an economy is opened. In this context, the Peru's Ministry of Agriculture (MA) is preparing a multidimensional strategy involving extension services to farmers and innovative financial schemes, with the private sector participating to facilitate access to better technology and new markets. Because of farmers' lack of bankable collateral, the MA intends to facilitate the emergence of a sustainable private agriculture insurance market.

Current Response

Two major efforts in the last decade have attempted to introduce agriculture insurance in Peru, but the results were disastrous. Lack of technical knowledge and exposure to catastrophic events like El Niño generated big losses in the industry. From the consumers' perspective, these schemes were not transparent and lack of education translated into dissatisfaction about the scope and use of these financial instruments. Currently, crop insurance or similar instruments are not available to farmers.

Proposed Agricultural Risk Management Structure

The government of Peru (GoP) created a special commission in 2003 to draft a strategic plan for the implementation of an agriculture insurance scheme. The treasury ministry, agriculture department, insurance regulator, private and development bank representatives, farm unions, and insurance representatives participated in the discussions and recommendations for the strategic work plan. A specific body designed for that purpose is the Technical Committee for the Development of Agriculture Insurance (TCDAI), which was created by ministerial resolution in September 2004 and is housed in the agriculture ministry. The TCDAI is currently working on several technical studies related to the design and implementation of agriculture insurance in Peru.

Policy Objectives

The main objectives of the GoP are (1) to maintain the prudent fiscal, monetary, and exchange rate policies essential to attract investment and promote continued growth; and (2) to complement growth with direct interventions that address inequality and poverty, focusing on excluded groups: indigenous people, Afro-Peruvians, and at-risk groups such as youths and single mothers (Peru, 2004–06).

Constraints

In addition to fiscal constraints, Peru's agricultural sector is divided into two: a group of powerful export-oriented, high-value agricultural producers concentrated in twelve valleys along the coast and a group of smallholder agricultural producers occupying the sierra (highlands) and selva (jungle) areas.

Products

The technical committee, assisted by CRMG, proposed a four-part work plan:

1. *Design of prototype index contracts:* The feasibility of these contracts is tested for several crops in the three main agricultural areas of Peru (coastal, sierra, and selva). The contract design requires weather data from the Peruvian weather service (SENAMHI), acquisition of which is a priority for the work plan.
2. *Demand assessment:* This activity will aim at gauging the demand for weather insurance by type of producer and will include participatory design sessions addressing questions such as what types of contracts to develop and for what periods. This activity will include training potential end users (farmers) regarding index insurance basics (for example, types of indemnities, how indemnities and premiums are calculated, and how contracts are settled).
3. *Delivery model design:* Based on a mapping of rural financial intermediation in Peru, this activity will evaluate segmented delivery models to be used for real distribution channels to farmers with small- and medium-sized farms with viable production potential. Prototype contracts by institution and client segment will be used in working with potential intermediaries.

4. *Regulatory review:* The purpose of this activity is to develop a strategic work plan with the insurance regulator to prepare the necessary technical documentation for the index insurance product to be approved under the guidelines of property insurance.

The TCDAI has defined the following crops and areas of interest for the feasibility study:

Rice—San Martín
Mango—Piura
Yellow maize—Lima
Potato—Huanuco
Coffee—Cuzco
Cotton (Tangis)—Ica
Cotton (Pima)—Piura
Asparagus—Lima

Risk-Transfer Structure

The GoP seeks to enhance risk-taking capacity in the country generally by facilitating special risk transfer arrangements with insurance companies in Peru, particularly those wishing to launch agricultural insurance. Specifically, the GoP wishes to set up a US\$50 million fund, managed by the leading second-tier bank (COFIDE), to take agricultural risk. In addition, the technical committee plans to develop for insurers index-based products directly transferable into international risk markets.

MONGOLIA

World Bank Contingent Credit for Livestock Mortality Index Insurance⁴³

Country Context and Risk Profile

The economy of the Mongolian countryside is based on herding: agriculture contributes nearly one-third of the national GDP, and herding accounts for over 80 percent of agriculture. Animals provide sustenance, income, and wealth, protecting nearly half the residents of Mongolia. Shocks to the well-being of animals have devastating implications for the rural poor and for the overall Mongolian economy. Major shocks are common as Mongolia has a harsh climate, and animals are herded with limited shelter. From 2000 to 2002, eleven million animals perished due to harsh winters (dzuds). The government of Mongolia has struggled with the obvious question of how to address this problem.

The Mongolian government requested specific assistance in coping with extreme livestock losses. Given the nature of highly correlated death rates for animals in Mongolia, an index-based livestock insurance (IBLI) product was proposed and in May 2005, and the World Bank approved a loan to Mongolia to finance the Index-Based Livestock Insurance Project. This project will support a three-season pilot program in three Mongolian states and includes a contingent debt facility to serve as a mechanism for protecting against extreme losses during the pilot. The major objective of the pilot program is to determine the viability of IBLI in Mongolia, including testing herders' willingness to pay for an IBLI product. The index would pay indemnities based on adult mortality rates by species and by soum (province). By law, Mongolia performs a census of animals each year. Elaborate systems are in place to assure the quality of the data. The proposed pilot involves three distinct layers of risk: (1) self-retention by the herder; (2) a base insurance product (BIP) for mortality rates in a certain range; and (3) a disaster response product (DRP) for livestock losses beyond the layer covered by the insurer.

An index-based insurance program was recommended because of significant concerns about the moral hazard, adverse selection, and extreme monitoring costs associated with any individual livestock insurance program in the vast open spaces of Mongolia. Weather index insurance was considered; however, it was determined that the weather events contributing to livestock deaths were too complex to develop this alternative. The project will support continued research to strengthen the mortality index by incorporating other indexes, for example, the Normalized Difference Vegetation Index (NDVI), as a means of establishing a more secure index for paying losses.

While it is believed that the index-insurance product can be effectively underwritten, significant financial exposure for a nascent insurance market with extremely limited access to global risk-shifting markets remains among the largest challenges. Given concerns about financing extreme losses, the pilot design involves a syndicate pooling arrangement for companies. Pooling risk among the insurance companies offers some opportunity to reduce the exposure for any individual insurer. In the short term, the government of Mongolia will offer a 105 percent stop-loss on the pooled risk of the insurance companies. Herder premiums go directly into a prepaid indemnity

pool. Insurers must replace the reinsurance cost and the exposure above 100 percent for the prepaid indemnity pool.

In the syndicated pooling arrangement, participants share underwriting gains and losses based on the share of herder premium they bring into the pool. Each insurer also pays reinsurance costs consistent with the book of business they bring into the pool. This gives the reinsurance pool the benefits of the pooling arrangement and provides the opportunity to build reserves for the overall activity. The reinsurance pool pays for the first layer of losses beyond the 105 percent stop-loss. Once the reinsurance pool is exhausted, the government of Mongolia can call upon the contingent debt to pay for any remaining losses.

A major advantage of having a prepaid indemnity pool is that all other lines of the insurance business are protected from the extreme losses that can occur from writing a highly correlated agricultural risk policy. In the long-term vision, the syndicate will be well positioned to find risk-sharing partners in the global community quickly, as the pooling arrangement is both risky and profitable. Reinsurers might be willing to provide capital and enter quota-share arrangements on that risk. To the extent that the risks within the pool are standardized, using the same measures and procedures, one can also envision this mechanism as a means to securitize the risk. Finally, the design also offers the opportunity to transition the system to the market once it is learned whether herders find the BIP an acceptable product and demonstrate a willingness to pay.

The first challenge to the risk transfer structure is the uncertainty of the livestock mortality index-based on an annual government census of all animals in the country. Several systems are in place to monitor potential problems during the pilot, for example, the movement of animals across soum borders. From the perspective of the reinsurer, even the government could have the incentive to tamper with the data if this data determines the level of reinsurance claims. The project seeks to establish systems to verify losses using third-party audits. A second challenge is the sustainability of the proposed pooling mechanism that determines reinsurance premiums for each participating insurer using advanced modeling procedures. Human capital within the country must be developed to perform these duties. Pooling mechanisms generally tend to fail because of collective action problems and high transaction cost. The challenge in Mongolia will be to move the pooling mechanism to a private sector entity by the comple-

tion of the pilot; otherwise, if left to the government to maintain, the system will likely be unsustainable.

GLOBAL STRATEGY

The Global Index Insurance Facility (GIIF)

Background

The economic growth prospects of developing countries are negatively impacted by external shocks, which create both short- and long-term physical and financial distress. The lack of coherent and timely response to shocks, coupled with indirect impacts on growth and investment, compound the cost of direct physical damage. Uninsured enterprises do not develop their full earnings potential because they engage in low-risk/low-return activities to minimize downside risks. Generally, too much capital goes into nonremunerated self-insurance. OECD countries, on the other hand, tend to be better equipped to manage shocks since they have larger diversified economies that can withstand such events and because private assets are insured. Demand for risk management instruments is often frustrated by market gaps and entry barriers. International reinsurers, for example, require substantial minimum risk amounts: “The greatest challenge is not to find capacity, but to find a large enough portfolio to make it worth underwriting” (Tobben 2005).

The GIIF seeks to close the gap between the developing country’s demand for insurance against severe shocks at public and private levels and the index insurance markets. The World Bank Commodity Risk Management Group (CRMG) already addresses the knowledge gap through technical assistance and the demonstration effects of pilot transactions, but credit and market gaps will limit its ability to scale up. GIIF would lower the entry barrier for international risk transfer by pooling smaller transactions, thereby helping to scale up risk transfer from developing countries.

Present

The European Commission allocated a total of 25 million for a commodity risk management facility and submitted the concept to the Council Working Group of Member States as part of the “conditional billion” package, the final tranche of the Ninth EDF/2003 to 2007. CRMG is putting together a proposal for a Global Index Insurance

Facility (GIIF) that would intermediate weather, disaster, and price risk (all index-based) among developing country-based primary insurers, governments, banks, and organized markets. CRMG is in intense dialogue with market makers as to the risk-taking capabilities of the GIIF, with a focus toward “crowding-in” rather than “crowding-out” the private sector. The facility would consist of a 100m capital investment in a risk-taking entity that would underwrite global weather, disaster, and price risks in developing and, in particular, the African-Caribbean-Pacific (ACP) countries. The main objective of the facility would be to achieve returns on equity and build a diverse portfolio of risk from developing countries not previously transferred to the capital and insurance markets, thereby leveraging private risk transfer. The main development objective would be to alleviate poverty by facilitating effective disaster insurance and risk reduction, allowing countries and enterprises to profitably invest resources rather than waste them with inefficient self-insurance. The GIIF would further facilitate risk transfer by absorbing transaction costs for developing country clients through cofinancing of premiums, funded separately by EC/ACP funds, and through reinvestment of dividends by public sponsors.

Types of Risks Underwritten by the GIIF

The GIIF would provide cover for disaster, weather, and price risks by underwriting index-based insurance contracts. Index insurance also allows very timely automatic settlements, which is crucial for effective disaster response. Price risk management contracts will be based on liquid exchange-traded instruments, set at market prices. All indexes must be objective, transparent, published, and sustainable; price indexes must be liquid. The GIIF would regularly publish insurable indexes.

Exit Strategy

The GIIF seeks to catalyze a commercial market for index-based insurance products in developing countries by “crowding in” the private sector. Following GIIF’s start-up phase, it is expected that the market for developing country risk will be sufficiently developed and competitive to offer risk management products to end-user countries and clients at a reasonable cost. This period could vary from seven to ten years.

Potential Roles for Governments and the World Bank

Agricultural producers and other rural residents are often exposed to a variety of biological, geological, and climatic factors that can negatively affect household income and/or wealth, as well as tremendous variability in output and/or input prices. Given this environment, risk-averse individuals often make investment decisions that reduce risk exposure but also reduce the potential for income gains and wealth accumulation. Thus, risk contributes to the “poverty trap” experienced by rural people in many developing countries.

For a variety of reasons (discussed in Chapter 2), markets for transferring these risks are typically either very limited or nonexistent. This “market failure” has stimulated a number of policy responses. Many developed countries have highly subsidized, farm-level agricultural insurance programs. Critics argue that, in addition to being very expensive, these programs stimulate rent-seeking activity, are highly inefficient, and may actually increase risk exposure by encouraging agricultural production in high-risk environments (Chapter 3). Given fiscal constraints in most developing countries, highly subsidized, farm-level agricultural insurance programs are not a realistic policy option.

Index-based insurance products have been proposed as an alternative risk-transfer mechanism for rural areas in developing countries. While not a panacea for all risk problems, index-based insurance products may prove to be valuable instruments for transferring the financial impacts of low-frequency, high-consequence systemic risks out of rural areas (Chapter 4). For a variety of reasons, however, government intervention may be required to generate socially optimal quantities of risk transfer. Governments must carefully consider the extent and nature of any intervention in markets for index-based insurance products (Chapter 5). These efforts can be facilitated by World Bank policy advice, lending instruments, and monitoring and evaluation systems (see World Bank 2004; 2005b). This chapter sets out policy and operational implications for governments and subsequently for the World Bank operational agenda.

GOVERNMENT ROLES

Risks in rural areas must be managed at the macro-, meso-, and micro-levels. Governments need to (1) understand the country’s rural risk profile; (2) quantify the impact of this risk on the economy and revenues; (3) design a rural risk management framework; and (4) implement risk reduction and risk transfer.⁴⁴

Identify the Risk Profile for Private and Public Assets and Business Flows

A natural risk assessment identifies the types of risks that affect major private and public assets and economic activities in rural areas.⁴⁵ This assessment distinguishes between micro- and macrolevel risk and considers both geographical and seasonal variations. Identification of risks at the microlevel is typically based on household surveys as well as specific risk surveys. The objective is to understand the types of risks that affect households and the nature of those risks. At the macrolevel, the assessment would consider the aggregate economic effect of household risk with a particular focus on government budget exposure.

Quantify Risk Impacts at All Levels

Once the major risks have been identified, governments need to quantify the potential impact of those risks. What is the magnitude of potential

physical and indirect losses for different types of assets and economic activities? As represented in Figure 7.1, a variety of indirect business flow losses often compound the direct physical losses caused by natural hazards.

Design a Rural Risk Management Framework

Government intervention in risk transfer markets must be based on a careful analysis of market shortcomings and a clear statement of how government involvement will address those shortcomings (Chapter 5). A well-designed rural risk management framework clearly delineates public and private roles in the ex ante world of risk reduction and risk financing and also in the ex post world of emergency response. This framework takes country-specific objectives and constraints into account instead of replicating developed country historical models (Chapter 3). The objective is to learn from these historical examples and then to apply that understanding to country-specific efforts that incorporate new and innovative risk transfer instruments (Chapter 4). To plan appropriately, private decision makers need to know where and how government would intervene at different risk levels. Where a credible and reliable insurance cover is in place, for example, agricultural enterprises might intensify production.

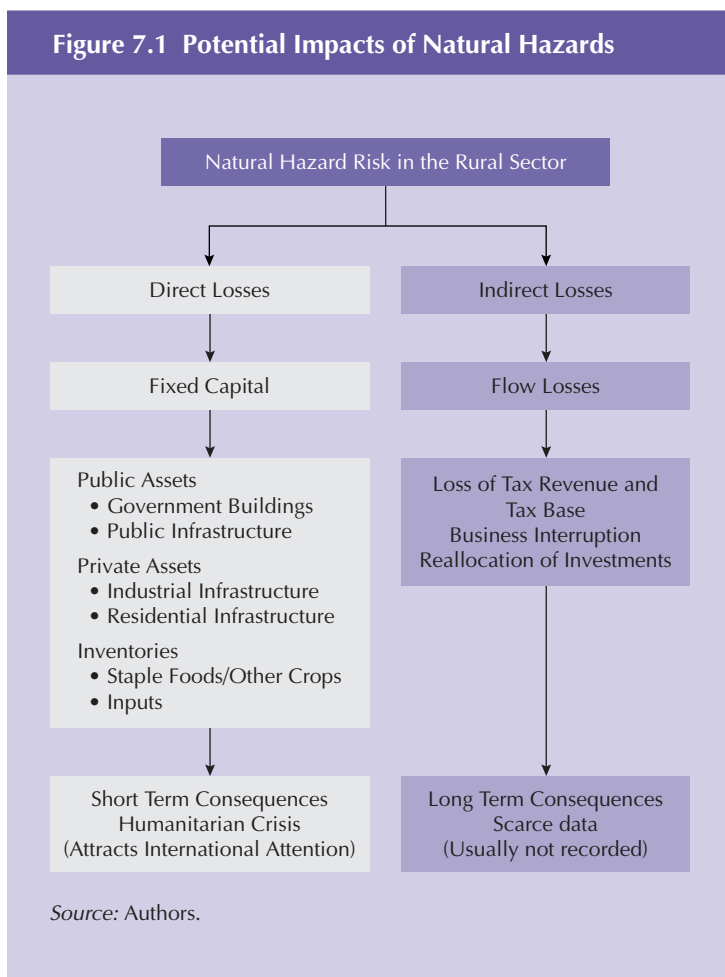
Implement a Risk Management Strategy

To be successful, a well-conceived risk management strategy must be supported by a credible government commitment that is sufficiently funded over the long term. While appropriate government roles will vary to reflect country-specific circumstances, one strategy might be government intermediation of index-based risk management products made available in international capital and reinsurance markets and government creation of infrastructure to support the development and implementation of new private risk management products.

WORLD BANK ROLES

The World Bank can engage in a number of activities that, in coordination with governments, may lead to increased risk-transfer opportunities for agricultural producers and other rural residents in developing countries. In general, these activities

Figure 7.1 Potential Impacts of Natural Hazards



include educational efforts, incorporating risk management into holistic rural development strategies, investment lending operations designed to encourage the development of risk transfer markets, ex ante coordination of donor responses to natural disasters, and monitoring and evaluation of the performance of index insurance instruments.

Building Global Knowledge of the Index Approach to Agricultural Risk Management

The World Bank is uniquely placed to reach governments and decision makers on all continents. The World Bank, in general, and ARD (the Agriculture and Rural Development department), in particular, can facilitate technology transfer across continents. This economic and sector work of ARD will be disseminated outside the World Bank: in fiscal year 2006. CRMG is planning Global Distance Learning events that will have a component on agricultural risk management concepts and also two workshops in two different regions, possibly in connection with weather insurance pilot project launches. Inside the World Bank, information sharing will take place mainly through “brown bag” lunches and workshops.

Incorporating Risk Management Strategies into Rural Development Strategy Formulation and Development Policy Lending Programs

While the World Bank and the IMF have a long history of assisting governments in dismantling unsustainable mechanisms for managing price risk, this often took place in the absence of alternative risk management tools or a clear risk management agenda for deregulated markets. This gap has contributed to a breakdown in marketing arrangements and credit channels, so that these efforts have sometimes not produced the projected results (Kherallah et al. 2002). While the task will be neither quick nor easy, the importance of addressing issues of collateral policies and institutional development as integral to reform is now widely understood.

While the index-based risk management tools discussed here are not a cure-all, they can help credit institutions, producer organizations, and (in some cases) producers to manage production risk directly; by doing so they can help reconnect farmers to output and credit markets. In assisting policymakers in the design of a country’s reform programs, the

World Bank should routinely consider how to facilitate the development of risk management instruments and should be prepared to support this process through policy advice and, in some cases, lending operations. Often, this may require reforming collateral, macroeconomic, or regulatory policies. Risk management instruments using international markets, for example, cannot operate properly while exchange controls are in place. Often, local regulations affecting insurance or financial markets also must be revised.

Because government or World Bank involvement in any risk management program may require trade-offs with other means of enhancing rural development and reducing vulnerability (for example, irrigation, infrastructure, and so on), the program should be embedded in an overall rural development strategy so any trade-offs can be carefully weighed. This will also allow formation of linkages with other rural development objectives (for example, rural finance). The overall rural development strategy should take a holistic approach to risk management, recognizing that diversification of income sources (remittances, off-farm employment, and others) is often an important means of reducing rural vulnerability. In addition to formal risk management markets, the strategy should consider what reforms are needed to encourage income diversification and to allow farmers a full range of choices in a functioning marketplace. This may include, for example, market liberalization and privatization; investments in transportation, communication, and market infrastructure; legal rights guaranteeing market access (especially for women and ethnic minorities); provision of market information; and measures to better integrate rural and nonrural labor markets (see Siegel 2005; Lanjouw and Feder 2001; Lloyd-Ellis 1999; and Mead and Liedholm 1998). Attention should also be dedicated to safety nets designed to minimize the need to liquidate productive assets in times of emergency and to be scaled up quickly and efficiently at need (see Jorgensen and Van Domelen 1999; Jutting 1999; and Morduch 1999).

Creating Investment Lending Operations that Encourage Risk Management

At the macrolevel, a number of World Bank instruments (and those of other donors) exist or are being explored that can cushion the fiscal and balance of payments adjustments required when countries

face shocks from natural disasters or international price movements of major commodity exports or imports. These include automatic mechanisms to adjust debt service—or even to augment financing—in response to exogenous shocks. (For a full discussion, see World Bank 2004; 2005b.)

At the mesolevel, risk management tools can be used to improve the functioning of government social safety net programs, either at central or decentralized levels. Index-based insurance instruments, for example, could be used to provide *ex ante* contingent funding that would allow safety net programs to expand when they are most needed, without the delays and uncertainties caused by reliance on budgeting processes or on external aid. Likewise, use of index-based insurance by individual farmers, associations, processors, or rural finance institutions would reduce their degree of uncertainty and facilitate primary producers' access to credit and input markets.

In addition to policy advice, the primary World Bank tool now being used to support development of risk management markets, investment lending projects may also be useful in some cases. Examples can be found in World Bank-facilitated price risk management efforts. In Turkey, for example, a commodity market development learning and innovation loan (LIL) had the objective of first supporting the development of physical commodity markets, which in the long term could evolve into a domestic platform for trading futures contracts. The project financed the upgrading of testing laboratories, warehouse facilities, and regional market infrastructure, and it provided technical assistance to enhance and harmonize grades and standards for some commodities, upgrade the warehouse receipts system, and improve the operations of the commodity market regulatory authority. While there Turkey still has no domestic futures trading, progress has been made toward the more limited objectives of establishing better linkages between producers and buyers and of encouraging forward contracting for spot delivery, providing another means of reducing price risk. In addition, the project has facilitated more efficient price discovery: the prices for cotton and wheat determined on two exchanges participating in the project now serve as the official record of domestic market prices for those two commodities.

Another project being explored focuses on the establishment of a regional system of weather insurance in southern Africa (see Box 7.1).

The target of the project, as currently conceptualized, would be individual farmers, but a project like this could be targeted at the mesolevel as well. Pooling risk at the subregional level (a complex climate system) can reduce financing requirements by taking advantage of scale. The subregion as a whole is more attractive to international insurance markets (due to risk-spreading) than would be individual countries. Other direct benefits include the faster spread of ideas and the more effective development of capacity made possible by cross-country collaboration and the presence of preexisting regional institutions ready to support project implementation.

Donor Coordination

Like farmers, governments may suffer from a form of moral hazard. Donor response to catastrophes can reduce the interest of the developing country government in using markets to shift natural disaster risk, as was the case in Nicaragua following the overwhelming donor response following Hurricane Mitch. Donor responses, however, cannot be predicted with certainty and often are not timely. Furthermore, the international community may overlook localized disasters, which may devastate a community despite having limited impact beyond it. A better solution would be to take advantage of these donations in a more structured and *ex ante* fashion. Donors could, for example, contribute to an insurance pool for the country or region. The World Bank—particularly the teams in countries especially prone to disasters—can play a leading role in this through the consultative group process.

A special case of aid in response to disaster is food aid following a serious drought. Here, the need for an improved approach is particularly acute, as in-kind assistance often has counterproductive effects in undermining development of local production and marketing channels. Also, aid given *ex post* in response to droughts is often late in arriving, forcing starving victims to liquidate productive assets, thus perpetuating a cycle of poverty. Use of an index-based instrument to fund emergency food aid holds the promise of a much more rapid response, since payment would be triggered by weather events far in advance of the actual food shortages, and of far less disruption of local markets, since food aid agency payouts would be made in cash that would be used to pro-

Box 7.1 Examples of Potential World Bank Investment Lending Projects to Facilitate Risk Management

Global level

Global Index Insurance Facility: The facility would consist of a capital investment in a risk-taking entity that would underwrite global weather, disaster, and price risks in developing countries. The main development objective would be to absorb costs for initial transactions for developing country clients through cofinancing of premiums, funded both separately and through reinvestment of dividends by public sponsors. The main commercial objective of the facility would be to generate a modest return to its shareholders through active management of a diverse portfolio of developing country risk not previously transferred to the capital and insurance markets. The facility would perform several commercial functions providing benefits to developing countries.

National level

Infrastructure: Fallback stations, new weather stations, maintenance of weather stations, communications equipment for weather services, contract with data vetting services (such as the U.K. Met Office), set-up of weather databases (online), and the cleaning and enhancing of weather data.

Regulatory assessment: Review of legislation, drafting of new regulations, general policy framework review, and country-specific policy framework review (including recommendations on subsidy levels, national weather risk funds, basis risk matching funds, and so on).

International market/pilot transactions: Travel to international reinsurance market contacts,

technical assistance from international experts (including CRMG), and premium cost-sharing funds. These premium support funds would compensate for the extra premium costs that international and national insurers add in the infancy stages of the product and as a result of data uncertainty. These premium support funds would be phased out as volumes increased and as the extra costs for premiums declined.

Knowledge transfer: Travel costs, expertise, design of methodologies and tools to quantify risk exposure, underwriting guidelines, manuals, operational system development, and study tours.

Financial backing of risk-taking entities: Government mediation of catastrophic risk between international risk insurance markets and insurers or other risk takers in the country; governments could either set up separate risk-taking vehicles or enter into contingent credit agreements with the World Bank to lower annual premium costs.

Regional level

Financial contribution to a regional index insurance fund: Pooling systemic risk at the regional level, significantly lowering premium costs and warranting set-up of a regional risk fund that would insure its members according to sound actuarial rates before it lays off risk in international markets.

Climate prediction and forecasting technologies: Can be cost effectively rolled out only at a regional level that achieves economies of scale and enforces collaboration.

Source: Authors.

cure food locally, to the extent possible, or to pay beneficiaries directly. The World Bank is collaborating with the World Food Program and other donors to pilot such an approach.

Monitoring and Evaluation of Transactions

The work on index insurance in developing countries is still in an early stage, and its development impact is not yet proven. A number of assumptions about the value of these instruments, their utility at

the farm level, and their development impacts need to be evaluated. CRMG has launched a first baseline study with DECRG (Research Department of the World Bank). Generally, utility at the farm level can be gauged by the level of take-up of unsubsidized and unbundled products and, particularly, the level of repeat buying. Panel studies will reveal the actual impact of these products. Indicators are the level of inputs used and the diversification of farm activities, particularly the share of cash crops in the overall portfolio. Another important

linkage will be to gauge whether index insurance products improve access to credit or improve the terms of credit for small farmers in developing countries. Both the Indian and the Mongolian pilot project have very explicit monitoring and evaluation components that will attempt to gauge these activities.

As with any innovation, index insurance products for agricultural production risk will go through some significant changes in the next few years. It is likely that we will learn that they work under some

circumstances and not under others. Mistakes will be made. Learning from those mistakes will require careful evaluation and subsequent adjustments. At this stage, the key value added from index insurance products appears to be the opportunity for structured ex ante financing of catastrophic risk tied to highly correlated losses resulting from weather risk in agriculture. Such risk cannot be pooled at the local level, and the special structures introduced in this ESW give hope that they can be shifted into global markets.

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Appendix 1

Weather Risk Management for Agriculture⁴⁶

The emerging weather risk market offers new risk management tools and opportunities for agriculture. The aim of this appendix is to illustrate how an end user in the agricultural industry could use a market-based solution to mitigate the financial impact of weather on its business operations. The appendix draws information from the wealth of literature written on the subject of weather risk management to provide the reader with a step-by-step guide to how weather risk management instruments could be developed for and used in the agricultural sector. After discussing the financial impact of weather on agriculture, this Appendix explores the key steps required to structure a weather risk management solution, from identifying the risk to execution. Also discussed are the pricing of weather risk management instruments, with a brief overview of how the weather market approaches and values weather risk and the implications for the end user. Finally, the Appendix treats the prerequisites for weather risk management instruments: the weather data used to construct weather indexes and settle contracts and the data cleaning and analysis necessary when pricing and structuring a potential transaction. Selected references suggest further reading on weather risk management.

THE FINANCIAL IMPACT OF WEATHER

Weather risk impacts individuals, corporations, and governments with varying degrees of frequency, severity, and cost. Around the world, people face the vagaries of the weather on a daily basis. The media continually reports catastrophic weather events—floods, hurricanes, and droughts—that impact individuals' property, health, and lives. Consequently, governments are also financially exposed to weather risk. They are called upon to provide direct financial, nutritional, and housing support to their citi-

zens in the event of weather-related disasters and must increase spending for rehabilitation and reconstruction of infrastructure and assets as a result of damage incurred. Moreover, the economy of a country is also at risk to weather through business interruption, supply shocks, diversion of domestic investment from productive activities to mitigation of the disasters' impacts and, for some countries, a reduction in foreign investment in the aftermath of an extreme weather-related event. While often such effects are reversible and short-term, the impact on the economy of a poor country can be significant and long lasting. Between 1997 and 2001, the average damage per natural disaster in low-income countries was 5.8 percent of GDP (IMF, 2003). Evidence from sixteen Caribbean countries shows, for example, that one percentage point of GDP in direct damage from natural disasters can reduce GDP growth by half a percentage point in the same year (Auffret 2003). Furthermore, the humanitarian cost of weather-related disasters is also greater in the developing world: approximately 80 percent of all fatalities due to weather disasters between 1980 and 2003 occurred in the "uninsured world," comprising predominantly low-income countries (Loster 2004).

Even noncatastrophic weather events have a financial impact. The U.S. Department of Commerce estimates that nearly one-third of the U.S. economy, or US\$1 trillion (U.S. Congress 1999) is modulated by the weather, and that up to 70 percent of all U.S. companies are weather sensitive. Weather risk can impact a business through its overall profitability or simply through the success or failure of an initiative as a consequence of the weather. Like governments, businesses can face both demand- and supply-driven weather risks. Energy companies, for example, can be exposed to demand-driven weather risk. In the event of a warmer than average winter, for instance, gas companies, in particular those dealing with domestic customers, face a potential drop in gas sales as customers use less gas

than expected to heat their homes. Therefore, even if the company has adhered to prudent price risk management practices by protecting their sales margin from fluctuations in the gas supply price, weather-driven demand fluctuations can lead to a drop in sales volume below expected levels that significantly affects budgeted revenues. A supply-side example of weather risk can be found in the construction industry. Because building materials have specific weather requirements, cold and wet weather conditions can impact construction progress; concrete, for example, cannot be poured in wet or below-freezing conditions. Contractors must assume this supply-driven weather risk, which can significantly delay a construction project and result in hefty penalties if the project is not completed on schedule.

Weather has traditionally been the scapegoat in business for poor financial performance (Clemmons 2002). Annual reports, financial statements, and press releases frequently contain declarations such as, “[c]ooling degree days were 21 percent below last year’s quarter and 16 percent below normal. The effects of milder weather compared with last year had a negative impact on [earnings before interest and taxes] of about \$35 million for the quarter” (Duke Energy 2003); “4 cents per share [decline] for lower gas deliveries due to warmer weather in the fourth quarter of 2003” (Energy East 2004); and “Europe’s performance continued to be impacted by unfavorable summer weather with volume down 12 percent in the third quarter and year-to-date volume down 6.5 percent” (Coca-Cola 2004). Given such examples, it is not surprising that the financial community has begun to seek practical solutions to controlling the financial impact of weather. Centrica Plc, for example, one of the largest domestic gas suppliers in Great Britain, is one of a number of utilities that has chosen to manage its weather risk in order to “protect the company against variability in earnings of its gas retail business due to abnormal winter temperatures in the UK” (Ulrich 2002), and it has been doing so since 1998. London-based Corney and Barrow Wine Bars Limited deploys several weather hedges to provide financial protection against cool summers resulting in poor customer patronage: “After the exceptional summer of 2003 Corney and Barrow was keen to secure protection against the possibility of the reverse experience [in 2004]” (XL Trading 2004). With the emergence of a market for weather risk management products, a business can now be protected

from such ancillary risks that create unpredictable earnings streams. Just as interest rate and currency risks are currently managed through market-based solutions, weather risks that increase business uncertainty can now be neutralized, allowing a company to focus on its core business and to protect earnings per share forecasts and growth.

THE WEATHER MARKET

In 1997, a formal weather risk market was born in the United States through the first open market derivative transaction indexed to weather. Motivated by the deregulation of the energy industry, which led to the break-up of regulated monopolies in electricity and gas supply, the nascent weather market responded to energy companies’ need to increase operational efficiency, competitiveness, and shareholder value. In 1996, the Kansas-based energy company, Aquila, entered into a transaction with New York-based Consolidated Edison that combined temperature and energy indicators, protecting the latter against a cool August that would reduce power sales. The first publicized transaction in 1997, however, was between energy companies Koch Energy and Enron. Additional deals soon followed, with other energy market participants wanting protection against risks, primarily temperature, associated with volumetric fluctuations in energy.

In 2001, the Weather Risk Management Association (WRMA)—the industry body—commissioned PricewaterhouseCoopers (PWC) to conduct a survey of weather risk contracts executed among WRMA members and survey respondents from October 1997 to March 2001 and since then on an annual basis. Since 1997, the survey has shown that over US\$20 billion has been transacted through the weather risk market⁴⁷: the market has grown to around US\$4.6 billion outstanding risk for the year April 2003 to March 2004 (PWC 2003; 2004; see Figure A1.1), although some believe this to be an underestimate.⁴⁸ Active trading occurs in U.S. European, and Japanese cities (Figure A1.2); most notable among the few transactions occurring outside these three main trading hubs are agricultural transactions in Mexico, India, and South Africa. The market has also evolved to include nonenergy applications. Survey respondents, when asked to list requests received from potential end users of weather risk management products, identified end users in the retail, agriculture, transport, and leisure and entertainment industries (Figure A1.3), although

energy still contributes approximately 56 percent of the potential weather risk management end user market. As a result of this expansion, the market has also broadened its product offering to include transactions on nontemperature indexes⁴⁹ such as rainfall, wind, and snow.

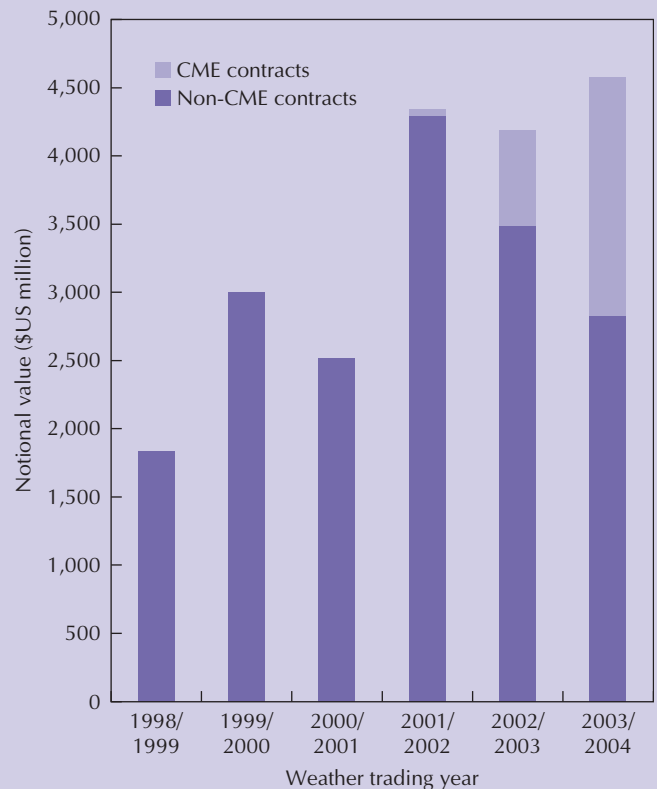
Today, the key market participants include (re)insurers, investment banks, and energy companies. (Re)insurers and investment banks provide weather risk management products to end user customers—such as Corney and Barrow Wine Bars Limited and Centrica Plc—and form the primary market; all three participate in a secondary market in which players transfer weather risk among themselves through over-the-counter (OTC) financial transactions and exchange-based derivative contracts on the Chicago Mercantile Exchange (CME)⁵⁰ to diversify and hedge their portfolios.

Weather risk management is also being introduced to the developing world through the work of organizations such as the World Bank Commodity Risk Management Group (CRMG) and the United Nations World Food Program (WFP). The World Bank was involved in the first index-based weather risk management program—in India in June 2003—and it is currently working on several projects around the world. The small pilot program was launched by Hyderabad-based microfinance institution BASIX and the Indian insurance company ICICI Lombard, in conjunction with CRMG, when 230 groundnut farmers in Andhra Pradesh bought weather insurance to protect against low monsoon rainfall (Hess 2003). Currently the WFP, in conjunction with the World Bank, is investigating the feasibility of weather-based insurance as a reliable, timely, and cost-effective way of funding emergency operations in countries such as Ethiopia (The Economist 2004). Work is also underway to see if developing country governments in southern Africa can benefit from weather risk management products and strategies (Hess and Syroka 2005). The global weather-risk market is particularly interested in these types of transactions, as they provide much sought after diversification to their books through new locations and risks.

WEATHER RISK AND AGRICULTURE

One of the most obvious applications of weather risk management products, weather insurance or weather derivatives is in agriculture and farming.

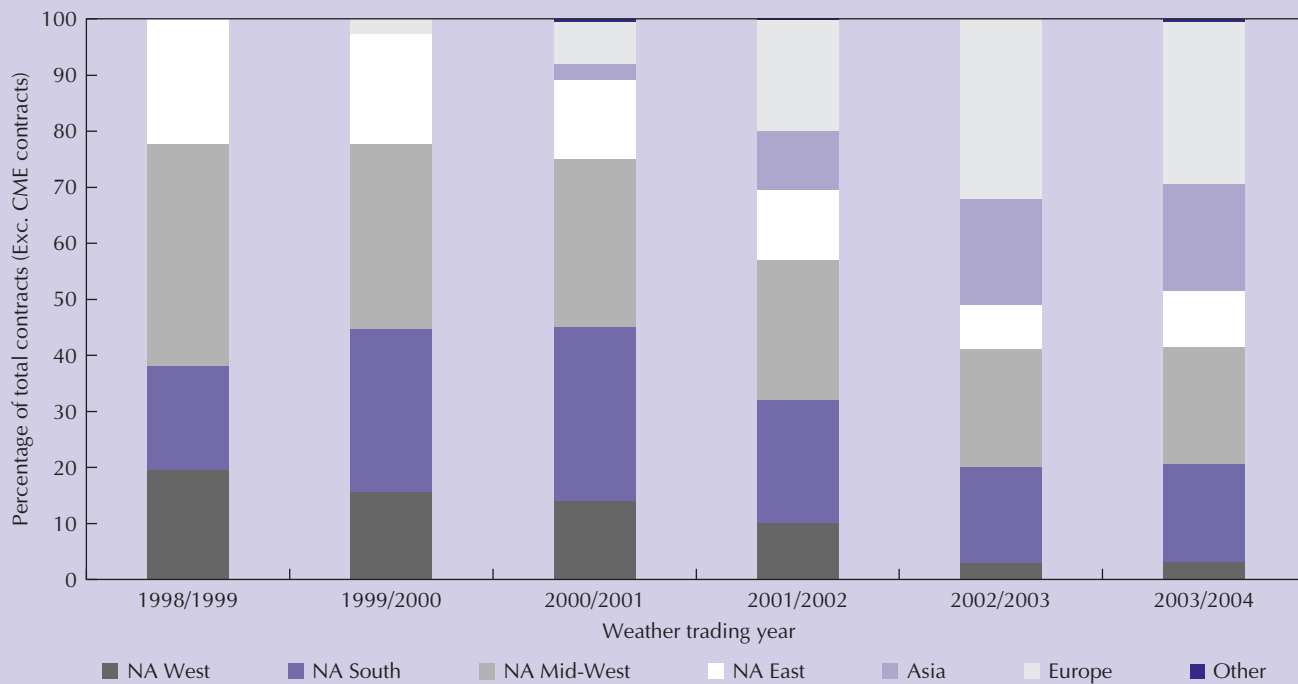
Figure A1.1 Notional Value of All Weather Contracts in US\$



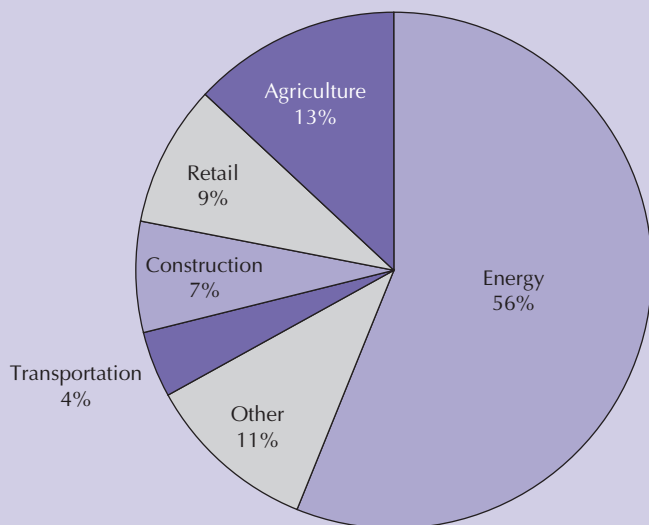
Source: Author's figures, using PricewaterhouseCoopers industry survey data from 2003 and 2004.

Indeed 13 percent (PWC 2004) of the end user requests in the weather market are now focused on the agricultural sector (Figure A1.3). Weather affects many aspects of the agricultural supply and demand chain. From the supply side, weather risk management can help control both production or yield risk and quality risk.

Technology plays a key role in production risk in farming. The introduction of new crop varieties and production techniques offers the potential for improved efficiency; however, agriculture is also often affected by many uncontrollable events related to weather—including excessive or insufficient rainfall, hail, extreme temperatures, insects, and diseases—that can severely impact yields and production levels. Countless examples can be given on the impact of cold temperatures on deciduous fruit (Guaranteed Weather 2005b), deficit rainfall on wheat (Stoppa and Hess 2003), excess rainfall on potato yields (Meuwissen et al. 2000), and even

Figure A1.2 Percentage of Total Weather Contracts by Location (excluding CME trades)


Source: Author's figures, using Pricewaterhousecoopers industry survey data from 2003 and 2004.

Figure A1.3 Potential End User Market by Economic Sector 2003–2004


Source: Author's figures, using PricewaterhouseCoopers industry survey data from 2004.

temperature stress on cattle and thus dairy production (Guaranteed Weather 2005a). In 2003, 59 percent of Ukraine's winter grain crop was destroyed due to winterkill temperatures (USDA 2003) and 40 to 50 percent of northeastern England's oil rape-seed crop was lost due to excessive rain at harvest in August 2004 (BBC 2004). The costs associated with drops in expected or budgeted production due to such uncontrollable factors can have a significant impact on a producer's revenues and contractual obligations. A producer may seek protection against adverse weather conditions affecting crop yield. Weather can also impact the quality, if not the absolute production levels, of a crop (Guaranteed Weather 2005c).

On the demand side, weather also affects related agricultural products through the use of pesticides, fertilizers, and herbicides. Agricultural chemical producers, for example, can use weather risk management instruments to hedge against the costs associated with fluctuations in the demand for chemicals by farm operators. The cotton boll weevil, for example, which costs cotton producers in the

United States US\$300 million per year,⁵¹ is a weather sensitive pest; its numbers vary from year to year largely due to the severity of the winter. In extremely cold winters, weevil numbers drop significantly, directly affecting the net earnings of an agrochemical company. Chemical producers could hedge their earnings volatility caused by fluctuations in pesticide sales by purchasing a weather risk management instrument specifically indexed to the phenology of the pests their products target.

Index-based weather insurance is a relatively new product, and the use of weather risk management products in the agricultural sector is still in its infancy, with very few publicized transactions in the United States and Europe. A number of agricultural transactions have occurred outside of the main weather market trading hubs, however, most notably in Canada (Ontario—maize; Alberta—forage), Argentina (Sancor—dairy), South Africa (Gensec Bank—apple cooperative freeze cover), and India (ICICI Lombard—groundnut, cotton, coriander, and orange). Given weather is one of the biggest risks faced by farmers, weather-indexed risk management products have been suggested as a potential alternative to the traditional crop insurance programs for smallholder farmers in the emerging markets.

STRUCTURING A WEATHER RISK MANAGEMENT SOLUTION

Developing a successful weather risk management and transfer program for agriculture involves four essential steps:

- Identifying significant exposure of an agricultural grower/producer to weather;
- Quantifying the impact of adverse weather on their revenues;
- Structuring a contract that pays out when adverse weather occurs; and
- Executing the contract in optimal form to transfer the risk to the international weather market.

Each of the steps is outlined in the following four subsections, and they are fully explored in the case studies in the next appendix.

Identifying the Risk

Identifying weather risk for an agricultural grower or producer involves three steps: identifying the re-

gions at risk from weather and the weather stations that reflect that risk; identifying the time period during which risk is prevalent; and identifying the weather index providing the best proxy for the weather exposure. This last step is the most critical in designing an index-based weather risk management strategy. Rather than measuring the actual impact on crop yields—or related fluctuations in demand, supply, or profitability—the index acts as a proxy for the loss experienced due to weather and is constructed from actual observations of weather at one or more specific weather stations.

Location and Duration

All weather contracts are based on the actual observations of weather variables at one or more specific weather stations. Transactions can be based on observations from a single station or a basket of several stations or on a weighted combination of readings from multiple stations. (More information on the weather station and data requirements for weather risk management instruments appears below.) If an individual farmer is interested in purchasing weather protection for his particular crop, the index-based weather contract must be written on the weather station nearest the farmer's land to provide the best possible coverage for the farmer client. A larger grower, with several production regions, may be more interested in purchasing a weather contract based on several weather stations to reflect the weather conditions in all areas covered by the business. The grower's risk management strategy can be either to purchase a weather contract on each of the identified weather stations or to purchase a single contract on a weighted average of several stations, with the weightings chosen to reflect the importance of the different stations to the overall weather exposure of the business. The approach chosen depends on the risk preferences and risk retention appetite of the grower, although weighting is generally the cheaper and more efficient approach. Retaining localized risks will most probably be a more cost-effective solution than would transferring them to a third-party, while still providing protection in situations where adverse weather affects several regions and involves the overall production portfolio of a producer. The latter approach will also reduce the risk of reliance on one weather station and hence the associated issue of basis risk,⁵² covered below.

All contracts have a defined start and end date to limit the period over which the underlying index

is calculated. This calculation period describes the effective dates of the risk protection period during which relevant weather parameters are measured at the specified weather stations. For agricultural end users, the duration of the weather contracts will be determined by the specific requirements of their business. Contract duration is flexibility to address individual end-user business exposures; contracts can be weekly, monthly, seasonal, and even multi-annual. Final settlement of the weather contracts typically occurs up to forty days after the end of the calculation period, once the collected weather data have been cross-checked and quality controlled by the relevant data-collecting body, usually the National Meteorological Service.⁵³

Underlying Indexes

A weather index can be constructed using any combination of measurable weather variables and any number of weather stations that best represent the risk of the agricultural end user. Common variables include temperature and rainfall, although transactions on snowfall, wind, sunshine hours, river flow, relative humidity, and storm/hurricane location and strength are also possible and are becoming more frequent. Unlike energy indexes, in which the relationship between energy demand and weather is more transparent and is linked primarily to temperature, weather indexes for agriculture demonstrate more complex, albeit still quantifiable, relationships between crop yields or pesticide use.

The normal process for designing an index-based weather insurance contract for an agricultural grower, for example, involves identifying a measurable weather index strongly correlated to crop yield rather than measuring the yield itself. After gathering the weather data, an index can be designed by (1) looking at how the weather variables have or have not influenced yield over time; (2) discussing key weather factors with experts, such as agrometeorologists and farmers; and/or (3) referring to crop growth models using weather variables as inputs for yield estimates or phenology models illustrating how weather variations relate to pest development. A good index must account for the susceptibility of crops to weather factors during different stages of development, the biological and physiological characteristics of the crop, and the properties of the soil. If a sufficient degree of correlation is established between the weather index and crop yield or quality, a farmer or an agricultural producer can insure his production or qual-

ity risk by purchasing a contract that pays if a specified undesirable weather event occurs or a specified desirable weather fails to occur. The index possibilities are limitless and flexible to match the exposure of the agricultural grower or producer, as long as the underlying data are of sufficient quality. A few examples of weather indexes for specific agricultural exposures appear below. Although the examples are based on temperature and precipitation, the principles apply to all weather parameters recorded by ground-based meteorological weather stations. More examples are given in the case studies in Appendix 2.

Example 1: Growing Degree Days

Growing Degree Days (GDDs) is a common index used in the agricultural sector, similar to HDDs and CDDs in the energy sector. GDDs are a measurement of the growth and development of plants (both crops and weeds) and insects during a growing season. Organisms that cannot internally regulate their own temperature are dependent on the temperature of the environment to which they are exposed. Development of an organism does not occur unless the temperature is above a minimum threshold value, known as the base temperature, and a certain amount of heat is required for development to move from one stage to the next. The base temperature varies for different organisms and is determined through research and scientific considerations. A GDD is calculated by the following equation:

$$\text{Daily GDD} = \max(0, T_{\text{average}} - L);$$

$$T_{\text{average}} = (T_{\text{max}} - T_{\text{min}})/2 \quad (1)$$

where L is the baseline temperature and T_{average} is the daily mean temperature, defined as the average of the daily maximum (T_{max}) and minimum (T_{min}) temperatures. If this average is greater than the threshold temperature L , the GDD accumulated for that day is the threshold temperature minus the daily average temperature. If the daily average temperature is less than the base temperature, then the GDD for that day is zero. Adding the GDD values of consecutive days gives the accumulated GDDs over a specific period. Accumulated GDDs are a good proxy for establishing the development stages of a crop, weed, or insect and can give an indication as to the development and maturity of a crop or the proper scheduling of pesticide or herbicide appli-

cations. Measuring the amount of heat accumulated over time provides a physiological time scale that is biologically more accurate than are calendar days (Neild and Newman 2005), and specific organisms, pest or plant, need different accumulated GDDs to reach different stages of development. By comparing accumulated GDD totals with those of previous years, it can be seen if a normal amount of heat energy has been made available to a crop. In general, assuming adequate moisture supplies are available, the total GDDs received by the end of the growing season are often related to crop yield, and therefore GDDs can be a good index for crop production. The cumulative temperature index can be used to establish a relationship between GDDs and production and thus ultimately with a producer's revenues.

Example 2: Event-based Indexes

Crop damage can also be the result of specific or critical temperature events that can be detrimental to yield or quality. Freezing conditions, for instance, were reported to have caused more than US\$600 million in damage to the U.S. citrus crop in a single week of December 1998, with US\$300 million occurring in Tulare County, California, alone (Guaranteed Weather 2005b). Critical temperatures causing crop damage may vary depending on the length of time that temperatures remain below freezing as well as on the variety, health, and development stage of a plant. Preventative and proactive measures can often be taken to protect crops from such events, but these may have limited impact or become more difficult for crops that are farmed in large areas, such as cereals and grains.

Winter wheat yields at harvest, for example, depend to a great extent on how well the plants survive the winter hibernation period. In the territory of Kherson, in Ukraine, winter wheat crops have been known to die when air and therefore soil temperatures fell below a critical level for one day or longer. These winterkill events cause damage and death of the plants' tillering node: "[with little or no snow, plants begin to die when] the daily minimum air temperature drops below -16 deg C; [a crop can be completely lost if this happens for] four days in a row or in the minimum temperature drops below -21 deg C" (Adamenko 2004). Snow cover considerably improves conditions of winter wheat hibernation, as the difference between air and soil temperature increases from 0.5 to 1.1°C per centimeter of snow cover. Snow cover on the territory

of Kherson is often unstable, hence complete winter wheat crop failure due to winterkill is a potential risk in the southern steppe zone of Ukraine; the crop usually dies in years with no snow cover or when the stable snow cover appears late in winter, as it did in 2003. A winterkill index, based on days when the daily minimum temperature is less than -16°C , could therefore be used by a farmer to obtain protection against such crop failure risk. A farmer could enter into a contract with the recovery of the full value of the crop, as expected under normal weather conditions, if the recorded daily minimum air temperature is less than -16°C for four or more consecutive days at any time during the winter period from November to March.

Example 3: Deficit Rainfall and Drought

Meteorological drought is usually defined in terms of deviation of precipitation from normal levels and duration of a region's dry periods. Agricultural drought refers to situations in which soil moisture content no longer meets crop growing needs in an area due to insufficient rainfall. Crops, particularly rain-fed crops, often have a minimum overall threshold of cumulative rainfall necessary for successful and healthy plant development. Dry beans, for example, can consume up to 368 mm of water during the growing season, depending on plant variety, soils, climate, and weather conditions (Efetha 2002). For dry-land corn farming, 450 to 500 mm or more of rainfall during the growing season is required for high yields (Neild and Newman 2005). These water requirements must be met by natural rainfall, stored soil moisture from precipitation prior to the growing season, or supplemental irrigation. Therefore, a deficit of rainfall below these levels, in the absence of irrigation, can cause plant moisture stress that affects development and reduces yields. A simple cumulative rainfall index can be developed to suit a grower's specific insurance requirements with regard to such decreases in rainfall and yield. Looking at historical yield data, for example, can establish an empirical relationship between seasonal cumulative rainfall and yield. The distribution of rainfall during the growing season or at specific stages of a plant's development is often more important than total rainfall, however, and customized indexes must be developed to capture this risk (Stoppa and Hess 2003). Such indexes may also include other weather parameters, such as temperature and relative humidity. Crop growth models or historical yield data can be used to infer

the empirical relationship between rainfall amounts and yield/quality for specific soil and crop types.

Quantifying the Risk

Once the index has been identified, it must be calibrated to capture the financial impact of the specified weather exposure as measured by the index. Two approaches are possible at this stage: identifying the financial exposure per unit of the defined index, and/or establishing the limit, the total financial protection, required per risk period, that is, the maximum payout necessary in a worst-case scenario. The approach chosen depends on the nature of the underlying index and weather event. If the weather exposure is event driven, for example, such as a Category 5 hurricane hitting a particular location or a cold winterkill event destroying an entire wheat crop, the latter approach is more appropriate. If the weather exposure is of a cumulative nature, such as drought or Growing Degree Days, the former approach should be chosen. Taking into consideration the maximum protection required per risk period can also inform the financial exposure per unit index.

Unit Exposure

After developing weather indexes to capture the impact of adverse weather conditions on a specific crop's yield, it is straightforward to calculate the financial impact of these events for producers. In designing the index, expert scientific agrometeorological assessments, either in conjunction with crop model output or with verification using historical yields, have been employed to construct an underlying index that best proxies the weather sensitivity of the crop in question. Having identified the index, the crop yield, Y , or volume, V , variability per unit of the defined index, I , can be defined, as follows:

$$\Delta Y = \Delta V/H = a(I)\Delta I \quad (2)$$

where, $a(I)$ is some function of I that relates the index to the yield Y , and H is the planting area of the crop. In order to calibrate an appropriate weather contract, the variation in crop yield must now be converted into a financial equivalent that mirrors the producer's exposure. This can be done, for example, by considering a producer's production and input costs per hectare planted or by considering his expected revenue from the sale of the crop at har-

vest. Producers with fixed-price delivery contracts or those using price risk management instruments to protect themselves from market fluctuations in the price of their crop at harvest time know the financial value of each kilogram or metric ton they produce and hence can quantify the financial cost of a shortfall in production. If a grain producer, for example, knows he will receive $\$X$ per metric ton of crop, the following relationship must hold for his change in revenue:

$$\begin{aligned} \Delta Revenue &= X \times (\text{Actual Yield} - \text{Expected Yield}) \times H \\ &= X \times \Delta V = \pm X \times H \times a(I) \times \Delta I \end{aligned} \quad (3)$$

A good weather hedge must offset the negative $\Delta Revenue$ fluctuation in the event of a drop in yield from budgeted levels if a producer is to protect his earnings. In order to perfectly replicate his position, the farmer could enter into a weather contract with the following incremental payout P per unit index:

$$\Delta P = X \times H \times a(I) \times \Delta I \quad (4)$$

Therefore, his overall position would be:

$$\begin{aligned} \Delta Revenue + AP &= -X \times \Delta Y \times H \\ &+ X \times H \times a(I) \times \Delta I = 0 \end{aligned} \quad (5)$$

Producers may have contractual obligations to deliver a predefined amount of their farmed product to a buyer at harvest time, with associated penalties if these obligations are not met. In such a situation, it would be straightforward to quantify and structure a hedging product to protect producers from these contractual costs in the event of weather-related shortfalls in production.

The Limit

Most weather contracts have a limit, which corresponds to the maximum financial payout or recovery from the contract in a worst-case scenario, such as a complete crop failure. The maximum payout can be set by either considering the value-at-risk for the producer in the event of a total crop failure or by looking at historical index, production, and sales data to find the worse-case scenario historically in order to establish a limit. Alternatively, a producer may simply want to insure his production and input costs in order to recover these outlays if the crop fails. If a producer's production costs are $\$Z$ per hectare farmed, $\$Z$ will therefore

correspond to the maximum payout, the limit of the weather contract, for each hectare the producer wishes to insure. The unit exposure P will therefore be as follows:

$$\begin{aligned}\Delta P &= (-\Delta Y / \text{Expected Yield}) \times Z \\ &= (a(I)\Delta I / \text{Expected Yield}) \times Z, \text{ for } \Delta Y < 0\end{aligned}\quad (6)$$

Structuring the Product

Structure Type

Once the index has been identified and calibrated, the next step is to structure a contract that pays when the specified adverse weather occurs, thus performing a hedging or risk-smoothing function for the agricultural grower or producer. Derivative and insurance products form the mainstay of the weather risk management market. While the two instruments feature different regulatory, accounting, tax, and legal issues, the risk transfer characteristics and benefits are often the same. One of the drivers of market growth has been the flexibility between both instruments and the possibility of tailoring risk management solutions to a client's needs (Corbally and Dang 2002). A risk management product can be either of the following:

- A traditional insurance-style product, that is, risk transfer that results in downside protection in exchange for a premium; for example, a call or put option structure. Or,
- A risk-exchange derivative-based product, that is, a product based on giving away upside in good years or seasons to finance downside protection; for example, a collar or swap structure.

Call and Put Options

A call option gives the buyer of the option the right, but not the obligation, to buy the underlying index at a predefined level at the maturity, or end date, of the contract.⁵⁴ In exchange for this right, the buyer pays a premium to the seller. Similarly, a put option gives the buyer the right, but not the obligation, to sell the underlying index at a predefined level at contract maturity; in exchange for this right, the buyer of the option pays a premium to the seller. Every option contract and, in general, most weather contracts are defined by a set of standard specifications including:

- The reference index, I , and weather station(s): complete specification of the index and data used to construct it;

- The term, T : the risk protection period of the contract, including the start and end date of the contract;
- A strike, K : also known as an attachment level, the level at which the weather protection begins;
- The payout rate, X : the financial compensation per unit index deviation above (call) or below (put) the strike at maturity, defined as the unit exposure in the previous section; and
- The limit, M : the maximum payout per risk protection period.

The payout, P_{call} , of a call option can be defined using the following equation:

$$P_{call} = \min(\max(0, I - K) \times X, M) \quad (7)$$

The payout, P_{put} , of a put option can be defined as follows:

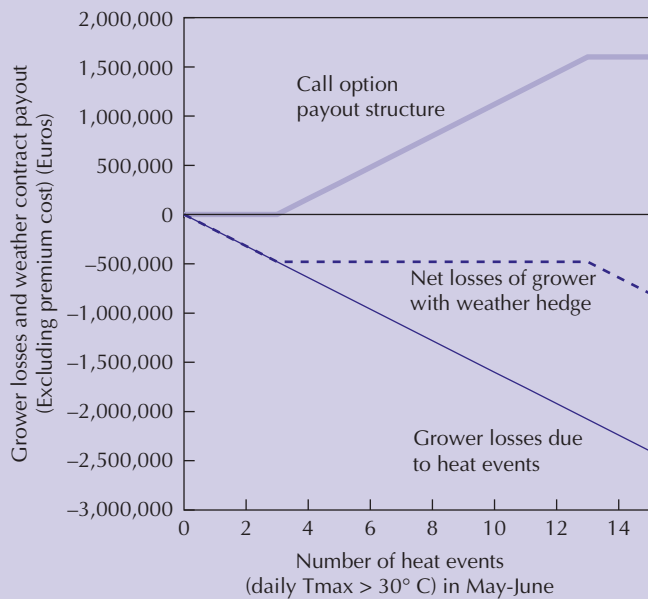
$$P_{put} = \min[\max(0, K - I) \times X, M] \quad (8)$$

The type of option purchased depends on the risk profile of the buyer. Assume, for example, a winter wheat grower loses 4 percent of his expected yield every day that the maximum daily temperature rises above 30°C in the months of May and June, incurring a cost per day per hectare of 16. The grower has 10,000 hectares of wheat under cultivation and is prepared to accept yield losses due to heat stress of up to 480,000, but he wants protection for any losses in excess of that amount. In this case, the grower may consider purchasing a call option, either in derivative or insurance form, with the following specifications:

Reference Weather Station (RWS):	Growerstown, ID No. 12345
Index:	Daily Tmax > 30 C, measured at RWS
Calculation Period:	1 May 2005 to 30 June 2005 (inclusive)
Call Strike:	3 events
Payout Rate:	€160,000 per event above the strike
Limit:	€1,600,000

To secure such protection the grower must pay a premium, but he is allowed to recover 160,000 for each day in May and June that the daily maximum temperature exceeds 30°C in excess of the strike level. Figure A1.4 illustrates the impact of such a hedging strategy on the revenues of the grower: by

Figure A1.4 Call Option Payout Structure and Wheat Grower's Losses



Source: Authors.

purchasing the call option, his downside exposure is now limited to 480,000, unless the number of heat events exceeds an unprecedented 13 during the calculation period. Modifications can obviously be made to this simplified example to better replicate the exposure of the grower; a more sophisticated product may be based, for instance, on an index that considers only consecutive days of excessive temperature, includes relative humidity, or establishes a nonlinear payout rate that increases compensation as the number of heat events during the calculation period increases. Alternatively, the grower may want to purchase a digital call option, an all-or-nothing structure that will pay the grower a lump sum, rather than incremental payouts, if the heat stress reaches a critical level at which most of the crop will be lost. Similarly, an end user buying a put option would protect himself from events when the index drops below the strike level.

Collars and Swaps

A business may be averse to paying an upfront premium for risk protection. An alternative is a contract in which the business receives downside protection in return for sacrificing upside revenue

if the weather is beneficial for the business. In essence, the business can forego a portion of profit to offset the cost of reduced revenues by selling a put option and then buying a call option from the provider, or vice versa. A collar, therefore, combines both a call and put option, but it does not involve an exchange of premium from the end user to the provider. A collar is a means by which two parties can exchange risk; hence, collars may often be structured with asymmetric call and put options to make the risk exchange of equal value to both parties. This approach may not be applicable to all weather risk management problems in agriculture. Furthermore, businesses may be averse to giving up profits in a good year. A very simple example of a possible application can be found by considering a local agrochemical company whose sales of a particular pesticide vary depending on the number of pest growing degree days (PGDDs) recorded in their sales region during the winter. When the recorded PGDDs are high, pest attack incidents increase, and pesticide sales increase accordingly. When PGDDs are low, demand for pesticides drops and sales are low. The company has quantified this risk and finds that, on average, it loses or gains \$12,000 per PGDD from budgeted revenues if the accumulated PGDDs are below or above the 1700 PGDDs expected in the region's normal winter. The company may be interested in a collar agreement because, not only is it costless to enter into, it also reduces the company's weather related revenue volatility. In this case, the company may consider purchasing a collar with the following specifications:

Reference Weather Station (RWS):	Growerstown, ID No. 12345
Index:	Cumulative PGDDs measured at RWS
Calculation Period:	1 November 2005 to 31 March 2006 (inclusive)
Call Strike:	1800 PGDDs
Put Strike:	1600 PGDDs
Payout Rate:	\$12,000 per PGDD above/below strikes
Limit:	\$2,400,000

The historical distribution of November to March PGDDs in Growerstown is found to be symmetric around the 1700 PGDD average with a standard deviation of 100 PGDDs; hence the call and put options have strikes equidistant of the average to create a zero-cost collar. Figure A1.5 illustrates the impact of such a hedging strategy on the revenues of the company: the collar reduces a potential two

standard deviation fluctuation in revenues for the company from \pm \$2,400,000 to \pm \$1,200,000.

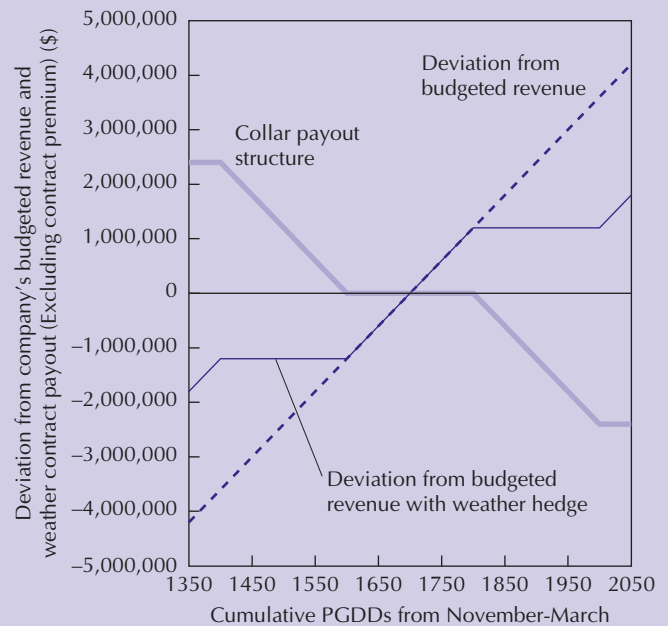
A swap is a contract in which a buyer makes a payment to the seller when a weather index rises above a predefined strike level and entitles the buyer to receive a payment from the seller when the index falls below the same level. Essentially, a swap is a put and a call option with the same strike, payment rate, and limit, which, like a collar, is costless to enter. In the example above, rather than using a collar contract, the local agrochemical company could “sell” a swap contract to a provider with a strike of 1700 PGDDs and a payout rate of \$12,000 per PGDD. This would ensure that the business achieves no more or less than its budgeted revenue. Swaps are derivative OTC contracts that are commonly traded in the secondary derivative weather risk market; they are rarely used outside the energy industry, however, as they do not always offer the best correlation to the underlying risk. Swaps are only available in derivative form (Raspe 2002).

Exotic Structures

In theory, a weather risk management solution can take any form or combination of options, swaps, triggers, and indexes. Possible exotic combinations include knock-in or knock-out options, which grant the buyer a standard call or put option if a particular knock-in or knock-out threshold is breached, either on the same or a different index (for example, a heat stress call option for wheat that is only triggered if precipitation during the same calculation period drops below a critical level); compound options, known as “an option on an option,” that grant the buyer the right to purchase an underlying option at some future date (for example, a multiyear structure that gives the buyer an option to buy an option on the weather conditions for the next growing season at the end of the current season); and structures with a variable start date depending on the timing of a pre-specified event (such a structure may be appropriate for crops with variable planting dates that can be associated with cumulative rainfall or growing degree day totals).

Reference indexes may also include nonweather variables. Temperature contingent commodity call options, for example, may give a purchaser the right but not the obligation to buy an underlying commodity at a prespecified price and volume only if certain temperature, that is, growing conditions, have been met. Such exotic structures could poten-

Figure A1.5 Collar Payout Structure and Agrochemical Company’s Deviation from Budgeted Revenue



Source: Authors.

tially provide total revenue insurance for agricultural producers whose revenues depend on both the price at which they sell their produce and the volume they produce. Such contracts exist and are traded in the OTC energy derivatives markets.

Risk Retention and Premium

It is clear that an important aspect to consider when structuring an index-based solution is the retention of risk by the party seeking protection. This means defining the index trigger level at which the weather protection begins. The strike determines the insured party’s level of risk retention and is the key to pricing and success in transferring the risk. A strike very close to the mean of the index indicates a low level of risk retention by the end user and a high probability that the contract will pay out. This implicitly means a large premium, as well as the possibility of inspiring little interest in the weather market if the location or nature of the risk is outside the main liquid trading hubs or variables. A strike farther away from the mean reduces the probability of a payout and hence the premium of the contract, as the entity is retaining the more frequent,

near-the-mean risk internally and transferring less to the market. The level of risk retention will depend on the risk appetite and business imperatives of the end user and the sensitivity to the premium associated with entering into a contract. To reduce the premium payment, for instance, the wheat grower in the call option example above could increase the strike for heat stress events. By retaining more risk, all things being equal, the producer would reduce the premium of the contract. Alternatively, the grower could reduce the payment rate to partially, instead of fully, hedge his exposure. Premium payment terms must be defined before entering a weather contract, and an overview of how such contracts are priced by weather market providers appears in the following section.

Execution

The Market Providers

The main providers of risk capacity, product structuring, and/or pricing for end-user customers in the current weather risk market can be categorized into three main groups:

- Insurance and reinsurance companies that view noncatastrophic weather insurance as a natural extension of their traditional business and given analysis capabilities. Examples include ACE, AXA, Munich Re, Partner Re, Swiss Re, Tokio Marine and Fire Insurance, and XL Capital. Most of these entities also offer derivative products and, although some may choose to retain the risk by dealing in a large amount of diversified end-user business, several are among the most active portfolio managers in the secondary market, using financial derivatives contracts to manage their weather risk portfolios, including both high- and low-frequency risk.
- Banks that structure weather risk solutions to fit the needs of their clients. Examples include ABN AMRO, Calyon, Deutsche Bank, Goldman Sachs, Merrill Lynch, and Rabobank. Banks have a large potential client base for weather derivative products and may find many marketing and cross-selling opportunities in many different sectors of business. Banks generally do not have as much risk capacity as do the (re)insurers; they often pass the positions of their end-user customers to other market providers or actively hedge positions in the

secondary OTC and exchange-traded derivatives market.

- Specialized hybrid companies or funds. These include organizations such as Coriolis Capital (formerly Société Générale) and Guaranteed Weather Trading Ltd., which were established specifically to trade and invest in weather risk. Such hybrid entities deal in weather derivatives and reinsurance and offer weather risk solution products to customers.

The energy companies responsible for the birth of the marketplace—Enron, Aquila, Southern Company, and Entergy Koch (now Merrill Lynch)—are no longer active in the weather market. Although the market is still predominantly driven by energy related weather risk, with energy companies and several banks hedging their energy portfolios with weather derivatives, the major source of secondary market liquidity is now driven by the three predominant types of counter-party outlined above, through the hedging of end-user deals or the taking of speculative positions.

Regulatory Issues

Depending on the jurisdiction, weather risk management products can be classified as financial (derivative), insurance, or gaming contracts. Depending on their classification, these contracts are subject to specific tax and accounting treatments, which can render one form more optimal than another for an end user's purposes and business. Interested parties are strongly advised to contact their local financial services authority, insurance regulator, or a professional specializing in insurance law to find out how weather contracts are treated in their jurisdiction and the legal and financial implications associated with each (Raspe 2002).

VALUING WEATHER RISK

Pricing Overview

The premium of an index-based weather contract is determined actuarially by conducting a rigorous analysis of the historical weather to reveal the statistical properties and distribution of the defined weather index and, therefore, the payouts of the insurance or derivative contract. Such an analysis includes (1) cleaning and quality control of the data, that is, using statistical methods to in-fill missing data and/or to account for significant changes, if any, as a result of instrumentation or station location changes; (2) checking the cleaned data for sig-

nificant trends and detrending to current levels if appropriate (this is particularly pertinent for temperature data, which, in general, exhibit a strong warming trend in the Northern Hemisphere); and (3) performing a statistical analysis on the cleaned and detrended data and/or a Monte Carlo simulation, using a model calibrated by the data, to determine the distribution of the defined weather index and the subsequent payouts of the contract. By determining the frequency and severity of weather events specified by the index, an appropriate premium can be calculated.

It should be noted that the premium charged by providers in the weather market may depend on several factors, not all as objective as the underlying statistical analysis of the weather data. Institutions charge different risk margins, or discounts, over the expected value or fair price to potential buyers; these choices are driven by the risk appetite, business imperatives, and operational costs of the provider (Henderson et al. 2002). An overview of pricing is given in this section, and the implications of the premium charged for the end user will also be discussed. The data issues associated with points 1 and 2 above will be covered later in this Appendix.

Expected Loss and Risk Margin

To illustrate the pricing process, an index-based weather contract is structured as a call option (see above). The payout, P , of the contract is determined by the following equation:

$$P = \min[\max(0, I - K) \times X, M] \quad (9)$$

where K is the strike, I is the index measured during the calculation period, X is the payout rate per unit index, and M is the limit of the contract. To calculate the premium for the contract, one must determine the following parameters:

- The expected loss of the contract, $E(P)$, that is, the average or expected payout of the structure each year;
- The standard deviation of the payouts of the contract, $\sigma(P)$, that is, a measure of the variability of the contract payouts; and
- The x th-percentile of the payouts, that is, a measure of the value-at-risk (VaR) of the contract for the seller, $VaR_x(P)$. The 99 percent VaR, for example, represents the economic loss for the provider that is expected to be exceeded, with 1 percent probability, at the end of the calculation period of the contract.

These three parameters quantify the expected (a) and variable or risky (b, c) payouts of the contract and must be determined from the historical weather data, either by using the historical index values from the available cleaned and detrended dataset or by using the data to calibrate a Monte Carlo simulation model to generate thousands of possible realizations of I in order to fill out the distribution of payouts and to determine better estimates of $E(P)$, $\sigma(P)$, and $VaR_x(P)$. A complete description of the various methods for determining these payout statistics are beyond the scope of this appendix, but an overview of possible approaches appears in the following subsection. It is clear, however, that $E(P)$, $\sigma(P)$, and $VaR_{99}(P)$ will vary with the strike, payout rate, and limit.

Having established values for the expected and variable payout parameters, the price of a contract is then determined by the risk preferences of the (re)insurance company or financial institution providing the risk protection: that is, by how they measure the cost of risk with respect to return for the purposes of pricing, risk management, and capital allocation (Henderson et al. 2002). As a result, this aspect of the risk pricing process is the most subjective, as it is largely driven by the institutional constraints and risk appetite of the provider. It is clear, however, that the provider will charge $E(P)$ plus an additional risk margin for taking the weather risk from the end user, that is,

$$\text{Premium} = E(P) + \text{Risk Margin} \quad (10)$$

There are many methods for measuring risk and hence for determining a risk taker's risk margin. Two examples of simple methods that have been suggested (Henderson et al. 2002) for the weather market are the Sharpe Ratio and the Return on VaR; both measure expected excess return in terms of some measure of risk and hence determine the "cost of risk" for the contract seller.

$$\text{Sharp Ratio}, \alpha = [\text{Premium} - E(P)] / \sigma(P)$$

$$\text{Premium} = E(P) + \alpha \sigma(P) \quad (11)$$

$$\text{Return on Var (99\%)}, \beta = [\text{Premium} - E(P)] / [VaR_{99}(P) - E(P)]$$

$$\text{Premium} = E(P) + \beta [VaR_{99}(P) - E(P)] \quad (12)$$

The Sharpe Ratio uses standard deviation as the underlying measure of risk; therefore α represents the “cost of standard deviation” as determined by the seller’s risk preferences. One of the benefits of relating risk to the standard deviation of payouts is that it constitutes an easy parameter for estimating; however, it is a symmetric measure of risk capturing the mean width of the payout distribution, and, for traditional risk exchange products, the payout distribution is often not symmetric but has a long tail. The Return on VaR method uses $VaR(99\%)$ as the underlying measure of risk and therefore β represents the “cost of VaR.” Value-at-Risk (VaR) is a term that has become widely used by insurers, corporate treasurers, and financial institutions to summarize the total risk of portfolios. The advantage of VaR_{99} is that it is computed from the loss side of the payout distribution, where loss is defined with respect to the expected payout $E(P)$, and therefore captures the potential financial loss to the seller. Using the Return on VaR method is more appropriate for pricing structures that protect against low-frequency/high-severity risk, which have highly asymmetric payout distributions. VaR_{99} is a harder parameter to estimate, however, particularly for strike levels set far away from the mean, and it is usually established through Monte Carlo simulation. The worst-case recorded historically can often be used as a crosscheck for VaR. In both methods outlined above, α and β quantify the risk loading appropriate for the risk preferences of the provider.

It is also worth noting that weather market participants can often enter into financial derivatives contracts to manage their weather risk portfolios and actively hedge positions in the secondary OTC and exchange-traded derivatives market. This is particularly true if the end-user risk is in a location included in or positively correlated to locations commonly traded in the market. Moreover, even if a market provider chooses to retain the risk internally, a new potential contract may look attractive in comparison to the overall portfolio of the risk taker; that is, it may be a contract that, like hedging, will reduce the relative σ and VaR_{99} parameters and the overall risk position of the portfolio and hence reduce or increase the premium while maintaining the same cost of risk α . A reasonable estimate for α and β , given prices in the weather market, are $\alpha = 15\text{--}30\%$ and $\beta = 5\text{--}10\%$.

Approaches to Pricing Weather Risk

In order to price a weather contract, given the overview above, the parameters that quantify the ex-

pected ($E(P)$) and variable ($VaR_{99}(P)$, $\sigma(P)$) payouts of the contract must be determined. This section briefly outlines three possible approaches, representing varying degrees of difficulty and effort, commonly used by weather market participants. In general, providers may use several or all of these methods to crosscheck results and compute a contract price.

Historical Burn Analysis

Historical Burn Analysis (HBA) is the simplest method of weather contract pricing. It involves taking historical values of the index, which may be based on raw, cleaned, and possibly detrended weather data, and applying the contract in question to them. Assuming the data used to calculate the historical indexes are of good quality for the risk analysis, HBA can give a useful and intuitive first indication of the mean and range of possible payouts of a weather contract from which parameters such as $E(P)$ and $\sigma(P)$ can be calculated. The method is simple and can easily be done in a spreadsheet. The disadvantage of HBA is that it gives a limited view of possible index outcomes: it may not capture the possible extremes, and it may be overly influenced by individual years in the historical dataset. Estimates of parameters such as $VaR_{99}(P)$ therefore become very difficult, although the largest historical value is always a good reality check when considering the possible variability of payouts. Additionally, the confidence level that can be attached to averages and standard deviation calculated from historical data is limited by the number of years of data available. The standard error in the average decreases as the number of years included in the average increases, however; although weather stations often have thirty to forty years of historical data, the representative nature of older data for today’s weather and climate should also be questioned (see below).

Historical Distribution Analysis

Much can be gained from understanding the statistical properties of the underlying index. If index values are calculated using historical meteorological data, then looking at the distribution of these index values and ascertaining the probability distribution function of the index will provide a better estimate of the parameters necessary to specify that function and, therefore, the expected and variable payouts of the contract. Historical Distribution Analysis (HDA) involves determining the probability distribution that best fits the historical (possibly

detrended) index data. The process is very much one of trial and error, and various standard tests and goodness-of-fit statistics, each with strengths and weaknesses, can be used to pick the best distribution from a potential selection; these include Quantile-Quantile plots, calculation of moments, and statistical tests such as chi-squared, Kolmogorov-Smirnov, Anderson-Darling, root-mean squared error, and maximum likelihood methods. By determining the distribution and therefore the parameters necessary to define it, such as the mean and standard deviation, the $E(P)$ and $\sigma(P)$ $VaR_{99}(P)$ can be calculated either by simulation from the distribution (see below) or analytically, depending on the type of distribution chosen and the underlying complexity of the contract to be priced. Closed form solutions can be derived for call and put options using different underlying distributions (Jewson et al. 2005), such as the Normal distribution, kernel density, and Gamma distribution. Although the HDA method is more accurate than HBA for computing expected and variable payouts (Jewson 2004a), and often simpler due to the availability of analytical formulas, it assumes the underlying distribution is a correct representation of the data. Fitting and putting too much emphasis on a distribution that does not capture the higher moments of variability, for example, can lead to an underestimate of variability and, therefore, the premium.

Monte Carlo Simulation

Once a distribution is identified to represent an index, constraints associated with the length of the historical data record are no longer valid, and thousands of realizations of the index can be simulated, to estimate the contract statistics to any arbitrary degree of statistical accuracy, using the distribution to make Monte-Carlo simulations. The Index Simulation (IS) method is commonly used for pricing weather contracts. Index values can be simulated statistically by drawing samples from the chosen distribution to generate large numbers (years) of artificial index values. The weather contract structure is applied to each of these values to create a range of payout outcomes that can be used to calculate the price of the contract. The IS method is particularly good for cumulative contracts, such as GDDs, or for contracts that depend on several weather variables where the correlation between these variables can be included in the simulation process. An additional advantage of the IS and HDA methods is that weather forecasts can be incorpo-

rated in the pricing process through the $E(P)$ and possibly $\sigma(P)$ terms by their dependence on $E(I)$ and $\sigma(I)$. The weather market actively follows forecast information and will modify its estimates of $E(I)$ and $\sigma(I)$ based on historical information if necessary (Jewson 2004b). Complex daily simulation methods can also be used. Building models that correctly capture the physical relationships between many meteorological variables at many sites at a daily resolution poses significant scientific, mathematical, and programming challenges (Brody et al. 2002), however, and should be required only for path-dependent contracts or nonlinear structures that depend on several variables or critical daily values.

End-User Perspective

On receiving a price quotation for a weather risk management solution from a market provider, an agricultural grower or producer must decide if, given the price, such a solution is the best strategy for the business to manage its weather risk. Some of the advantages and disadvantages for end users of using a market-based risk management tool are highlighted below. A grower can take many technical and practical measures to make crops more resilient to the vagaries of the weather; examples include better irrigation systems, new strains of seed, or new farming technologies. Likewise, an agricultural product sales company, for example, may choose to diversify into other products to reduce their overall exposure to a particular weather event. Although such strategies will not be covered in this appendix, end users should consider the relative cost and efficiency of choosing such approaches over an insurance or derivative weather based-solution. Ideally, the end user should focus on the most cost-efficient and effective means for dealing with weather risk by determining the optimal interaction of risk retention, risk transfer, and potential operational strategies to create a comprehensive risk management solution.

Revenue Volatility and Value-at-risk

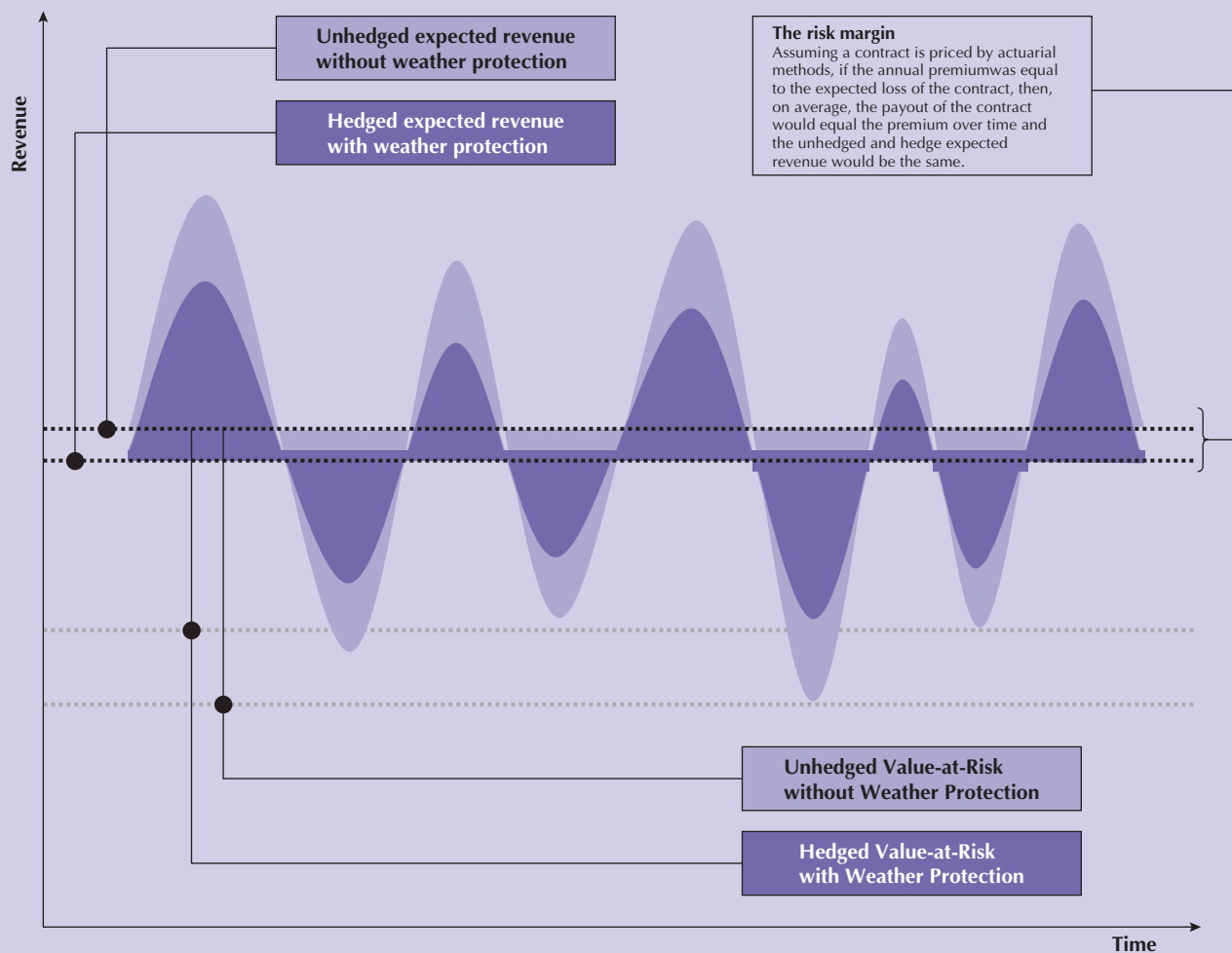
From an agricultural end user's perspective, the cost of $E(P)$ is essentially already embedded in the business: it is the average annual cost (loss) of weather inherent in running the business in question, be it farming a crop in a particular region or selling a specific agrochemical product. In other words, without protection, the grower or producer

can expect to lose this amount on average each year. Therefore, the premium the grower or producer ultimately pays for a weather risk management product is only the risk margin charged by the provider over the expected loss. This is illustrated by the schematic below (Figure A1.6). By purchasing a tailored weather hedge, an end user receives a reduction of revenue volatility due to weather, but at a cost: the risk margin. Reducing the volatility at an appropriate cost, however, increases the return per unit risk, or the quality of earnings of the end user.

Obviously, the end user must also consider the efficacy of the weather hedge and decide whether the risk management contract offers adequate pro-

tection, particularly in a worst-case scenario, for his business. This can, to a certain extent, be quantified with historical information. The relevant question the end user should consider is whether the payout from a risk management contract based on a weather index effectively reduces the end user's value-at-risk (*VaR*); in other words, the end user should determine whether the contract reduces the potential for economic loss with a given probability within a given time horizon (Hull 2000). A grower or producer's *VaR* is an effective measure of the overall vulnerability of the business to external shocks, be it price movements or fluctuations in supply and demand for his product. Weather protection that limits a business's potential downside

Figure A1.6 Schematic of Historical Revenues of a Business and the Impact of Weather Hedging



Source: Authors.

revenue exposure reduces the end user's overall *VaR*. Minimizing *VaR* also has the associated cost—the risk margin—but it raises the question as to whether a business could withstand extreme systematic shocks and their ramifications without protection, limiting losses in catastrophic years.

The birth of the weather market has created an opportunity for businesses to attain protection on their income statements from the impact of noncatastrophic weather variations. Previously, traditional insurance products dealt primarily with losses affecting the balance sheet by protecting physical assets from damage due to catastrophic weather. A business that protects its revenues and, as a result, has a less volatile revenue stream may benefit by receiving, for example, a lower cost of debt or an increased access to credit and, for public companies, potentially improved stock valuations or stronger credit ratings (Malinow 2002). Eliminating the uncertainty associated with noncatastrophic weather-related risk allows an operation to concentrate on its core business and focus on controllable targets and growth. These benefits associated with reducing revenue volatility and *VaR*, in relation to the effective cost of hedging, are considerations for the end user. Just like the weather market providers, end users must also decide how they value risk in relation to return in the context of their business. It must define how much risk it is willing to hold and the budgeted cost at which it is willing to do so.

Basis Risk

A major concern with index-based weather risk management products is basis risk: the potential mismatch between contract payouts and the actual loss experienced. On considering weather-index insurance as a product for growers, Skees (2003) writes, “[t]he effectiveness of index insurance as a risk management tool depends on how positively correlated farm yield losses are with the underlying area yield or weather index.” As with the regulatory concerns regarding the definition of insurance (described above), this statement relates to the question of whether insurance based on a weather index can substitute for a traditional crop insurance policy and indemnify the grower for his losses.

Basis risk is a concern with all weather variables, but it is particularly important for rainfall, which exhibits a high degree of spatial and temporal variability. The weather station on which a weather contract is based, for example, may not experience

the same rainfall patterns or totals during the calculation period as do the locations an end user wishes to protect. For this reason, weather market providers do not offer contracts based on hail; hail is a highly localized meteorological phenomenon, and although it can be indexed to an observing weather station, such indexing may not be an effective risk management strategy for an end user. Although historically an index and losses may correlate strongly—showing that an index could be used as an underlying trigger to indemnify losses in an insurance contract (see above)—a good correlation is not a guarantee that the underlying contract payout will match the actual loss experienced. Basis risk, therefore, which can often be minimized by effective or intuitive structuring and by using local stations (Hess and Syroka 2005), is always an issue when dealing with an index-based risk management solution. A potential basis risk outcome can be quantified by using historical data; however, the key point to consider, as outlined above, is the efficacy of the hedge and the effective reduction in the insured party's overall operational *VaR* (Hess 2003).

WEATHER DATA

Data Requirements

In order to implement a successful weather risk management program, the data used to construct the underlying weather indexes must adhere to strict quality requirements, including reliable and trustworthy on-going daily collection and reporting procedures; daily quality control and cleaning; an independent source of data for verification, for example, GTS (Global Telecommunication System) weather stations; and a long, clean, and internally consistent historical record permitting proper actuarial analysis of the weather risks involved (at least thirty years of daily data are ideal).

The premium associated with weather risk management strategies is based on a sound actuarial analysis of the underlying risk. The commercial risk taker will charge a premium reflecting the given probability and severity of specific weather events; hence the quality of historical and on-going weather data is paramount. Nearly all weather contracts are written on data collected from official National Weather Service (NWS) weather stations; ideally, these will be automated stations reporting daily to the World Meteorological Organization (WMO) GTS providing data in the internationally recognized standard format that then undergo standard

WMO-established quality control procedures. End users without access to weather data satisfying the above criteria, or living in areas in which the spatial coverage of a NWS weather station network may not be sufficient to fully represent their weather risk profiles, may not be able to benefit from weather risk management solutions.

All contracts traded in the active secondary OTC derivative market are based on climatic weather data collected and published by the NWS of the country in question. Historical climate data, and daily up-dates, can be purchased from each NWS, a list of which can be found on the WMO website (www.meteo.org/wmo). In the United States, for example, the primary source of weather data is the National Climatic Data Center. In Great Britain, weather data can be purchased from Weatherxchange (www.weatherxchange.com), a joint venture with the U.K. Met Office set up to support the European weather derivatives market. Weatherxchange provides quality-controlled historical climate and SYNOP datasets across Great Britain and has distribution rights to data from several NWS organizations across Europe, including those of Germany, Italy, France, Netherlands, Austria, and Spain. Data can also be purchased from private data vendors, such as Risk Management Solutions/EarthSat (www.rms.com, www.earthsat.com) and Applied Insurance Research (AIR; www.air.com). Private vendors often offer additional value-added services such as data cleaning and adjusting (see below).

Cleaning and Adjusted Data

Despite the NWS quality control procedures, data from some meteorological observing stations may still have missing and erroneous values. Stations may also have undergone instrumentation and/or station location changes, which can introduce systematic changes to a historical dataset. A station moved from a rural to an urban location, for example, may now be in a location several degrees warmer than before, creating an artificial jump in the station's historical temperature record. Records of station or instrumentation changes are usually kept by the NWS for each weather station. For data to be usable for pricing weather risk management products, the raw data must be cleaned to correct for errors and missing values and checked and perhaps adjusted for nonclimatic inhomogeneities that could make the historical data unrepresentative of

current values. The methods of cleaning and adjusting data often involve statistical procedures beyond the scope of this appendix. An awareness of the possible need for cleaning and adjusting data is recommended, however, and the approaches used are briefly outlined below. Cleaned and adjusted datasets can also be purchased from private vendors with proprietary data estimation models, such as RMS and AIR.

Detrending Data

Meteorological data often contain trends that arise due to natural climate variability, urban heating effects, or the impact of global warming. Regardless of the cause, in some circumstances it may be useful to be able to remove such trends from the data. Such a procedure is known as *detrending*. The aim of detrending data for pricing weather risk is to obtain better estimates or forecasts of $E(I)$, $\sigma(I)$, and $VaR_x(I)$ based on historical data. Warming trends, for instance, can significantly impact the defining parameters of the underlying data. By failing to account for such trends, $E(I)$ may be significantly underestimated and $\sigma(I)$ overestimated, which can lead to mispricing of contracts that settle based on future data. Many different mathematical methods exist for detrending data, each based on a different set of assumptions.

In essence, the aim of detrending is to statistically model the underlying process by decomposing a dataset into a deterministic trend and a stochastic noise term around the trend:

$$D(t) = Y(t) + \varepsilon(t), \varepsilon(t) \sim N(0, \sigma^2) \quad (13)$$

where, $D(t)$ is the process represented by the dataset, $Y(t)$ is the deterministic and therefore predictable component, $\varepsilon(t)$ is a normally distributed noise component with a mean of zero, and standard deviation σ and t is unit time. Determining how much of the historical data variability is attributed to $Y(t)$ gives an indication of how well a particular model represents the underlying data. The method and approach chosen for detrending data can be highly subjective, and the decision to detrend or not should be informed by some underlying criteria (Jewson and Penzer 2004). Choosing a detrending method that is better than another at predicting future data values—or even not detrending at all—is preferable to using a method that increases uncertainty in predicting future values. The performance of

different methods can be compared by considering characteristics of the distribution of errors in the predictions they make. By using the historical data to back-test various detrending methods and approaches, estimates of the uncertainty around the trend can be found and can inform the error associated with a particular method for estimating future values.

Identifying trends and their cause is itself a subjective process, however, and care should always be taken to check the sensitivity of detrending results to the underlying method used. Crosschecking several detrending methods and approaches and visually sense-checking the data are always recommended. The weather market often uses the ten-year average of an index as a quick first-guess estimate for $E(I)$. The simplest and most commonly used method for detrending data is polynomial detrending. The aim of this method is to fit a polynomial function of time to a meteorological dataset, usually a first-order polynomial trend—a linear trend—that fits a straight line through a set of data points (Weisstein 2002). Examples of other detrending techniques include the moving average (Henderson et al. 2002), LOESS (Cleveland 1979), and low-pass filter (Von Storch and Zwiers 1999) methods.

FURTHER READING

Information for this appendix was taken from the wealth of sources available on the subject of weather risk management. These works are strongly recommended to interested readers for further information and discussion. An excellent in-depth introduction to the weather market can be found in Banks (2002), *Weather Risk Management: Markets, Products, and Applications*. Information on general weather risk and weather risk management issues can be found in Dischel (2002), *Climate Risk and the Weather Market*, and Geman (1999), *Insurance and Weather Derivatives*. The Social Science Research Network at <http://www.ssrn.org> offers a large quantity of papers and articles on many aspects of weather derivatives, including analytical pricing methods, simulation models, detrending methods, and the use of forecasts. The papers written by Dr. Stephen Jewson are particularly recommended and can be found on <http://www.stephenjewson.com>. The recent publication, *Weather Derivative Valuation: The Meteorological, Statistical, Financial and Mathematical Foundations* (Jewson et al. 2005), contains an excellent summary of this work and the theoretical founda-

tions for pricing weather risk. Another good source of articles and information on weather derivatives and the market is the Artemis website at <http://www.artemis.bm> and the industry body website, the Weather Risk Management Association, <http://www.wrma.org>. The Guaranteed Weather website at <http://www.guaranteedweather.com/casestudies.php> includes a wealth of case studies and weather risk management examples. Information on weather risk management in the developing world can be found at <http://www.itf-commrisk.org>.

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Appendix 2

Case Studies of Agricultural Weather Risk Management

This appendix presents four case studies—from Canada, Mexico, India, and Ukraine—showing the successful application for agricultural end users of weather risk management insurance and derivative products. The first section of this appendix focuses on the Agriculture Financial Services Corporation (AFSC), the Canadian financial crown corporation of Alberta that has been offering Growing Degree Day products to maize farmers in the province since 2000. The second section covers Agroasemex, the Mexican agricultural reinsurance company that has been using weather derivatives to manage agricultural portfolio risk since 2001. The third section presents two case studies from the recent work of the World Bank Commodity Risk Management Group in developing agricultural weather risk markets in India and Ukraine. The Technology Application Case Studies described at the end of this appendix briefly outlines the principles of the AFSC program to insure grassland for pasture on an index basis using satellite imagery and the grassland insurance program in Spain.

INDEXED-BASED INSURANCE FOR FARMERS IN ALBERTA, CANADA

The AFSC Case Study

Corn Heat Unit Insurance

The Corn Heat Unit insurance program is a weather index-based insurance product offered by the AFSC to protect farmers against the financial impact of negative variations in yield for irrigated grain and silage corn. The contract is designed to insure against lack of Corn Heat Units (CHU) over the growing season. It has been offered on a pilot basis since 2000 and was planned to last until 2005. The program is scheduled for a thorough evaluation to assess its impact over the next year. The index has been designed to indemnify the policyholder against an an-

nual CHU below Threshold Corn Heat Unit (TCHU) level at the specified weather station. The CHU index falls into the Growing Degree Day category, discussed briefly in Appendix 1, and represents the energy available for the development of corn. Given the small window for agricultural production in Canada, the availability of sufficient solar energy is vital for the development of this crop. The CHU is estimated from daily maximum and minimum temperature, beginning on May 15 each year. The Celsius-based formula used to calculate daily CHUs is defined as follows (Brown and Bootsma, 1993):

$$CHU = 0.5 \times Y_{min} + 0.5 \times Y_{max} \quad (1)$$

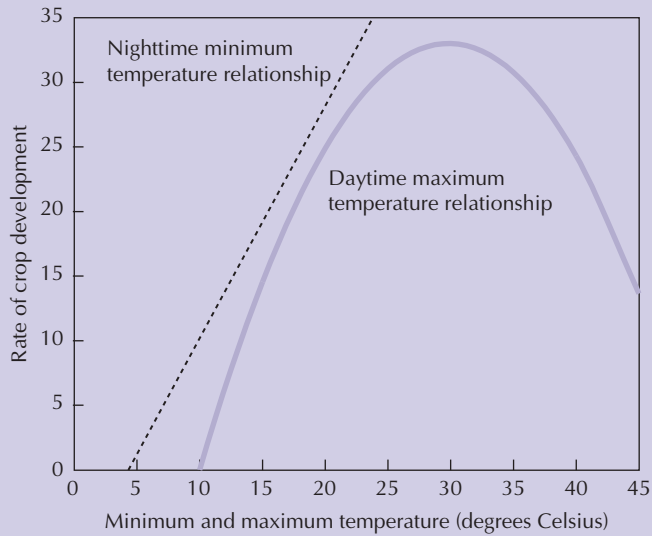
$$Y_{min} = 9/5 \times [T_{min} - 4.4] \quad (2)$$

$$Y_{max} = 3.33 \times [T_{max} - 10.0] - 0.084 \times [T_{max} - 10]^2 \quad (3)$$

where T_{min} and T_{max} are the daily minimum and maximum temperatures, respectively.

The daily CHU values are calculated from these temperatures. The daytime relationship involving T_{max} , uses 10°C as the base temperature (if T_{max} is less than 10, its value is set at 10) and 30°C as the optimum temperature, as warm-season crops do not develop when daytime temperatures fall below 10°C and develop at a maximum rate at around 30°C. The nighttime relationship involving T_{min} uses 4.4°C as the base temperature below which daily crop development stops. (If T_{min} is less than 4.4, its value is set at 4.4.) The CHU value is calculated by taking into account the functional relationship between daytime and nighttime temperatures and the daily rate of crop development, as shown in Figure A2.1. The nighttime relationship is a straight line (Equation 2), while the daytime relationship appears as a curve that records greater CHUs at 30°C than at higher or lower temperatures (Equation 3). The accumulation of CHU stops on the first day on

Figure A2.1 Relationship Between the Daily Rate of Development of Corn Minimum and Maximum Temperatures



Source: Brown and Bootsma 1993.

which a minimum temperature of minus two degrees Celsius or less is recorded, after 700 CHU have been accumulated. This means the accumulation continues until the first killing frost hits the crop. An early frost setback is also built into the AFSC calculation.⁵⁵

The weather data for settlement of the contracts are provided by the federal and provincial weather stations and compiled by the Irrigation Branch of the Alberta Government. Contract end users can select a weather station for the settlement from the federal and provincial stations available, choosing the station that best represents the temperatures on their farms. Weather stations used for CHU insurance are divided into three groups based on similar historical heat accumulations. Weather stations within each group have similar threshold options, premium rates, and loss payment functions.

Coverage is available in \$25 Canadian Dollar (CD) increments with a minimum of CD\$100 per acre for both grain and silage corn and a limit of CD\$225 and CD\$300, respectively. Farmers can buy the insurance product until April 30 of the year to be covered for that year's growing season. When

buying the insurance policy, farmers must elect the dollar coverage per acre, select the weather station for settlement purposes, and indicate if they prefer a hail endorsement to the contract or the variable price benefit.

The farmer must insure all the seeded acres of eligible corn and must insure a minimum of five acres for each crop: grain and silage crops are considered separate for the purposes of referring to a specific insurance contract. Only producers growing grain or silage corn on irrigated land in AFSC designated areas are eligible to buy a CHU insurance contract. The farmer must complete seeding by May 31 and must declare the final number of seeded acres and a legal description for the location of each crop no later than June 1. The insurable crop shall be grown within the risk area boundaries as determined solely by AFSC. Furthermore, the AFSC is responsible for controlling the use of these contracts to ensure that they are used only for insurance purposes. For control and product evaluation purposes, the farmer is required to present a harvested production report, stating the production of all insured crops, no later than fifteen days after completion of the harvest but no later than December 15 of each calendar year.

The premium payable under the CHU contract is due upon receipt of the contract by the farmer. A table of premium rates and payment rates for grain and silage corn is made available to the farmer and indicates the base premium rate and the percentage payment triggered, depending on the heat unit level recorded at the station chosen.⁵⁶ The formula to calculate the indemnity for each insurable crop is given by the following equation:

$$\text{Indemnity} = \text{Dollar Coverage per Acre} \\ \times \text{Payment Rate} \times \text{Number of Insured Acres}$$

If a farmer chose to insure one hundred acres at \$225 per acre, for example, and the accumulated CHU payment rate was 30 percent of the expected level, a claim of \$6,750 dollars would result. The maximum indemnity payable is 100 percent of the Dollar Coverage per Acre (including the additional dollar coverage if the Variable Price Benefit is activated) multiplied by the number of insured acres.

Producers can choose between two CHU insurance deductibles or threshold options (High

and Low “Trigger”); see Table A2.1. Payments begin sooner under the high threshold option, so this choice has a higher cost than the low threshold option.

Claims are based on accumulated CHUs calculated using the temperature data recorded at the selected weather station. CHUs accumulated before the killing frost are compared to the threshold chosen by the producer at the weather station. If the annual CHUs are less than the chosen threshold, the insurance program starts to make payments according to a predetermined table. The further the annual CHUs are below the threshold, the greater the insurance payment.

The main peril for producers is lack of heat during the growing season, but this insurance plan also includes a provision for late spring frost. A late spring frost can set back corn plant growth and affect production. To trigger this provision, a temperature of less than zero degrees Celsius must be recorded on or after June 1 and prior to the recording of 700 CHUs at the weather station. If both these conditions are met, 50 CHUs will be deducted from the accumulated total CHUs at the end of the year for the first day and an additional 15 CHUs will be deducted for every other day between June 1 and the day the frost in question occurred.

It is important to point out that the CHU contract with the hail endorsement is designed to protect corn against two major perils: lack of heat and hail. The grain and silage corn farmers are also eligible for traditional crop insurance contracts based on individual records; nevertheless, the premiums are lower for the CHU contract because of AFSC’s reduced transaction costs. It should also be noted that the premiums paid by the farmers for the CHU contract are subsidized by approximately 55 percent, so the farmer pays only 45 percent of the cost of the contract. The subsidy is 40 percent for the hail endorsement. The federal and provincial governments coshare the financial burden of the program, and they subsidize all AFSC’s administration costs.

ALTERNATIVE INSURANCE THROUGH WEATHER INDICES IN MEXICO

The Agroasemex Case Study

Agroasemex is a Mexican government-owned reinsurance company operating exclusively in agri-

Table A2.1 Options for CHU Contracts

Station Grouping	Deductible or Trigger (Annual CHU)		
	Long-Term Normal	Low Option*	High Option**
A	2,505	2,260	2,380
B	2,387	2,160	2,280
C	2,332	2,100	2,220

*Approximately 90 percent of long-term CHU normal.

** Approximately 95 percent of long-term CHU normal.

Source: AFSC.

cultural insurance. Agroasemex relies heavily on the traditional reinsurance market to protect its agricultural portfolio from inordinate losses. As a result of a 70 percent increase in the retrocession rates of 2001, Agroasemex’s search for new alternatives led it to analyze the comparative efficiency of the weather derivatives market. The purpose of this case study is to present the background, design, and guiding principles behind the weather derivative structure ultimately created for use as a hedge for the Agroasemex agricultural portfolio. It is worth noting that the institution’s weather derivative transaction in 2001 was the first of its kind in the developing world. This simplified case study will outline the approach and thought processes behind the structuring of the Agroasemex weather risk transfer program.

Designing a Weather Risk Transfer Solution for the Agroasemex Agricultural Portfolio

Selection of Risks

There are two agricultural production cycles in Mexico: spring-summer and autumn-winter. The former is primarily a rain-fed production cycle, while the latter is generally irrigated. The Agroasemex weather risk transfer program was specifically designed for the autumn-winter cycle of 2001 to 2002. The main weather risks for agriculture during this cycle were potentially large negative deviations in temperature and excess rainfall. For some areas, where irrigation was not used, lack of rainfall was also an important risk. The percentages of crops distributed in five states were included in the weather risk transfer program.

The crops and weather risks were selected given their relative importance in the portfolio, the consistency of the numerical analysis between negative deviations in the agricultural portfolio and the protection provided by the proposed weather derivative structure, and the availability of consistent and high-quality historical weather data. Based on the original risk profile and business plan report for the autumn-winter cycle of 2001–2002, the total liability for the crops and risks selected for the weather risk transfer program are shown in Table A2.2.

The total expected traditional reinsurance premium for the entire Agroasemex portfolio was estimated to be US\$1,917,422. The subset in Table A2.1 represents approximately 10 percent of the risk in the entire portfolio for 2001–2002.

Transforming Weather Indices into the Expected Indemnities of the Agroasemex Agricultural Portfolio

The following method was used to establish the relationship between weather indices and the expected indemnities of the Agroasemex agricultural portfolio. First, a severity index was created for each crop in the portfolio in order to understand, at the portfolio level, how important this crop risk would be when a given weather phenomenon, as captured by an index, occurred. A very simple severity index (SI) is defined as follows:⁵⁷

$$SI = \left(\frac{\text{Indemnities}}{\text{Total Liability}} \right)_i \quad (4)$$

$t = 1991/92, 1992/93 \dots 1999/2000;$
Autumn-Winter Cycles

$i = \text{Crop}$

Table A2.2 Total Liability Factored into the Agroasemex Business Plan for Autumn-Winter 2001–2002 (the basis of the design of the weather derivative contract)

State	Crop	Total Liability (US\$ Million)
Nayarit	Tobacco	22.4000
Sinaloa	Beans	0.1917
Sinaloa	Chickpeas	0.4600
Tamaulipas	Sorghum	1.8200
Sinaloa—Sonora	Maize	2.0190

Source: Authors.

Once the severity index was calculated for each crop, the next step was to find a mathematical relationship between the SI and the weather index most relevant to the crop. Agroasemex performed linear least square regressions for each crop severity index to establish the SI–weather-index relationship:

$$y_t = m_0 + m_1 x_t + \varepsilon_t \quad (5)$$

where

$$y_t = \left(\frac{\text{Indemnities}}{\text{Total Liability}} \right)_t; \quad (6)$$

and

$$x_t = \text{FCDD}_t,$$

where FCDD (*Factores Climaticos Dañinos Diarios*)—damage degree days or periods—that represent the index that captures the critical weather risk of each crop in the portfolio outlined in Table A2.3 (see below); ε_t is a normally distributed noise term; and the estimators for the linear gradient and intercept, m_1 and m_0 , were calculated using a least squares regression method.

The gradient estimator for m_1 , in particular, is very important, as it establishes the relationship between the individual severity indices and the relevant weather indices. Once all the linear regressions for each crop are performed and all the linear estimators are calculated, the expected indemnities (in monetary terms) for each severity index, given a certain weather index (FCDD) and total liability, can be calculated as follows:

$$(\text{Indemnities})_t = (\text{Total Liability})_t \times \text{FCDD}_t \times m_1 \quad (7)$$

FCDDs: The Weather Indices

The FCDD terms for each crop in the preceding section represents the weather index or indices that best capture the weather risk for that crop. If we are analyzing the exposure of beans to low temperatures, for example, the FCDD index could be defined as the number of days that the daily minimum temperature drops below a specified daily threshold during the growing season. To construct the appropriate weather indices for the Agroasemex portfolio, the relevant weather historical information was collected: five Mexican weather stations on the Pacific Ocean coast were chosen to represent the western area of the country (Sonora, Sinaloa, and Nayarit), while two U.S. airport stations (McAllen

and Brownsville) were used to represent the north-eastern area (Tamaulipas).

It is important to note that even though each severity index, as defined above, is a seasonal aggregate, the types of risks relevant for an agricultural portfolio of crops can occur over very short periods of time; for example, crop damage due to frost can occur in just one day. Therefore the selection of the individual weather indices for each crop was based on two criteria: first, and primarily, on the agronomical surveys and experience of the technical personnel of Agroasemex, and second, on the strength of the mathematical relationship obtained when comparing the available data on indemnities for the crop in question, with the weather index (Equation 4)—this was done both on a daily basis (data on indemnities were available in daily resolution) and on a seasonal basis.

To understand how each individual FCDD was estimated, consider the example for the weather index chosen for tobacco in Nayarit: DDD-12. Low temperature is the greatest risk for tobacco crops in Nayarit; when the daily minimum temperature

drops below 12°C, the expected tobacco yields will be below average. Hence 12°C is the minimum temperature threshold level for tobacco crop damage: DDD-12 represents Damage Degree Days with a 12°C threshold. The DDD-12 index is defined as follows:

$$DDD-12 = \sum \max(0, 12 - T_{\min}) \quad (8)$$

where the DDD-12 summation is over each day in the growing period of tobacco: November 1 to March 31 of the following year. Daily minimum temperature, T_{\min} , is measured at a single weather station, Capomal, in Santiago Ixcuintla, Nayarit. The data are aggregated at a seasonal level. The DDD-12 estimation is consistent with the El Niño, as the worst year recorded of cold temperatures affecting the tobacco-producing area.

In total, eleven independent FCDDs were designed to represent the exposure of the crops and risks selected. The FCDD calculation methodologies using daily weather data are presented in Table A2.3 for all crops in the portfolio.

Table A2.3 Summary of the Methodology to Calculate the Eleven FCDD Indices

State	Crop	FCDD	Weather Station	FCDD Calculation Methodology (in mm and deg Celsius)	Calc. Period
Nayarit	Tobacco	DDD-12	Capomal	DDD-12 = Sum Daily [max (0, 12 – Tmin)]	Dec 1–Mar 31
		EMNF	1 Capomal 2 La Concha	EMNF = Sum Daily [Rainfall Station 1] + Sum Daily [Rainfall Station 2]	Nov 1–Feb 28
		EMMA	1 Capomal 2 La Concha	EMNF = Sum Daily [Rainfall Station 1] + Sum Daily [Rainfall Station 2]	Mar 1–Apr 30
Sinaloa	Beans	DDD-5	Sanalona	DDD-5 = Sum Daily [max (0, 5 – Tmin)]	Oct 1–Apr 30
		DDD-3	Sanalona	DDD-3 = Sum Daily [max (0, 3 – Tmin)]	Dec 1–Dec 31
		EMF	1 Sanalona 2 El Fuerte 3 Jaina	EMF = Sum Daily [Rainfall Station 1] + Sum Daily [Rainfall Station 2] + Sum Daily [Rainfall Station 3]	Nov 1–Mar 31
		MAX-5	1 Sanalona 2 El Fuerte 3 Jaina	MAX-5 = max (MP – 200, 0); MP = max (Sum 5-day D3) – max rainfall for a consecutive period of 5 days, where D3 = Daily Rainfall Station 1 + Daily Rainfall Station 2 + Daily Rainfall Station 3	Nov 1–Mar 31
Tamaulipas	Chickpeas	EMG	Sanalona	EMG = Sum [max (Daily Rainfall – 55, 0)]	Nov 1–Apr 15
	Sorghum	MAXPS	1 Brownsville 2 McAllen	PS = Sum [max (250 – CMP1, 0)] + 2 * Sum [max (250 – CMP2, 0)]; CMP1 = Monthly Cum. Rainfall Station 1 CMP2 = Monthly Cum. Rainfall Station 2	Oct 1–May 31
Sinaloa Sonora	Maize	DDD-5	Sanalona	DDD-5 = max [D5 – 22, 0]; D5 = Sum Daily [max (0, 5 – Tmin)]	Oct 1–Apr 30
		DDD-3	Sanalona	DDD-3 = Sum Daily [max(0, 3 – Tmin)]	Dec 1–Dec 31

Source: Authors.

The mathematical relationship between each FCDD index and the indemnities for the corresponding crop in the Agroasemex portfolio were established using equations 4 through 6, defining a means of converting FCDD indices into expected indemnities in monetary terms. By combining this information, the basket of all the expected indemnity indices was used to replicate the overall weather exposure of the agricultural portfolio. This “combined index”—essentially the sum of all the expected crop indemnity indices—was used as an underlying proxy and therefore hedge for the weather exposure of a portfolio. A derivative structure based on this combined index, such as a call option, is therefore conceptually the same as a stop-loss reinsurance strategy for the portfolio, as weather is the greatest risk to Agroasemex.

Historical Back-Testing

The strength of the approach outlined above—to establish a basket of indices that best captures the weather exposure of the Agroasemex agricultural portfolio—was back-tested by using annual historical indemnity and total liability information from the Agroasemex direct insurance operations from 1990 to 2001. The historical portfolio indemnity records were compared to the estimated indemnities, given the total liability observed for that year

and using the FCDD-indemnity relationships established in Table A2.3.

The values of the severity index for each crop were calculated using both the historical and the modeled data for comparison. The results showed that the combined weather index established for the Agroasemex portfolio had an acceptable predictive power, mainly because it captured the large historical deviations in the portfolio (Table A2.4).

The results demonstrate that the combined weather index model explains about 93 percent of the variability demonstrated by the empirical data.

Valuation of the Weather Derivative Structure and the Agroasemex Transaction

Monte Carlo simulation, as described in Appendix 1, was used to generate an estimate of the distribution of the possible results of the combined weather index and therefore the maximum liability of the Agroasemex portfolio (see Figure A2.2).⁵⁸ The green line in Figure A2.2 is constructed using only historical information, while the darker, smoother line is established from the stochastic Monte Carlo simulation analysis of the underlying weather variables. It is clear that the historical payout of the Agroasemex portfolio has never exceeded US\$1.65 million, while the simulation analysis generates more extreme results, exceeding the US\$2.5 million level.

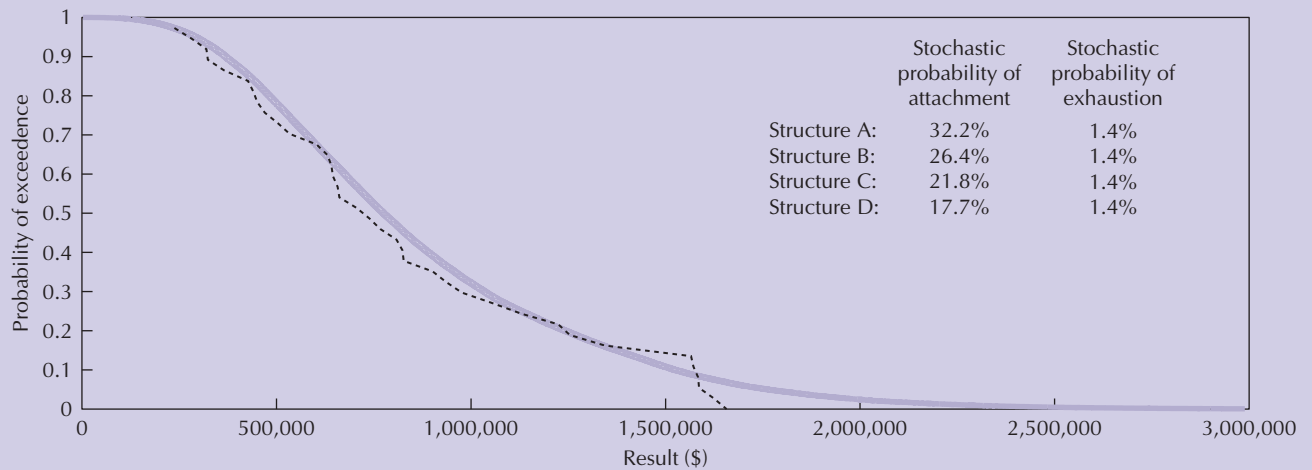
Table A2.4 Comparative Analysis Between the Observed Historical Severity Indices (indemnities/total liability) and the Estimated Severity Indices for the Crops and Risks Selected

Tobacco		Beans		Chickpeas		Sorghum		Maize		Total	
Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
0.052	0.060	0.000	0.086					0	0	0.038	0.057
0.017	0.019	0.020	0.018	0.003	0	0.085	0.093	0	0	0.021	0.023
0.004	0.009	0.027	0.043	0	0.015	0.133	0.122	0	0	0.016	0.021
0.007	0.002	0.109	0.113	0.043	0.042	0.233	0.178	0	0	0.037	0.033
0.009	0.006	0.059	0.047	0	0	0.131	0.158	0	0	0.019	0.018
0.067	0.068	0.164	0.178	0.117	0.126	0.000	0.004	0.017	0.017	0.067	0.069
0.052	0.046	0.403	0.407	0.117	0.104	0.010	0.071	0.142	0.142	0.109	0.103
0.008	0.006	0.167	0.140	0	0	0.084	0.061	0.011	0.011	0.033	0.027
0.007	0.006	0.099	0.115	0	0	0.064	0.175	0.003	0.003	0.010	0.014
r = 0.985		r = 0.968		R = 0.988		r = 0.702		r = 0.999		r = 0.970	
r2 = 0.971		r2 = 0.936		R2 = 0.976		R2 = 0.492		r2 = 0.999		R2 = 0.939	

Note: Figures are in decimals.

Source: Authors.

Figure A2.2 Comparative Accumulated Distribution Probability Function Based on a “Probability of Exceedence Curve” for the Historical and Modeled Results (payouts in US\$)



Source: Authors.

The original analysis performed by Agroasemex focused on four possible call option derivative structures, which varied in the strike price and limit of payout that could be used as an alternative to a traditional stop-loss reinsurance contract to manage the portfolio risk (Table A2.5).

The historical results and the stochastic analysis for the actuarial fair value of risk for each call option structure (average and standard deviation) are summarized in Table A2.5. In addition to the actuarial fair value of risk, the market the premium charged for risk management solutions combined the expected or fair value of the risk—the pure risk premium—with an additional risk margin. Considering market standards at the time,⁵⁹ the following risk loadings above the expected value were considered:

- Loading Based on Standard Deviation:⁶⁰ Market standards 20 to 40 percent. An intermedi-

ate loading of 30 percent was considered by Agroasemex.

- Loading Based on the Uncertainty due to Gaps in the Historical Weather Data: When missing data exceed 1 percent of data points, market players usually design a sensitivity analysis to estimate the impact of using alternative in-filling methods (see Appendix 1) and charge for the uncertainty that arises as a result of such gaps in the historical record. No established method exists for calculating this uncertainty loading in the market, which generally depends on the risk appetite of the individual weather risk taker.
- Loading for Administrative Expenses: A margin of 15 percent was added.

The weather stations used for the project in Mexico were carefully selected. Nevertheless, missing data ranged from 2.70 percent to 9.20 percent. The

Table A2.5 Specifications of Call Option Structures Considered by Agroasemex

Structure	A	B	C	D
Strike Price (US\$)	1,000,000	1,100,000	1,200,000	1,300,000
Payout Limit (US\$)	1,200,000	1,100,000	1,000,000	900,000

Source: Authors.

weather data gaps were in-filled by Risk Management Solutions (RMS) on a monthly basis, based on data collected from neighboring weather stations. In order to quantify the sensitivity and robustness of the in-filling method, instead of filling gaps with data inferred from the most correlated stations, the gaps were also in-filled with the most extreme observations from a sample of stations that had acceptable correlations to the station with the missing data points, both for temperature and rainfall. The uncertainty loading due to missing data was estimated to be 50 percent of the resulting change in the average payout, as a result of this sensitivity analysis, plus 50 percent of the change in the standard deviation observed. The results were aggregated to complete the analysis; Table A2.6 shows the estimated commercial premium (expected value plus risk margin) calculated for the four weather derivative structures.

Despite the risk loading, Agroasemex eventually bought structure D from the market. The main motivations for this choice were the following:

- The transaction included the donation of three automated weather stations, worth approximately US\$36,000, as fallback stations. Taking this cost into account, the ratio of the commercial price of the derivative to the pure risk premium was the lowest for structure D: 1.57 vs. 1.62 for the nearest structure.
- To establish credibility and brand recognition for future weather transactions.
- To set a market reference for the risk margin, so that future, larger deals could be negotiated under more narrow risk margins.

Developments Since 2001

After devising the initial weather derivative transaction presented above, Agroasemex devoted its institutional efforts and experience to developing a local weather risk market. These activities included a thorough review of the weather data; further improvements to the weather observation infrastructure, in conjunction with the Mexican National Weather Service; and training and education for potential end users within Mexico. The greatest interest generated by the 2001 transaction was from the Mexican government regarding their catastrophic weather exposure: since 2001, Agroasemex has sold weather index insurance to three Mexican states to cover the states' catastrophic exposure related to agriculture. In turn, Agroasemex has bought protection for this risk, on a quota share basis, in the international weather derivatives market. The three transactions together have an approximate notional value of US\$15 million, with several other states in the coverage pipeline. There are unofficial reports that the international market has also closed several transactions with the private industry in Mexico as a result of this first weather derivative transaction.

WEATHER INSURANCE FOR FARMERS IN THE DEVELOPING WORLD

Case Studies from India and Ukraine

The Commodity Risk Management Group (CRMG) at the World Bank started working on pilot weather

Table A2.6 Estimated Commercial Premium for Weather Derivative Structures (in US\$)

Analysis and Statistics	Structure A	Structure B	Structure C	Structure D
Last Ten-Year HBA				
Pure Risk Premium	181,447	151,447	121,447	91,447
Standard Deviation Loading	83,372	69,669	55,987	42,347
15% Margin	46,733	39,020	31,312	23,611
Full Price	311,552	232,229	186,622	141,157
Simulation Analysis				
Pure Risk Premium	133,460	104,291	80,252	60,528
Standard Deviation Loading	80,241	70,226	60,638	51,634
Data Uncertainty Loading	31,750	27,584	23,693	20,136
15% Margin	43,315	30,797	24,863	19,793
Full Price	288,766	232,898	189,447	152,091

Source: Authors.

risk management projects in 2003. The CRMG was involved in its first index-based weather risk management contract in India in June 2003. Since then, the number of projects has grown. CRMG is currently working on pilot projects for smallholders in India as well as projects in Peru, Nicaragua, Ethiopia, Thailand, Kenya, Malawi, and Ukraine. Providers in the global weather risk market are extremely interested in such new transactions both to diversify their weather portfolios through new locations and risks and to offer opportunities for business growth and expansion.

Two case studies will illustrate some of the CRMG work in this new area. The first case study examines the developing weather market in India, particularly the recent work of the Mumbai-based insurance company ICICI Lombard General Insurance Company Ltd. and the Hyderabad-based microfinance institution BASIX in making weather insurance available to smallholder farmers in Andhra Pradesh. This case study provides an example of the role of insurance in access to finance for farmers exposed to weather risk. The second case study focuses on the 2005 weather insurance pilot program for winter wheat farmers in the southern oblast of Kherson in Ukraine.

Weather Insurance for Agriculture in India

In 1991, a household survey in India addressing rural access to finance revealed that barely one-sixth of rural households had loans from formal rural finance institutions and that only 35 to 37 percent of the actual credit needs of the rural poor were being met through these formal channels (Hess 2003). These findings implied that over a half of all rural household debt was to informal sources, such as moneylenders charging annual interest rates ranging from 40 to 120 percent. A survey based on the Economic Census of 1998 (Hess 2003) showed that India's formal financial intermediaries reportedly met only 2.5 percent of the credit needs of the unorganized sector through commercial lending programs.⁶¹

In this context, the CRMG, in collaboration with the Hyderabad-based microfinance institution BASIX and the Indian insurance company ICICI Lombard, a subsidiary of ICICI Bank, initiated a project to explore the feasibility of weather insurance for Indian farmers and to determine if, by reducing exposure to weather risk, it would be possible to extend the reach of financial services to the rural sector.

BASIX: Weather Insurance for Groundnut and Castor Farmers

Established in 1996, BASIX has since emerged as one of India's leading microfinance institutions. It has systematically addressed the issues of risk mitigation and cost reduction with the twin aims of attracting investment from the mainstream capital markets while maintaining and expanding its lending in rural areas, including lending for agriculture in drought-prone regions (Hubka forthcoming). BASIX is the umbrella name used to denote a group of companies focused on the provision of microcredit and investment services as well as on improving the livelihoods of its clients and borrowers. To date, BASIX has approximately 150,000 borrowers and 8,600 savers in 7,800 villages in ten Indian states, disbursing US\$37 million in loans since 1996; currently 49 percent of loans are for nonfarm activities (Hubka forthcoming). Its goal is to affect one million livelihoods by 2010: 500,000 directly through financial services and another 500,000 through indirect means. BASIX thinks of itself not as a microfinance institution but as "a new generation livelihood promotion institution,"⁶² implying that credit alone is not the solution to the problems of rural areas.

BASIX manages its risk at two levels: first, it manages its own, institutional-level risk through customer selection and lending practices and partnerships with other institutions; and second, it helps its borrowing customers to reduce their risk (Hubka forthcoming). By helping customers to mitigate and manage their own risk, and hence the risk of defaulting on their loans, BASIX in turn protects the quality of its own portfolio. In 2003, in order to further extend the risk management offerings it provides its clients, BASIX joined forces with ICICI Lombard, and with technical support from CRMG, they designed, developed, and piloted a weather insurance product for farmers with small and medium holdings in Andhra Pradesh.

BASIX recognized that, in many areas, farmers' yields depend critically on rainfall and that its loan default rates were highly correlated to drought. Furthermore, BASIX found that the losses sustained by individual farmers from below average rainfall were on account of several factors, not direct impacts on yields alone (KBS LAB 2004). In addition to weather-related yield loss affecting an individual farmer's ability to meet credit repayments—with credit default disrupting the next season's loan disbursement and hence the farmer's agricultural cycle—

the systematic nature of drought leads to area-wide production drops, resulting in local price inflation and harder credit terms for the next growing season for all producers.

The government-sponsored area-yield indexed crop insurance scheme offered by the National Agricultural Insurance Company (NAIC) is compulsory for all crop-loan borrowers using Indian banks and the only crop insurance option available to BASIX customers. BASIX, as have others (Hess and Skees 2003), found, however, a number of inefficiencies in the federal program in relation to drought. In particular, they noted that the NAIC program only led to recovery in extreme situations, that is, following district drought declarations by the state government, which were often the result of political maneuvering rather than objective criteria. Furthermore, in the NAIC program, recovery was based on minimum crop prices and in general occurred two to three years after the failed harvest. By comparison, index-based weather insurance offered the potential of a transparent, objective, and timely settlement processes for economic losses associated with noncatastrophic weather risk, with recovery based on fair market price estimates. With the requirements of farmers in rain-sensitive regions in mind, BASIX considered these to be compelling reasons to launch a pilot weather insurance program.

First Pilot Program: 2003

The initial pilot launched by BASIX and ICICI Lombard was based in the Mahabubnagar district of Andhra Pradesh, with an objective of selling weather insurance policies to two hundred groundnut and castor farmers through Krishna Bhima Samruddhi Local Area Bank (KBS LAB), a BASIX subsidiary licensed by the Reserve Bank of India providing microcredit and savings services in three districts.⁶³ The farmers selected for the initial pilot were members of a Bore Well Users' Association (BUA)⁶⁴ in four BUA villages in the Mahabubnagar district: Kodur, Pamireddypally, Utkoor, and Ippalapaddy. In 1999, for example, the BUA in Pamireddypally received an agricultural loan from BASIX. With a 100 percent repayment rate, and therefore a good BASIX credit history and standing, they were planning to borrow a further amount for the financial year 2003–2004. Based on this strong customer relationship, BASIX launched the weather insurance pilot in Pamireddypally and the other three villages. In particular, by linking the

new insurance pilot to farmers who had accessed finance, BASIX would form a base from which they could begin to understand the interaction between such a product, credit repayment, and, ultimately, their crop-loan portfolio default rates.

The Weather Insurance Contract Design

Groundnut is the primary rain-fed crop grown in the Mahabubnagar district during the June to September monsoon, or khariff, season, followed by castor. While most of the cultivation of groundnut and castor is during the khariff, crops are also cultivated in the winter, or rabi, growing season, in pockets of irrigated land. The economics of cultivating groundnut and castor per acre during the khariff and rabi seasons were established through interactions with the BUA members in feedback sessions and workshops organized by KBS LAB and ICICI Lombard, with additional information and crosschecking from the local agricultural university in Hyderabad. Total input costs for groundnut were estimated at Rs 6,500 (khariff) and Rs 6,000 (rabi), and for castor at Rs 3,000 (khariff) and Rs 3,100 (rabi).

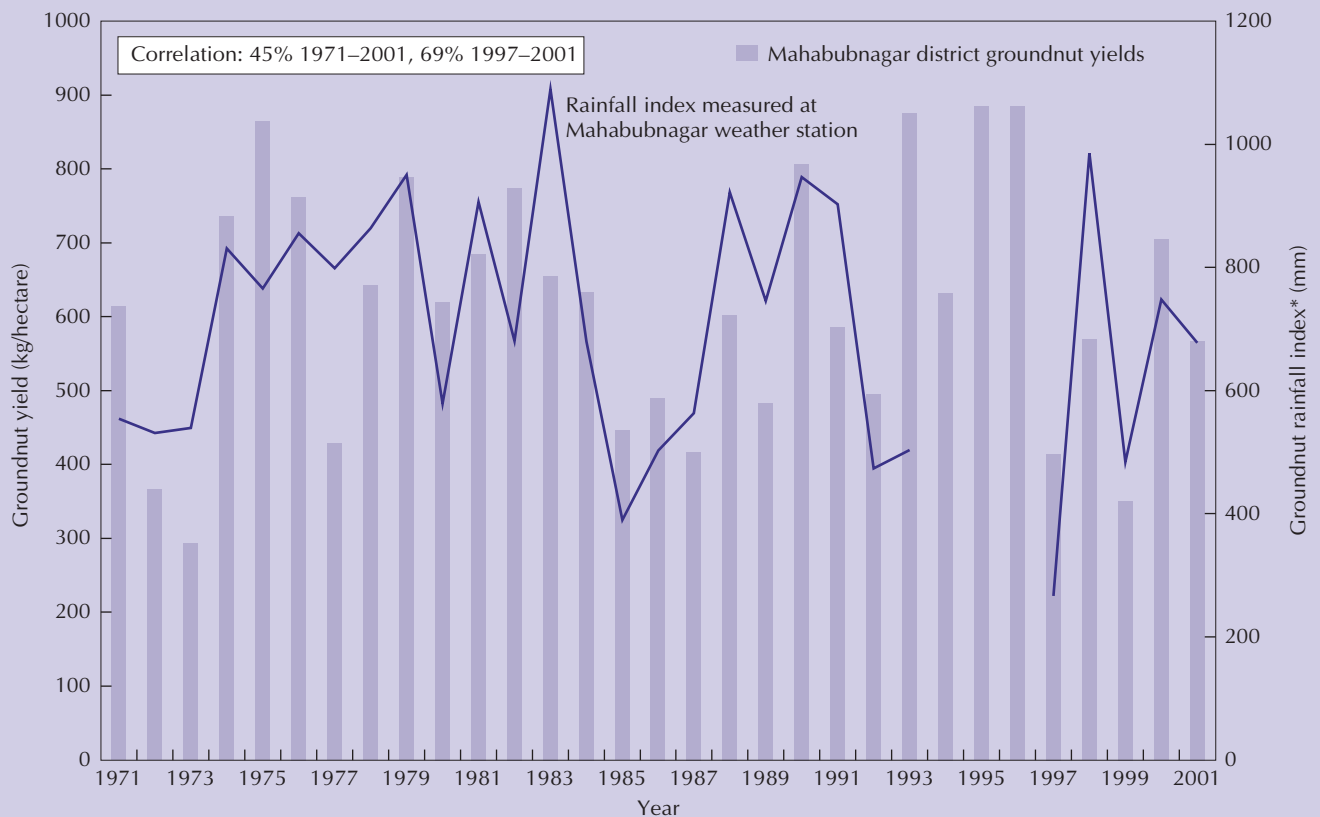
The aim of the 2003 pilot program was to design weather insurance contracts to insure farmers' input and production costs. The initial weather insurance contracts designed for the castor and groundnut farmers were based on a weighted rainfall index of rainfall collected and recorded at the Indian Meteorological Department (IMD) official district weather station in the district capital town, Mahabubnagar. High-yield rainfall correlations were measured for khariff crops in the area; nevertheless agronomic information was used to enhance and strengthen the yield-rainfall relationship for the contract structures. In the case of groundnut, for example, the most critical periods—when groundnut is most vulnerable to low rainfall and therefore water stress—are the emergence periods immediately after sowing and the flowering and pod-filling phase two to three months after emergence (Narahari Rao et al. 2000). On the basis of farmer interviews, agrometeorological studies (Gadgil et al. 2002), local yield information, and models such as the United Nations Food and Agriculture Organization (FAO) water satisfaction index (UNFAO 2005), a groundnut-specific rainfall index was developed. The index was defined as a weighted sum of cumulative rainfall during the period from May 11 to October 17, the average calendar dates for the groundnut growing season. Individual weights

were assigned to consecutive ten-day periods of the growing season, so the index gave more weight to the critical periods during the crop's evolution when groundnut is most vulnerable to rainfall variability. Furthermore, a ten-day cap on rainfall of two hundred millimeters was introduced to the index because excessive rain does not contribute to plant growth. The individual weights were determined by groundnut water requirements, as advised by local agrometeorologists, that maximized correlation between district groundnut yields and the rainfall index (Figure A2.3) but defined homogeneous rainfall periods, making the contract understandable and more marketable to the farmers and less susceptible to basis risk (see Appendix 1). More information on the index construction can be found in Hess (2003).

The average or reference weighted index value for groundnut and castor at the Mahabubnagar

weather station were determined to be 653mm and 439mm, respectively. These reference-weighted index values represent the expected growing conditions that produce satisfactory yields for farmers of these crops in the region. The weather insurance contracts were designed so that payouts started at 95 percent of this reference level. Farmers participating in the program received a payment if the index fell below the predetermined threshold, indicating that the insured should be granted an indemnity to cover lost production and input costs as a result of lower than expected yields. The initial pilot limited how much insurance a farmer could purchase by offering three different fixed contracts depending on the size holding of the farmer wanting to buy the insurance (Table A2.7). The payout schedule as a function of index for small, medium, and large farmers is given in Figure A2.4.

Figure A2.3 Mahabubnagar District Groundnut Yields Versus Groundnut Rainfall Index



Source: District yield data are from the government of Andhra Pradesh, Bureau of Statistics and Economics in Hyderabad. Rainfall data from 1994–1996 are missing.

Table A2.7 Weather Insurance Contracts Offered to Groundnut and Castor Farmers

Category	Premium (Rs)	Farmer Eligibility	Sum Insured (Rs)
Groundnut			
Small	450	< 2.5 acres land holding	14,000
Medium	600	2.5–5 acres land holding	20,000
Large	900	> 5 acre land holding	30,000
Castor			
Small	255	< 2.5 acre land holding	8,000
Medium	395	> 2.5 acre land holding	18,000

Source: Authors.

The Marketing and Sales Campaign

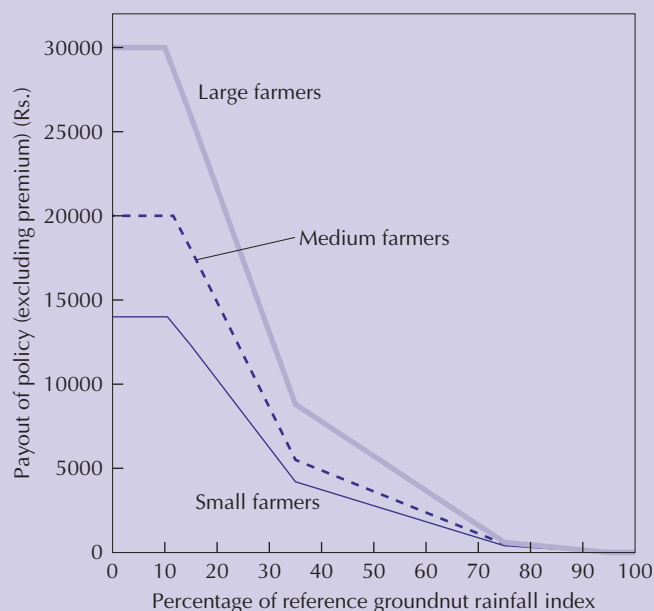
The products were marketed and sold by KBS LAB extension officers to the four villages through workshops and meetings with the BUA members. The sales period ended on April 30, 2003. In total, 230 farmers bought the insurance: 154 groundnut farmers and 76 castor farmers, most having small land

holdings. Of the 154 groundnut farmers, 102 were women who belonged to Velugu (light) self-help groups. Velugu works with four hundred thousand poor women organized into self-help groups in Andhra Pradesh. Funded by the World Bank, Velugu is implemented by the Society for Elimination of Rural Poverty (SERP), an autonomous society set up by the government of Andhra Pradesh to fulfill its poverty alleviation objectives. The women were keen to purchase protection against the vagaries of the monsoon, as all their households and most of their fellow villagers grew groundnut. These fellow villagers were the primary customers of the women in the self-help groups; therefore these women felt the impacts of a poor monsoon season additionally through drops in sales and purchases of their services and hence wanted to protect themselves also.

The entire portfolio of weather insurance contracts sold by BASIX was insured by ICICI Lombard, with reinsurance through one of the leading international reinsurance companies. ICICI Lombard filed all the necessary forms and terms of insurance with the Indian insurance regulator, registering their products before the program was launched.

At the end of the contract term, the final values of the weighted indices at Mahabubnagar weather station were calculated by multiplying the cumulative rainfall totals in each ten-day period from May 11 to October 17, 2003, by the specific weight assigned to that period. The weighted rainfall indices for groundnut and castor were calculated to be 516mm and 490mm, respectively, for khariff 2003, triggering a payout for groundnut farmers and no

Figure A2.4 Payout Structure of Groundnut Weather Insurance Policy Held by Farmers with Small, Medium, and Large Land Holdings



Source: Authors.

payout for castor farmers. Groundnut farmers with small, medium, and large holdings recovered Rs 320, Rs 400, and Rs 480, respectively, within two weeks of the end date of the contract, after the rainfall data were collected and crosschecked by the IMD (see Table A2.8).

Farmer Feedback

The overall farmer feedback from the first pilot was positive; the farmers welcomed the new product and appreciated the objective nature of the weather insurance contracts and the timely payment of claims. In particular, groundnut farmers received a timely recovery from the policies they purchased, even though the Mahabubnagar district was not declared a drought area by the government of Andhra Pradesh in 2003 and, as a result, no payments were made from the government's crop insurance program. The following positive aspects of the pilot, as reported by KBS LAB from feedback sessions with the BUA members in Pamireddypally in January 2004, included the following:

- Farmers had the opportunity to reflect on rainfall shortages and the economic losses associated with them and to learn about the concept and process of rainfall insurance;
- Farmers were happy that they could buy rainfall insurance to protect themselves from the most critical risk to their farming operations;
- The product was introduced through KBS LAB, a credible source of services and facilities for the farmers; and
- Claims were paid in a timely manner.

Some shortfalls were perceived in the product design, however; in particular, the farmers expected that more weight would be given to the initial sowing period of groundnut. Moisture stress at sowing was associated with the greatest financial risk for farmers, as the farmers invest most of their production costs at sowing time. If the plants do not germinate and survive the establishment period, the entire crop will be lost along with the investment costs, and the farmer will have to resow, incurring further input and production expenditures. In 2003, for example, the groundnut farmers expected a greater payout than the amount recovered, as the rains during sowing were delayed and not optimal. The farmers felt the index did not properly reflect that most of the investment in

Table A2.8 Pilot Statistics, 2003

Statistic	Groundnut	Castor	Total
Total number of farmers insured	154	76	230
Aggregate value of insurance (Rs)	2,250,000	858,000	3,108,000
Aggregate premium paid (Rs)	71,700	22,880	94,580
Aggregate amount of claims (Rs)	50,417	0	50,417
Net Incurred Claim to Net Premium Earned (%)	70.3	0	53.3

Source: KBS LAB.

the crop was made at the beginning of the growing season; they believed more emphasis should have been given to this phase. Other shortfalls, as reported by KBS LAB after feedback sessions with the BUA members in January 2004, included the following:

- Rainfall data were collected at Mahabubnagar weather station, but the farmers felt the station did not represent the rainfall of their village well.
- Claim calculation criteria were not clearly communicated to the farmers during the sales and marketing campaign; in particular, the farmers were more comfortable with indexing claims in millimeters rather than in percentile points, and the farmers did not understand the nonlinear payout function of the insurance contract and were expecting a linear relationship between the rainfall index and the claim amount. In 2003, for example, a 22 percent shortfall occurred in the rainfall index; hence the farmers expected Rs 2,800 as the claim amount: 22 percent of the Rs 14,000 sum insured for small-hold farmers.
- Farmers felt that the product should offer phase-wise payouts for each growing phase, subject to the maximum limits, so that it would be clear how the weights and therefore payouts related to each growing stage. The farmers also requested that in the future the insurance company send a progress report on the rainfall for each of the crop phases in order to

facilitate a better understanding within the farming community.

- Farmers noted that excess rainfall at harvest could result in severe crop losses and requested that protection against the risk of excess rainfall be offered under the weather insurance product.

Second Pilot Program: 2004

The second pilot program in Khariff 2004 introduced significant changes to the 2003 design. The program was extended to four new weather reference station locations in two additional districts in Andhra Pradesh: Khammam and Anantapur. The weather insurance contracts were offered to both BASIX borrowers and nonborrowers and were marketed and sold through KBS LAB in Khammam and Mahabubnagar districts and through Bhartiya Samruddhi Finance Ltd. (BSFL)⁶⁵ in Anantapur district at village meetings, farmer workshops, and feedback sessions in the month leading up to the groundnut and castor growing season. A portion of the weather insurance contracts were written on local rain gauges monitored by the government of Andhra Pradesh, rather than on the district IMD stations. Because 60 percent of agriculture in Andhra Pradesh is rain-fed, the government of Andhra Pradesh maintains a network of 1,108 rain gauges throughout the state. This monitoring is done at the smallest administrative unit in the state, known as a *mandal*, which is a grouping of approximately fifteen villages. In Andhra Pradesh there are forty to fifty mandals in each district, and each mandal has one rain gauge: 232 of the rain gauges are owned by the IMD, and all conform to World Meteorological Organization specifications. Records begin in 1956, and historical data can be purchased from the Government Bureau of Statistics and Economics in Hyderabad. The second pilot used these rain gauges,

and, as a result, in general all rain gauges were ten kilometers away from the farming villages involved in the scheme. This limited the basis risk to farmers, because the gauges were closer to their actual farms, but made it more difficult and indeed impossible to find international reinsurance for the final portfolio of weather insurance contracts sold by BASIX and insured by ICICI Lombard. In 2004, therefore, ICICI Lombard chose to keep the risk itself without international reinsurance support.

The biggest difference in 2004, however, was the design of the weather insurance contracts. In light of the farmer feedback from Khariff 2003, the drought protection products for 2004 were structured by dividing the groundnut and castor growing seasons into three phases each, corresponding to the plants' three critical growing periods: (1) establishment and vegetative growth, (2) flowering and pod formation, and (3) pod filling and maturity. With a departure from the weighted index design, the new contracts specified a cumulative rainfall trigger for each of the three phases, with an individual payout rate and limit for each phase. The groundnut drought insurance policy offered to farmers in Narayanpet mandal in Mahabubnagar district, for example, appears in Table A2.9.

Trigger levels and payout rates were determined in consultation with local agrometeorologists and farmers and with reference to local yield data as in 2003. Premiums and threshold levels vary by weather station, depending on the risk profile of each individual location. This simplified design was introduced to give clarity to the recovery process by clearly associating each critical growth phase with an individual deficit rainfall protection structure. If the rainfall deficit reached the lower limit in each phase, the total payout limit for that phase would be triggered to indemnify farmers for the severe corresponding crop losses associated with

Table A2.9 Payout Structure Per Acre for Groundnut Weather Insurance Policy for Narayanpet Mandal, Mahabubnagar District (2004)

Phase	Dates	Strike (mm)	Limit (mm)	Payout Rate (Rs)	Limit (Rs)
Establishment and Vegetative Growth	June 10–July 14	75	20	15	3,000
Flowering and Pod Formation	July 15–August 28	110	40	10	2,000
Pod Filling and Maturity	August 29–October 2	75	10	5	1,000

Source: Authors.

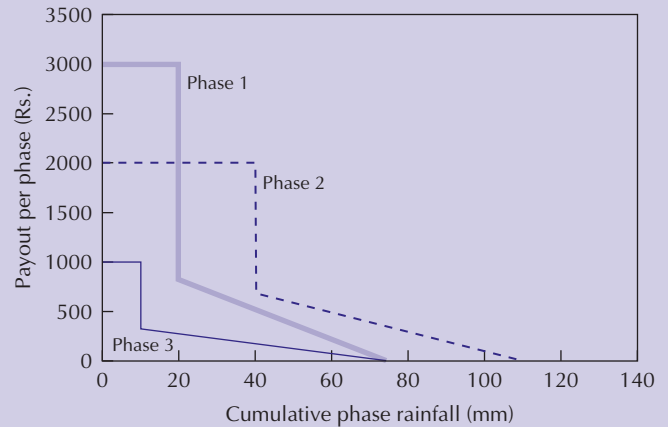
the lack of rainfall. Figure A2.5 shows the contract payout structure. In a further departure from the 2003 pilot, the contracts were designed to be sold per acre.

A farmer could buy as many acres of protection as he wished, provided he actually cultivated that many acres of the crop to be insured. The premium associated with the product in Table A2.9 is Rs 250 per acre insured, for a sum insured of Rs 6,000 per acre. New contracts were also offered for cotton farmers in Khammam district, and an excess rainfall product for harvest was offered to all castor and groundnut farmers with the structure shown in Table A2.10.

In total, over 400 farmers bought insurance through BASIX in 2004, and a further 320 groundnut farmers, members of a Velugu self-help group organization in Anantapur district, bought insurance directly from ICICI Lombard. Several farmers were repeat customers from the 2003 pilot. In contrast to 2003, ICICI Lombard did not seek re-insurance for the BASIX farmer weather insurance portfolio in 2004. As in 2003, all contracts were settled promptly, within thirty days of the end of the calculation period. An example of the marketing leaflet developed by KBS LAB and ICICI Lombard detailing the weather insurance contracts for castor, groundnut, and excess rainfall for Narayanpet mandal is shown in Figure A2.6. For example, in khariff 2004, the rainfall in Narayanpet mandal was not good for groundnut farmers. The rainfall recorded at the local mandal rain gauge measured 12mm for Phase 1 and 84.2mm for Phase 2; rainfall during Phase 3 was above average, at 112mm. Farmers who bought this policy received a payout of Rs 3,258 per acre insured on September 22, 2004.

In autumn 2004, CRMG commissioned a baseline survey to be conducted for the World Bank by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Hyderabad to ascertain the overall farmer feedback for the first two years of weather insurance. The survey, involving one thousand farmers, some of whom have been involved in both pilot programs, will be used as base from which the impact, efficiency, and acceptability of the weather insurance concept can be measured. The results provide strong guidelines and direction for future weather insurance programs in India, particularly regarding the issues of scalability and sustainability. The results also indicate how these new products function in the overall rural finance framework, with particular

Figure A2.5 Payout Structure of Groundnut Weather Insurance Policy for Narayanpet Mandal, Mahabubnagar District, 2004



Source: Authors.

emphasis on access to credit and credit repayment by farmers.

The Future for BASIX Weather Insurance

In 2004, a number of other transactions also took place within the Indian private sector in response to the 2003 pilot. In 2004, BASIX bought a crop-loan

Table A2.10 Payout Structure Per Acre for Castor and Groundnut Excess Rainfall Weather Insurance Policy for Narayanpet, Mahabubnagar



<i>Dates</i>	September 1–October 10
<i>Rainy Day Index</i>	Daily rainfall greater than or equal to 10 mm
<i>Premium Limit</i>	Rs200 per acre insured Rs6,000 per acre insured

Excess Rainfall Payout Structure

Number of Consecutive Rainy Days	Claim Amount (Rs)
4	1,500
5	1,500
6	3,000
≥ 7	6,000

Source: Authors.

Figure A2.6 An Example of the Marketing Leaflet for Groundnut (DGN), Castor (DCN), and Excess Rainfall (EN) Protection in Narayanpet Mandal, Mahabubnagar District, 2004

వాతావరణ భీమా పథకము

"వర్షపాత హెచ్చుతగ్గుల మూలముగా పంటను పండించుటలో సంభవించు రాబడి లోటును పూర్ణ భీమా పథకము".

భమా కోడ్ : DGN
 భమా రకము : వర్షపాతము తగ్గుదల వలన సంభవించు లోటునకు భీమా.
 పంట : వేరుశనగ
 వాతావరణ కేంద్రము : నారాయణపేట్

భమా కాలము :

దశ	మొదటి దశ (తిక్క దశ)	రెండవ దశ (పూక మరయు ఊడ దశ)	మూడవ దశ (పక్క దశ)
సుండి	10 జూన్	15 జూలై	29 ఆగస్టు
వరకు	14 జూలై	28 ఆగస్టు	2 అక్టోబర్

భమా వర్షపు స్థాయిలు :

దశ	1	2	3
నిర్ణీత వర్షపాతపు స్థాయి (మి.మి.)	75	110	75
భీమా రూ॥ ప్రతి మి.మి. తగ్గుదలకు	15	10	5

అధిక మొత్తం భమా వర్షపు స్థాయిలు :

దశ	1	2	3
నిర్ణీత అత్యధిక వర్షపాత స్థాయి (మి.మి.)	20	40	10
భీమా మొత్తం రూ॥	3000	2000	1000

భమా ప్రీమియం : ఒక ఎకరమునకు రూ॥ 250/- మాత్రమే

భమా కోడ్ : DCN
 భమా రకము : వర్షపాతము తగ్గుదల వలన సంభవించు లోటునకు భీమా.
 పంట : అముదము
 వాతావరణ కేంద్రము : నారాయణపేట్

భమా కాలము :

దశ	మొదటి దశ (తిక్క దశ)	రెండవ దశ (పూక మరయు ఊడ దశ)	మూడవ దశ (పక్క దశ)
సుండి	10 జూన్	15 జూలై	29 ఆగస్టు
వరకు	14 జూలై	28 ఆగస్టు	12 అక్టోబర్

భమా వర్షపు స్థాయిలు :

దశ	1	2	3
నిర్ణీత వర్షపాతపు స్థాయి (మి.మి.)	60	100	75
భీమా రూ॥ ప్రతి మి.మి. తగ్గుదలకు	10	15	15

అధిక మొత్తం భమా వర్షపు స్థాయిలు :

దశ	1	2	3
నిర్ణీత అత్యధిక వర్షపాత స్థాయి (మి.మి.)	20	40	50
భీమా మొత్తం రూ॥	1500	2000	2500

భమా ప్రీమియం : ఒక ఎకరమునకు రూ॥ 200/- మాత్రమే

భమా కోడ్ : EN
 భమా రకము : అధిక వర్షపాతము వలన సంభవించు లోటునకు భీమా.
 పంటలు : వేరుశనగ మరియు అముదము.
 వాతావరణ కేంద్రము : నారాయణపేట్
 భమా వర్షపు కాలము : 1 సెప్టెంబర్ సుండి 10 అక్టోబర్.
 వర్షపు దినము : ఒక్క రోజులో 10 మి.మి. కిని అంతకు ఎక్కువ కాని వర్షము పడవలెను.

భమా చెల్లింపు (ఎకరాకు) :

వరుస వర్షపు దినములు	పొందు భమా బిలువ రూ॥ లలో
4 లేక 5 రోజులకు	1500
6 రోజులకు	3000
7 రోజులకు అపై	6000

భమా ప్రీమియం : ఒక ఎకరమునకు రూ॥ 200/- మాత్రమే.

గమనిక :
 సైన్ ఇన్వలడిన్ పథకము పేర్కొనబడిన ప్రాంతంలో సూచించిన పంటకు, నిర్ణయించిన కాలమునకు మాత్రమే వర్తించును.

వివరములై ఈ క్రింది చిరునామాను సంప్రదించగలరు :

క్షయ భీమా సమ్మర్షి లోకల్ ఏరియా బ్యాంక్
 1-10-87/5/డి, చి.కె.రెడ్డి కాంప్లెక్స్, న్యూ టౌన్,
 సుహూబ్ నగర్ - 509 001.
 ఫోన్ : 08542-255105, 256264

INSURANCE IS THE SUBJECT MATTER OF THE SOLICITATION.

Source: ICICI Lombard/BASIX.

portfolio insurance policy based on weather indices. For the first time, BASIX used this protection to cover its own risk and passed neither the cost nor the benefits to its client farmers. The protection allowed BASIX to keep lending to drought-prone areas by mitigating default risk through the insurance policy claims in extreme drought years. BASIX bought a policy to cover three business locations, which was insured by ICICI Lombard and then reinsured into the international weather market.

In 2005, BASIX scaled-up the weather insurance program for farmers, extending the projects to all of their branches in seven Indian states for khariff 2005, with a sales target of ten thousand policies. BASIX sold 7,685 policies to 6,703 customers in thirty-six locations in six Indian states during the 2005 monsoon season. The new policies featured a

dynamic contract start date determined by a rainfall trigger and minimum and maximum limits to the rainfall counted (for example, rainfall below two millimeters per day is not counted). In addition, BASIX simplified and largely automated the underwriting process, which is why BASIX could roll out weather insurance to every branch. Intense training sessions with loan officers, who became literally one-stop-shop full customer service agents, allowed BASIX to service a large array of rainfall insurance products. At the same time, the policies became more general "monsoon failure" policies, meaning they were area-specific rather than crop-specific products, targeting general livelihood losses of farmers that have diversified agricultural portfolios at risk to weather, rather than losses associated with yield variations of a specific crop. For the

first time BASIX also worked with another insurance provider, NAIC, as well as ICICI Lombard, to sell weather insurance policies in some locations. In 2005, over seventy new automated weather stations were installed throughout India, by private company Delhi-based National Collateral Management Services Limited (NCMSL) in partnership with ICICI Lombard, on which weather insurance contracts were written, including many BASIX contracts. By establishing stations closer to the farmers, BASIX had more reliable automatic stations as settlement bases for their contracts and more accurate products for their farmers. NCMSL plans to scale-up their installations throughout the country with more insurance provider partners in 2006, which will benefit end users like BASIX in subsequent seasons.

BASIX is also interested in making the insurance available to landless laborers and self-help group women in its operating regions, whose livelihoods also suffer from the vagaries of the monsoon. In 2004, three hundred women bought a weather insurance policy from ICICI Lombard directly, traveling by train to Hyderabad.

BASIX's ultimate goal is to offer weather-indexed loans to their borrowers. BASIX can package a loan and a weather insurance contract (Hess 2003), based on the drought indices described above, for example, into one product, such as a weather-indexed groundnut production loan. The farmer would enter into a loan agreement with a higher interest rate that accounts for the weather insurance premium that BASIX would pay to the insurer. In return, in the event of a drought as defined by the index, the farmer will not repay all the dues. In the event of a moderate drought, instead of paying the loan principal and interest, the farmer would repay the principle only; in the event of a severe drought, he would only need to repay part of the principle.

During 2004 and 2005, not only did BASIX expand their weather insurance program, a number of other institutions, including the originator, ICICI Lombard, began expanding the market for weather insurance in India. IFCCO-Tokio, a joint venture insurance company, launched weather insurance contracts similar to the 2003 contracts in 2004, selling over three thousand policies to farmers throughout India in 2004 and over sixteen thousand in 2005. In conjunction with ICICI Lombard, the government of Rajasthan launched a weather insurance program for farmers for the 2004 growing seasons, insuring 783 orange farmers from insufficient rainfall in khariff 2004 and 1036 coriander farmers in rabi

2004; this was scaled up to include more crops and farmers in 2005. The NAIC, responsible for the government-sponsored area-yield indexed crop insurance scheme, also launched a pilot weather insurance scheme for twenty districts throughout the country in 2004, reaching nearly 13,000 farmers; the scheme was even mentioned in the government of India budget for the financial year 2004 to 2005. In 2005, NAIC sold weather insurance to approximately 125,000 farmers throughout India. In the same year, ICICI Lombard scaled up its agricultural weather insurance sales, reaching approximately 100,000 farmers, and expanded into other economic sectors. New insurance providers such as HDFC Chubb also entered the market in 2005. In total it is estimated that during khariff 2005 250,000 farmers bought weather insurance throughout the country. Given this strong level of interest and the potential size of the end user market, agriculture weather risk management in India is set to grow (Divyakirti 2004).

Weather Insurance for Agriculture in Ukraine⁶⁶

Ukraine is one of the biggest grain and oilseed producers in the world and the agricultural sector is of great importance for the national economy: agriculture accounts for 14 percent of the country's GDP.⁶⁷ For their production, Ukrainian farmers face multiple perils, such as drought, excess rain, and frost, which make their incomes unpredictable and limit their access to credit.

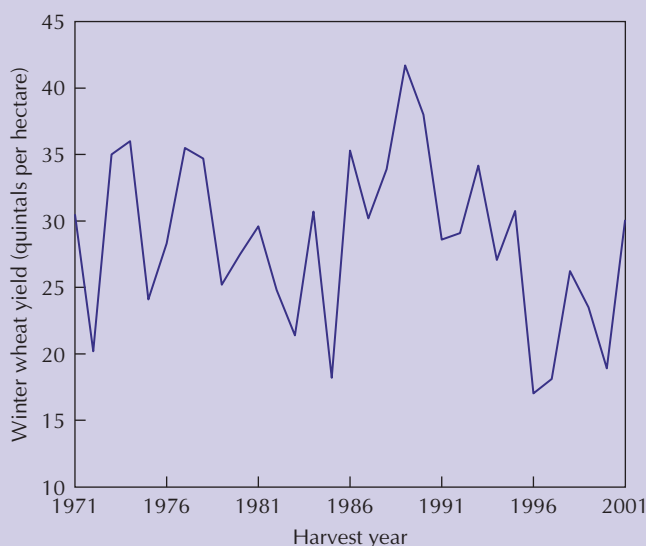
Empirical evidence demonstrates that the largest risk to crop production in the Kherson oblast (province) is weather, namely drought in spring and summer and low temperatures in winter. Traditional multiple-peril products offered by local insurance companies somewhat addressed winter risks, but drought coverage was excluded from the insurance products available to farmers. In addition, the insurance companies did not have the professional staff with agricultural expertise nor the infrastructure necessary to offer comprehensive agricultural insurance products. Consequently the farmers did not trust the insurance companies and the policies offered. High administrative costs and asymmetry of information further compounded these problems, rendering the agricultural insurance system in the country ineffective.

In 2001, the CRMG introduced the concept of index-based weather insurance to Ukraine in col-

laboration with IFC-PEP. The concept of weather insurance appeared particularly feasible in Ukraine because of a widespread system of 187 weather stations, eight in Kherson, and the excellent quality of data. After extensive consultations with the farmers, local authorities, and agricultural scientists, IFC-PEP decided to investigate the feasibility of weather insurance in the southern oblast of Kherson. In order to reach the acceptable volume of contract sales, IFC-PEP decided that the weather pilot project should concentrate on regional farmers' most important crops susceptible to weather risk. Potential crops included winter wheat, spring barley, sunflower, and corn. Of these, winter wheat has the biggest planted area and considerable value at risk: 1.5 to 2 million tons is produced in the oblast annually with an approximate crop value of US\$200 million, and, in addition, most of this crop is cultivated without irrigation. Furthermore, financial institutions in the oblast had recently started to accept standing crops of grain as security for agricultural loans, despite concerns over lack of sufficient insurance protection.

With this basis in 2004, the CRMG together with IFC-PEP Agribusiness Development Project agreed to run a small pilot project for the Kherson oblast in spring 2005.

Figure A2.7 Winter Wheat Yields for Kherson Oblast, 1971–2001



Source: Hess et al. 2005.

The Kherson Oblast

A cursory glance at winter wheat yield data for the Kherson oblast shows a significant interannual variability in yield in the region (Figure A2.7), which reflects the agroclimatic risk inherent to the oblast. Formal interviews with winter wheat farmers in the region indicated the greatest perceived risks were related to weather.

Designing the Index

Historical yield data for Kherson are unreliable (not reported accurately) for the purposes of index construction, as the data does not faithfully represent the actual production in the rayons (subregions) of the oblast. In order to design an effective weather risk management instrument, key weather factors had to be discussed with experts, such as agrometeorologists and farmers, and crop models using weather variables as inputs for yield estimates had to be developed. To this end, a report (Adamenko 2004) was commissioned by the CRMG and ICF-PEP from the Ukrainian Hydrometeorological Center (UHC) in Kiev to assess the agroclimatic conditions and weather risks for growing winter wheat in the Kherson oblast. In the absence of reliable yield data, expert assessment and the results from the report based on the UHC oblast-specific crop model were used as the basis for constructing an appropriate weather index for winter wheat in Kherson.

Identified Weather Risks

According to the UHC report (Adamenko 2004) the most significant weather risks for growing winter wheat in the Kherson oblast are (1) winterkill during the crop's hibernation period from December to March, and (2) moisture stress during the vegetative growth period from mid-April to June.

Winter wheat yields at harvest depend to a great extent on how well the plants survive the winter and the hibernation period. In the territory of Kherson, the primary cause of winter wheat winter crop death is one day or more of air temperature and, therefore, soil temperature below the critical level. These winterkill events cause damage and death of the plants' tillering node. Snow cover considerably improves conditions for winter wheat hibernation, as the difference between air and soil temperature increase by 0.5 to 1.1°C for each centimeter of snow cover. The crop usually dies in years without snow cover or when the stable snow cover appears late in winter, as it did in 2003.

Low moisture is the other main limiting factor for high winter wheat yields in the Kherson oblast. In fact, lack of moisture in the soil and air during the vegetative growth period is the main cause of low winter wheat yields. In particular, all five rayons of the oblast are subject to frequent droughts; the probability of a severe and medium drought (defined subsequently) during the vegetative period in the region is 15 to 20 percent and 40 to 50 percent, respectively. The first critical period in which winter wheat yield formation is highly susceptible to moisture stress is the phase from leaf-tube formation to earing. Due to the climatic conditions of the region, this period lasts from April 15 to May 25. The water requirements for winter wheat during this stage, when compared to the climatic conditions for this period for the oblast, are estimated by the UHC to be 80 percent of the optimum. During the most recent years, in 50 percent of cases the moisture conditions during this period were close to optimum (1998, 1999, 2001), while in the other 50 percent of cases they were insufficient (2000, 2002, and 2003). The second critical period for winter wheat is the phase from earing to milk ripeness, which is the kernel formation stage; this lasts, on average, from May 22 to June 14, but it can extend later into June. Lack of moisture during this period directly decreases the number of kernels in a wheat ear and leads to excessive drying of the kernels. The water requirements for winter wheat during this stage, when compared to the climatic conditions for this period for the oblast, are estimated by the UHC to be 90 percent of the optimum.

The Selyaninov Hydrothermal Ratio Index (SHRI)⁶⁸

The previous findings indicate the need to include drought risk in a meaningful insurance product. An example of a product that has been suggested for Kherson oblast is outlined in this section. Agricultural drought can take two forms: air drought and soil drought. Air drought describes conditions in which precipitation is low and high air temperature persists against a background of low relative air humidity. This leads to unfavorable conditions for plant vegetation and drastically reduces crop yields. Soil drought describes the excessive dryness of soil, resulting in a scarce supply of moisture available for crop growth and development. Air drought, characterized by a long rainless period, high air temperature, and low air humidity, is often described using the Selyaninov Hydrothermal Ratio (SHR). For the vegetative growth period for winter wheat

in Kherson, April 15 to June 30, the SHR is defined as follows:

$$SHR = \frac{\sum_{15\text{ April-June}} \text{Daily Rainfall}}{(0.1 \times \sum_{15\text{ April-June}} \text{Average Daily Temperature})}$$

It holds for periods when daily average temperatures are consistently above +10°C. This period, on average, begins on April 15 in the Kherson oblast. The SHR does not always serve as a reliable criterion of agricultural drought because it does not account for soil moisture, but because soil dryness, unlike rainfall and average temperature, is generally not an observed variable, the SHR is the only objective indicator that can be used to capture drought risk during the vegetative period. Conditions for obtaining the best harvest are when the SHR is between 1.0 and 1.4. When the SHR is greater than or equal to 1.6, plant yields will be depressed by excessive moisture. When the SHR is less than or equal to 0.6, plants are depressed by drought conditions. In general, the isoline SHR = 0.5 coincides with regions of semidesert climate conditions. Results from the UHC crop model (Adamenko 2004) that suggest the impact on yields of SHR during the vegetative growth stage between April 15 and June 30 are defined in Table A2.11.

The SHR can therefore be used as an index to monitor the impact of air drought on winter wheat crop yields.

Quantifying the Impact of Weather

There are two possible levels for weather insurance protection that can identify the appropriate limit for

Table A2.11 Relationship Between SHR and Winter Wheat Yields During the Vegetative Growth Phase of Plant Development

SHR	Description	Yield Loss (%)
1.6	Excessive humidity	30+
1.3–1.6	Damp	—
1.2–1.0	Sufficient humidity	—
0.9–0.7	Dry	—
< 0.7	Drought conditions	—
0.5–0.6	Medium drought	20
0.4–0.5	Severe drought	20–50
< 0.4	Extreme drought	50+

Source: Hess et al. 2005.

a weather insurance contract: Production costs and expected revenue. The former, in general, is more appropriate for catastrophic weather risks early in the growing season, such as winterkill, when the farmer has an opportunity to resow another crop for summer harvest if the winter wheat crop is completely destroyed. The latter is, in general, more appropriate for weather risks later in the growing season, when there is no opportunity for resowing, yet conditions, such as an April to June drought, can cause yield to vary significantly from the expected levels. The choice of a factor, however, depends on the preferences of the farmer. Informal interviews with farmers in the oblast indicate that farmers are less concerned with winterkill risk than with drought risk, even though it can potentially cause complete damage, because of the potential to resow.

Winter wheat farmers spend a maximum of (Ukrainian Hryvna) UAH 1000 per hectare on production and inputs costs during the crop's entire growing season. The limit of a mid-April to June drought insurance contract to cover production and input costs should therefore be set at UAH 1000 per hectare insured. In the event of total crop failure as a result of a very extreme drought, for example, say a $SHR < 0.15$ event, the farmer would be indemnified for UAH 1000 per hectare insured to compensate for the loss of the investment. The payout rate of the insurance contract can be determined from the information in the UHC report and is summarized in Table A2.12.

Table A2.12 Relationship Between SHR and Financial Losses Associated with Winter Wheat Yield Fluctuations

SHR	Payout per Hectare
0.6–0.51	UAH 200 (20% loss)
0.5–0.46	UAH 300 (30% loss)
0.45–0.41	UAH 400 (40% loss)
0.4–0.36	UAH 500 (50% loss)
0.35–0.31	UAH 600 (60% loss)
0.3–0.26	UAH 700 (70% loss)
0.25–0.21	UAH 800 (80% loss)
0.2–0.16	UAH 900 (90% loss)
< 0.15	UAH 1000 (100% loss)

Source: Hess et al. 2005.

Calculating the limit and payout rate for a contract to protect farmer revenue is a little more difficult, as harvest-time commodity prices are not known in advance when the insurance is purchased. Furthermore, commodity prices also often vary in response to extreme production shocks, and it is often difficult to quantify the production (weather) price correlation. Estimates for the harvest-time price can be made, however; for example, the previous year's harvest-price or the five-year average of the September price from the local commodities exchange could be used as a best estimate, or the government minimum support price could be used as a lower boundary for the selling price.

Structuring a Weather Insurance Contract

The Sum Insured

In order to ensure that the insurance product has some relationship with the true risk exposure of the farmer, the limit of the insurance contract is negotiable with the farmer; however, it cannot exceed a maximum estimated by the potential insured loss to the farmer, as outlined in above. In the design of the contract, an upper limit on the risk volume per client will be set at the total area of the crop planted multiplied by the expected selling price, determined as mentioned above by the previous year's selling price according to records, the five-year average, or the government's minimum support price.

Contract Specifications

As outlined in Appendix 1, in addition to defining the index, the buyer/seller information (names, crop, and hectareage insured), limit and tick-size, an index-based weather insurance contract must also include the location (weather station of reference), the calculation period, the strike or deductible, and the premium. In the case of Ukraine, to provide the best possible coverage for the farmer client, index-based insurance contracts must be written on the UHC weather station nearest to the farmer's land. Indeed, the extent of the UHC weather observing network may be a limiting factor for the applicability of this type of insurance in regions that do not have a UHC station. The correlation coefficients for the interannual variation in cumulative rainfall, cumulative average temperature, and SHR for April 15 to June 30 from 1973 to 2002 for five weather stations in the oblast are given in Table A2.13.

Table A2.13 Correlation Coefficients for the Interannual Variability of Cumulative Rainfall, Average Temperature, and the SHR Index Measured at Five UHC Weather Stations in Kherson Oblast

Station Name	Behtery	Genichesk	Kherson	N Kahowka	N Sirogozy	Station Location
April 15–June 30 Cumulative Rainfall Correlation Coefficients (1973–2002)						
Behtery	1					46°15' N 32°18' E
Genichesk	0.72	1				46°10' N 34°49' E
Kherson	0.74	0.59	1			46°38' N 32°34' E
N Kahowka	0.70	0.41	0.65	1		46°49' N 33°29' E
N Sirogozy	0.35	0.54	0.39	0.50	1	46°51' N 34°24' E
April 15–June 30 Cumulative Temperature Correlation Coefficients (1973–2002)						
Behtery	1					46°15' N 32°18' E
Genichesk	0.93	1				46°10' N 34°49' E
Kherson	0.98	0.93	1			46°38' N 32°34' E
N Kahowka	0.98	0.95	0.99	1		46°49' N 33°29' E
N Sirogozy	0.95	0.95	0.98	0.98	1	46°51' N 34°24' E
April 15–June 30 SHR Correlation Coefficients (1973–2002)						
Behtery	1					46°15' N 32°18' E
Genichesk	0.72	1				46°10' N 34°49' E
Kherson	0.74	0.59	1			46°38' N 32°34' E
N Kahowka	0.74	0.44	0.68	1		46°49' N 33°29' E
N Sirogozy	0.38	0.58	0.42	0.50	1	46°51' N 34°24' E

Source: Hess et al. 2005.

A very loose rule-of-thumb is that farmers living within a thirty kilometer radius of the weather stations may purchase weather insurance indexed to that station. Temperature exhibits less spatial variability than does rainfall. The benefit of the SHR index is that, by combining cumulative rainfall with temperature, the spatial variability of the index, in comparison to indexes of cumulative rainfall alone, is slightly reduced. In this example, the calculation period for the SHR drought insurance contract is April 15 to June 30 to cover the

leaf-tubing to kernel formation growth period of winter wheat. Final settlement of the weather insurance contracts typically would occur up to forty-five days after the end of the calculation period, once the collected weather data have been cross-checked and quality controlled by the UHC. The strike would be set at a predefined SHR level appropriate to the weather station under consideration. A pricing example for winter wheat drought risk is given below for Behtery weather station.

Example: Pricing Drought Risk as Measured by the SHR Index

In Behtery, droughts of varying intensity happen quite frequently. Although irrigation is partially used by farmers in this area, farmers have expressed interest in products that protect against extreme drought. Figure A2.8 shows the cumulative average temperature and cumulative daily rainfall measured at the Behtery station from 15 April to 30 June 1973 to 2002. The temperature data exhibit strong trends, hence the data must be detrended to make the historical data consistent with recent warmer conditions that may make severe drought events more frequent in Behtery now than thirty years ago. The weather data from the UHC are of high quality and do not need to be cleaned or quality controlled prior to analysis. The data are detrended by fitting and removing a best-fit least mean square linear trend to the cumulative average temperature totals for April 15 to June 30 (see Appendix 1). Figure A2.9 shows the corresponding SHR index: medium droughts ($SHR < 0.6$) have occurred nine times in the past thirty years and severe droughts ($SHR < 0.4$) twice. The driest conditions occurred in 1996, with $SHR = 0.21$.

The payout of a SHR index insurance contract at Behtery is determined by the following equation:

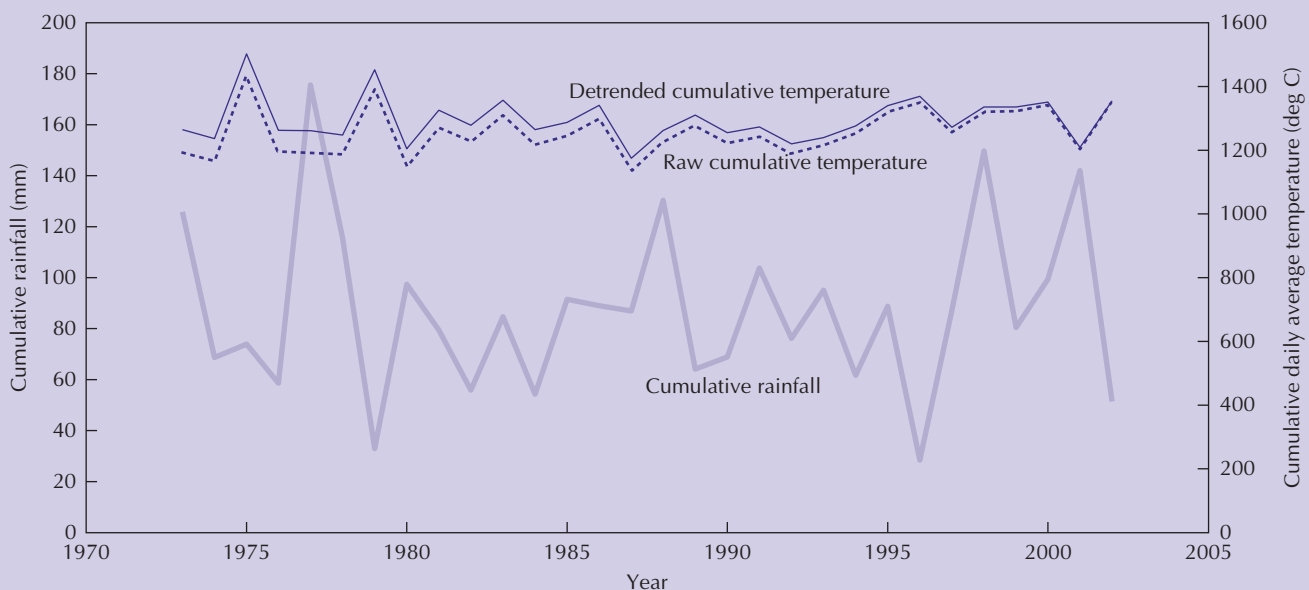
$$Payout = \min(\max(0, K - SHR) \times X, M)$$

where K is the strike, SHR is the SHR index measured during the calculation period, X is the payout rate, determined by the structure of the contract, and M is the limit of the contract. A reasonable estimate for the risk loading factors α , β , given prices in the weather market, are $\alpha = 25\%$ and $\beta = 5\%$. By simply taking the thirty years of payouts in Figure A2.9, the payout statistics for a weather insurance contract with a strike level of $SHR = 0.4$ can be calculated as follows: $E(SHR) = \text{UAH } 70$, $\sigma(SHR) = \text{UAH } 220$ and $Var_{97}(SHR) \text{ UAH } 800$. A first-order estimate of an appropriate premium to charge a farmer for an insurance contract with a strike level of $SHR = 0.4$ at Behtery Weather Station, therefore, is between UAH 110 and 125 per hectare for a sum insured of UAH 1000.⁶⁹ (See Figure A2.10 for the terms of an example of a prototype contract for Behtery.)

The 2005 Pilot in Kherson

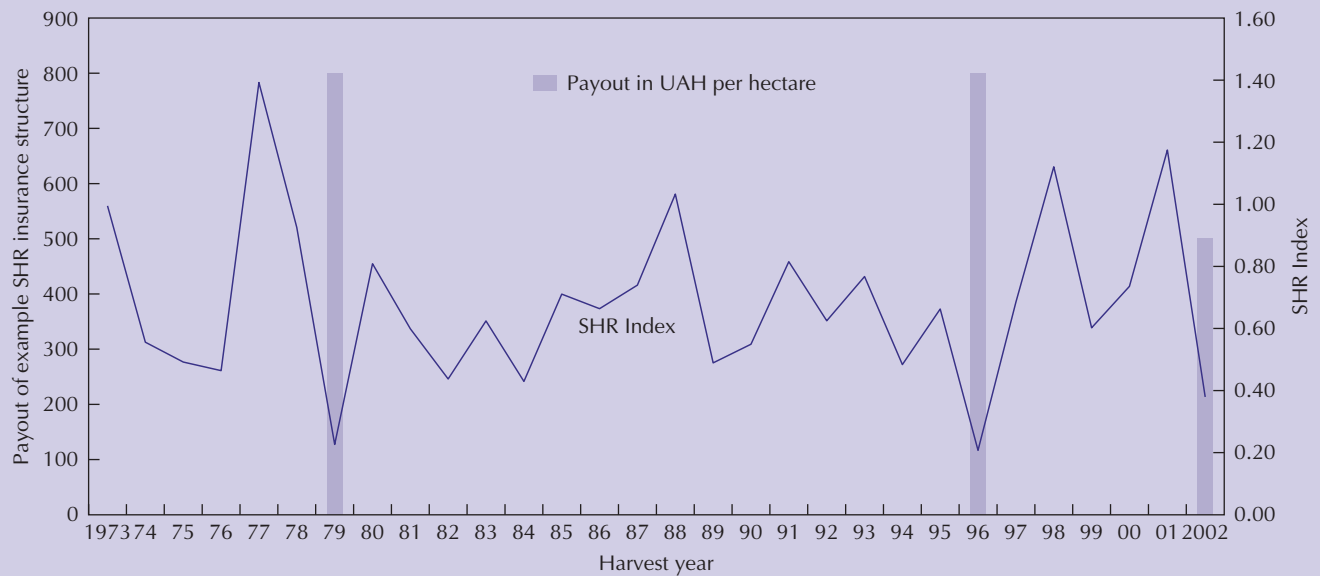
According to Ukrainian legislation, in order to be able to introduce a new product, such as index-

Figure A2.8 Cumulative Rainfall and Average Temperature for Behtery Weather Station for April 15 to June 30, 1973–2002



Source: Authors.

Figure A2.9 SHR Index for Behtery Weather Station, 1973–2002



Source: Hess et al. 2005.

based weather insurance, to the market, the participating company (or companies) must design and register the rules of insurance with the state regulatory body. Although the law on insurance—the leading document regulating the insurance industry—does not specifically reference “index” insurance, other legislative documents introduce index-based products in relation to agricultural applications; for example, relating to agricultural insurance and state finance support of the agricultural sector. As a result, there was no direct legislative barrier prohibiting the use of index-based products in Ukraine. In April 2005, the regulator agreed to register rules of insurance that permit the development of different types of index-based insurance products for agribusiness applications.

The insurance company partner, Kiev-based Credo Classic, working with IFC-PEP and CRMG, submitted the necessary package of documents to the regulator in Kiev. This included drafting and registering the rules of insurance for index-based weather insurance products with the regulating body. The rules of insurance were accepted at the beginning of April 2005, clearing the way for the first weather insurance pilot in Ukraine. The regulator confirmed that, given the nature of the product, the insurer is not required to carry out field checks and loss adjustments, despite the po-

tential of basis risk. The regulator further stated that the insured area must not be greater than the seeded area and, for the purpose of this product, a farmer’s report declaring the seeded area should be sufficient proof of the maximum possible area for insurance.

The weather insurance contract designs and marketing materials for the proposed pilot program in Kherson were finalized following receipt of State Regulator approval of the rules of weather index insurance for agricultural applications. Using feedback and workshop sessions, IFC-PEP worked with the insurance partner in Kherson oblast to target groups—including farmers, agribusinesses, and financial institutions—who could benefit from the new insurance products. Only two weather insurance contracts protecting against drought were sold during the brief marketing period, primarily due to the timing of the pilot and late regulatory approval. The protection period for the first pilot finished in July 2005. The results of the small first pilot have been communicated to the public to raise awareness about index insurance and the pilot experience: the concept and methodologies developed have been made publicly available. Presently, the insurance company leading the pilot in Kherson is already providing consultations to other markets players in Ukraine on designing index-based products in-

Figure A2.10 Sample Contract for Behtery Weather Station

Buyer	Farmer Z 1 Wheat Street, Behtery, Kherson, UA
Seller	ABC Insurance Company
Hectares of Winter Wheat Insured	100 Hectares
Calculation Period	April 15, 2005 to June 30, 2005 (inclusive)
Location Behtery	Behtery Weather Station
Index, SHR	$\text{SHR} = \text{Index 1} / (\text{Index 2} * \text{Scaling Factor})$ <p>Where:</p> <p>Index 1 = Cumulative Capped Daily Rainfall measured during the Calculation Period at Location. Measuring Unit: mm</p> <p>Index 2 = Cumulative Daily Average Temperature measured during the Calculation Period at Location. Measuring Unit: Degrees Celsius</p> <p>Scaling Factor = 0.1</p>
Capped Daily Rainfall	<p>Capped Daily Rainfall = min (50, Daily Rainfall Total)</p> <p>Measuring Unit: mm</p>
Strike, K	0.4
Maximum Payout, M	UAH 1000 per Hectare Insured
Settlement Calculation	<p>1. If the Index SHR is greater than the Strike K no payment is made.</p> <p>2. If the Index SHR is less than or equal to the Strike K the Buyer receives a payout X per hectare insured from the Seller according to the following Settlement Calculation:</p> <p>If $0.36 < \max(K - \text{SHR}, 0) < 0.41$, X = UAH 500</p> <p>If $0.31 < \max(K - \text{SHR}, 0) < 0.36$, X = UAH 600</p> <p>If $0.26 < \max(K - \text{SHR}, 0) < 0.31$, X = UAH 700</p> <p>If $0.21 < \max(K - \text{SHR}, 0) < 0.26$, X = UAH 800</p> <p>If $0.16 < \max(K - \text{SHR}, 0) < 0.21$, X = UAH 900</p> <p>If $\max(K - \text{SHR}, 0) < 0.16$, X = UAH 1000</p>
Maximum Settlement	The maximum payment that can be made from the Seller to the Buyer is UAH 100,000.
Premium	The Buyer will pay the Seller a premium of UAH 12,000 for the weather protection outlined above.
Settlement Data	Ukrainian Hydrometeorological Centre, Kiev
Settlement Date	Within 45 days of the end of the Calculation Period.

Source: Hess et al. 2005.

house and drafting the insurance rules for these new products. There are also plans to scale up weather insurance activities to cover more crops and regions in 2006.

TECHNOLOGY APPLICATION CASE STUDIES

Grassland Index Insurance Using Satellite Imagery

In recent times, the availability of new technology, such as satellite imagery, has sparked the introduction of new initiatives to insure grasslands. The most common technical justifications for the adoption of satellite imagery (SI), as the principle of area-yield insurance, are the following: (1) SI can measure pasture health and growth and represents a multiple-peril insurance approach; (2) SI can economically reduce the size of the area on which pasture growth and potential insurance payments are based, thereby reducing basis risk as compared to other approaches (that is, the cage clipping alternative); and (3) SI can assess pasture conditions throughout the growing season and thereby lends itself to “intra-seasonal coverage options.” This section will discuss the use of satellite imagery in creating useful indices to insure grassland following a parametric and objective procedure and will describe relevant experiences in Canada and Spain, the two countries that have made the most effective use of this kind of parametric insurance.

Use of the Normalized Difference Vegetation Index (NDVI) for Insurance Purposes

One of the satellite networks with more information available for these purposes comes from the NOAA satellite. The NOAA satellite has blue, green, red, infrared, and thermal sensors and takes one image per day for every square kilometer of the earth’s surface. The NDVI is a type of vegetative index based on the relationship between red light and near-infrared light. Healthy vegetation absorbs the red light from the sun and uses it for photosynthesis while reflecting near-infrared light from the sun. The formula used to calculate the NDVI is given by:

$$NDVI = (NIR - "Red") / (NIR + "Red")$$

where *NIR* is near-infrared light and *Red* is red light. The more red light is absorbed by the plants, the

smaller the amount of red light is, in turn, reflected by the plant and recorded by the satellite, therefore the larger the NDVI value.

Another important input for the use of NDVI as index insurance is the design of an appropriate mask. A mask is simply a set of geo-referenced information identifying specific land features that can be laid over the satellite imagery information. The overlaying of this information allows some of the satellite imagery to be extracted from the information file prior to making production assessments.

Grassland Insurance in Alberta (AFSC operated)⁷⁰

In 2001, Alberta launched a pilot project using satellite imagery to define a historical “benchmark” production and assess annual pasture production. The pilot was limited to a geographical area of the province where pasture is the predominant land cover. An NDVI, scaled appropriately to reflect native pasture production, was calculated for each township in the pilot area. Insured farmers received payments according to a predetermined payment schedule when the annual township NDVI fell below the historical benchmark NDVI for the township. The program was expanded slightly in 2002 to the portion of the province in which the square kilometer resolution (pixel image) of the NOAA satellite system was considered practical for pasture.⁷¹

The mask used for the project selects only information known to be at least 85 percent native or improved pasture at a quarter section level (160 acres). In the pilot area, where satellite imagery insurance operated, a significant percentage of land, 80 to 90 percent, is native pasture. Areas of crop irrigation and some bush land also need to be extracted, or they significantly influence the program outcome. If a quarter section of land has irrigation, it is removed from the program dataset.

The process for calculating a township NDVI included the use of daily images to estimate the NDVI for each square kilometer section and scaled to identify variations in pasture observations to generate a pasture vegetative index (PVI). All weekly “pixel image” PVI values within a township are averaged to get the weekly township PVI value. While ample data existed to calculate the PVI, little accurate “in-field” pasture information was available to judge whether the PVI actually correlated to pasture growth. In the past, however, AFSC had

operated a cage clipping system that allowed it to obtain production estimates. The availability of information allowed pursuit of a statistical procedure to assess the efficiency of the index indicator to reflect the variations in volume of grassland, basically by comparing historical PVI values to pasture production trends over time, and to confirm any correlation with farmers.

The pasture production data were available for correlation comparisons from 1991 to 1999 from the cage clippings at designated and consistent sites. In addition, AFSC personnel compared satellite imagery to trends in precipitation measured at select Environment Canada weather stations. Correlation results, however, were not good (approximately $r = 0.65$). Through a series of client meetings, AFSC asked farmers to identify their two best and two worst pasture production years in the last fifteen-year period. Since a PVI value could be calculated for each township from 1987 to 2000, farmers could see whether the extreme PVI values compared to their recollections of historical pasture production trends. Production shortfalls due to drought and cool early season temperatures appeared to be identified in the historical PVI values. Geographical differences among township PVI values corresponded to the anecdotal production perceptions of farmers surveyed.

To augment the information acquired by satellite imagery, AFSC developed research plots throughout the pilot pasture area to measure rainfall and the growth of pasture under cages and to note changing pasture conditions over the growing season throughout the pilot area (thirty in total). The correlations were improved substantially through this process.

Pasture insurance is sold in the spring of each year, but farmers must make their purchasing decisions by the end of February. Farmers must insure all the acres of pasture within the same category—native, improved, or bush pasture—but a lower than normal PVI value in one township is not offset by a higher than normal PVI in another. Coverage and premium are expressed in dollars and derived by multiplying the pounds of pasture production expected in each forage risk area, as determined by AFSC, by 80 percent of one of the four price options available to the farmer. The premium rate for the 2003 native pasture insurance program was 21 percent (60 percent is subsidized by the government).

Grassland Insurance in Spain

The parametric insurance scheme in Spain was engineered mainly to cover farmers from droughts affecting the pasture areas. The index utilized is also the NDVI (estimated from NOAA images). The product has been offered since 2001 for all the farms performing extensive livestock production, specifically cattle, sheep, horses, and goats, and is designed to cover the farmers experiencing more than thirty dry days (defined as based on the average historical information on pasture).

In contrast to the previous case study, the insurable index is based only on pure imagery, that is, no verification with actual yields was performed. The index is therefore constructed using a historical evolution of the pixels to create a curve, and the indemnity is defined when the actual observations in a particular year are located below the average curve, based on eighteen years of data.

Also in contrast to the weekly NDVI values, this scheme is based on a ten-day period NDVI index. A Maximum Value Composite Index (MVCI) is estimated for each ten-day period to eliminate the effect of clouds. The reference curves built from the MVCI are smoothed using different algorithms and are defined as beginning on the first ten-day period of October and finalized on the last ten-day period of September of the next calendar year. Whenever information is not available for a particular period, a linear interpolation method is used to fill the missing gaps.

The mask in this scheme is based on the Corine Land Cover (CLC-90), which is used to discriminate between areas with and without grassland production. The deductible is calculated from the ten-day period and is defined as the historic average MVCI for each area, minus 1.25 standard deviations from the average MVCI. The second item of the deductible is related to the amount of ten-day periods below the individual deductible for each time window. The time deductible is three periods below the reference threshold for every ten-day period, which is equivalent to thirty days with dry vegetative indicators.

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EXECUTIVE SUMMARY

1. The ex ante or ex post classification focuses on when the reaction to risk takes place: prior to the occurrence of the potential harmful event (ex ante) or after the event has occurred (ex post).

CHAPTER 1

2. While the focus of this document is on natural disaster risks, the World Bank is also heavily involved in assisting the transfer of commodity price risk for certain commodities. CRMG will produce a separate document on lessons learned in the price risk management area in 2006.
3. Given the combination of price risk and weather risk management transfer, farmers with storage can reduce risk and improve income by storing commodities and bargaining for higher prices.

CHAPTER 2

4. For similar classifications, see Hardaker et al. 2004; and Harwood et al. 1999.
5. For other classifications, see Hazell 1992; World Bank 2001; Anderson 2001; Dercon 2002; Townsend 2005; Siegel 2005.
6. This section is based on Townsend 2005.
7. See Dercon 2002. See also World Bank 2001 for a discussion of the role of safety nets in risk management in developing countries.
8. Examples are the Tanzanian coffee and cotton hedging activities of a major cooperative and CRDB Bank Ltd., the leading private agricultural bank in the New York coffee and cotton futures markets.
9. See the Skees, Barnett, and Hartell (2005) background paper for more discussion of "cognitive failure" and "ambiguous loading."

CHAPTER 3

10. For more detailed reviews of the U.S. program, see Glauber 2004; Skees 1999a; and Skees 2001.
11. The remaining 2 percent of the premiums pays for a variety of other insurance products.
12. Under certain conditions, policyholders can choose to divide farms into separately insured smaller units.
13. The catastrophic policy only covers yield losses in excess of 50 percent of the APH yield at a rate of indemnity only 60 percent of the expected market price.
14. Information in this section is based on Pikor and Wile 2004.

CHAPTER 4

15. This section is based on the background paper by Skees et al. 2005. Appendix 2 offers additional technical details.
16. This paper does not address the responses to the price risk management needs of developing countries, as CRMG is preparing a separate analysis and evaluation (possibly in an ESW) of its ongoing transaction support and capacity-building work in this area.
17. By contrast, area-yield indexes in developing countries often are not measured in a reliable and timely manner.
18. Basis risk also exists with traditional farm-level, multiple-peril crop yield insurance. Typically, a very small sample size is used to develop estimates of the central tendency in farm-level yields (for example, four to ten years in the United States). Given simple statistics about the error of small sample estimates, it can easily be demonstrated that these procedures sometimes generate large mistakes when estimating expected farm-level yield. This makes it possible for farmers to receive insurance payments when yield losses have not occurred and to fail to receive payments when payable losses have occurred. Thus, basis risk occurs not only in index insurance but also in farm-level yield insurance. Another type of basis risk results from the estimate of realized yield. Even with careful farm-level loss adjustment procedures, it is impossible to avoid errors in estimating the true realized yield. These errors can also result in under- and overpayments. Longer series of data are generally available for area-level yields or weather events than for farm-level yields. Because of this, the square-root of n rule suggests there will be less measurement error for index insurance products than for farm-yield insurance products when estimating the central tendency. If the standard deviation of the random variable used for the index is lower than the standard deviation of farm-level yields (as would be the case if the index is based on area-level yields), the index insurance will have even less measurement error relative to a farm-level insurance product.
19. Temperature, for example, can be measured with field lodged temperature gauges that automatically transmit data to a central server.

CHAPTER 5

20. Byerlee (2005) distinguishes between growth strategies for irrigated high potential systems and areas with limited market access in marginal dry lands. Strategies for these two very different types of agricultural systems put different emphases on agricultural policy options of intensification, diversification, increasing farm size, enhancing off-farm activities, or encouraging exit from agricultural activities.

21. Dercon (2005) also cites the importance of macroeconomic stability and better functioning asset markets because they increase the usefulness of self-insurance. In addition, "Better access to alternative economic activities and increased income-earning opportunities could strengthen income-based strategies. Public safety nets could be a useful alternative, although initiatives to develop such programs should take into account their effect on existing risk-coping strategies. Strengthening self-insurance through group-based savings, for example, is an alternative that remains insufficiently explored" (161).
22. Little, et al. (2004), describe how disastrous droughts in Ethiopia were the key external factor that "pushed vulnerable households into poverty out of which many had not recovered by 2003," three years after the major drought event. Moreover, "the occurrence of periodic droughts tends to wipe out asset gains that poor households attain" (15–17).
23. These estimates are from Skees, et al. (2005). U.S. Summary of Business data were used for the U.S. estimate, and data from Pikor and Wile (2004) were used for the Canadian estimate.
24. Timely payment of claims was one of the key reasons for the success of the Indian weather insurance pilot programs. See Appendix 2 for the Indian experience with weather insurance.
25. CRMG, for example, conducts participatory sessions with farmers to identify contract and delivery model designs. In Ethiopia, smallholders designate kebeles (local elected leaders of around six hundred farmers) to collect insurance premiums for group insurance. In one Malawian village, residents wanted local leaders to contract weather insurance that covered the smaller farmers under the programs of the smallholder farmers' association. In India, microfinance institutions function as trusted intermediaries for small farmers. In some places, cooperatives have gained the trust necessary to deliver insurance products to farmers.
26. This probability distribution was developed using procedures that smooth historical data. In reality, few observations have been made below the five hundred millimeter level.
27. To be clear, the threshold where cognitive behavior begins is unknown. In this example, five hundred is used for illustration purposes only. If the value were known with certainty, it would also be relatively easy to develop an analytical solution for the optimal subsidy level.
28. A more detailed discussion of index insurance is found in Appendix 1.
29. International donors could also reinsure this layer through a contingent credit.
30. This section draws on an idea formulated in Skees and Hess (2003) proposing a "standing disaster insurance program."
31. See the Agroasemex case study in Appendix 2 for details on reinsuring an agricultural insurance portfolio with a weather index contract.
32. DOC contracts would most likely be reinsured using direct or packaged transfers of the underlying indexes. Pooling prior to transfer is likely to offer only minimal benefits, since in-country spatial diversification opportunities are generally limited for catastrophic layers.
33. See Appendix 1 for details on pricing methodologies.
34. This section borrows from World Bank (2005a).
35. The weather shock insurance safety net concept has been launched by a Malawian government official, Patrick Kabambe, and is more broadly based on the work on covariate shock insurance in Africa by the World Bank CRMG-Social Protection unit (Harold Alderman and Will Wiseman) and the CRMG-Southern Africa rural sector unit (Rick Scobey).

CHAPTER 6

36. More details on several of these case studies as well as additional country examples are presented in Appendix 2.
37. The unorganized sector corresponds to India's informal or submerged economy, small-scale nonregistered businesses, for example, particularly in rural areas.
38. This is a BASIX subsidiary and a Reserve Bank of India licensed bank providing microcredit and savings services in three districts.
39. BSFL is another BASIX subsidiary company. Launched in 1998, BSFL is the "flagship" company of the group and is a Reserve Bank of India registered nonbank financial company engaged in microcredit and retailing insurance and the provision of technical assistance.
40. A 2002 IFC survey of agricultural enterprise participants in Ukraine reveals that the failure of farmers to repay credit was often due to low sale prices, limited product demand, lack of market information, and high interest rates. Only 12 percent of respondents cited bad harvests as the reason for farmers' inability to repay their debts. In the years before the survey was taken, farmers experienced marketing problems for grains and good harvests. Crop failures due to frost and drought in the 2002 to 2003 season may have significantly altered farmers' perceptions.
41. The estimate of \$1.6 billion was determined by assuming WFP costs for the 1999–2000 drought, in which the WFP was responsible for 45 percent of the total food aid deliveries appealed for by the DPPC. Using that cost estimate to determine 100 percent of the cost of the drought in 1999–2000, then multiplying this cost by the magnitude of the 1984 drought (assumed to be the worst case scenario), the total cost today of a 1984 drought was estimated to be \$1.6 billion.
42. See Hess and Syroka (2005) for more details on Malawi and the SADC region.
43. Skees provided some of the background for this section; see also Mahul and Skees (2005).

CHAPTER 7

44. See Appendix 1 for a four-step design of a risk management plan at the microlevel.
45. For information on this topic, see the World Bank Hazard Risk Management Unit Web site.

APPENDIX 1

46. This appendix abridges a chapter in a forthcoming Istituto di Servizi per il Mercato Agricolo Alimentare (ISMEA) publication on innovations in agricultural risk management.
47. The last PWC Survey was published in June 2004; this figure therefore includes transactions up to March 2004. A new PWC survey is expected in June 2005.
48. In the publication *Energy Risk*, survey respondents estimated that the market was worth around 45 percent more in 2004. The WRMA survey relies on figures from nineteen companies, all members of the Washington-based organization. Some large weather trading operations, such as Deutsche Bank and Calyon, are not WRMA members, however, making the true size of the market difficult to determine.
49. Most energy-related weather transactions are based on temperature indexes, such as Heating Degree Days (HDDs) and Cooling Degree Days (CDDs), designed to correspond to fluctuations in demand for gas (heating) and power (cooling, that is, air conditioning).

50. In 1999, the Chicago Mercantile Exchange (CME) began listing and trading standard weather futures and options contracts on temperature indexes. They now list twenty-two locations in the United States, Europe, and Japan.
51. National Cotton Council of America, <http://www.cotton.org/>.
52. Basis risk is a potential mismatch between insured party's actual loss and the weather contract payment.
53. More information on the weather station and data requirements and providers appears below.
54. To be precise, this definition describes a European Option, an option that can only be exercised at the end of its life, that is, at maturity. In general, this is the most appropriate type of option on an underlying weather index. Other types of options include American Options, an option that can be exercised at any time during its life; Bermudan Options, an option that can be exercised on specific dates during its life; and Asian Options, an option with a payout function that depends on the average value of the underlying index during a specified period.

APPENDIX 2

55. Specific information on this is not available for public disclosure.
 56. The actual premium and payment rates are not available for public disclosure and are omitted from this paper. Since the lack of heat units affects the end use of grain corn more than it does silage corn, the table of premium and payment rates differs for the two types of crop.
 57. Besides working as a severity index, this mathematical relationship is a percentage relationship, allowing the comparison of figures from different years without concern for the scale of the measurement or inflation rates. It also helps eliminate variations in the total sum insured on a yearly basis.
 58. The weather information for the Mexican transaction was reviewed directly by Risk Management Solutions (RMS; www.rms.com) which determined that no significant trends, particularly in the temperature data, occurred in the information used to construct the weather derivative structure.
- Therefore, the following pricing exercise does not include any "detrrending" procedures such as those described in Appendix 1.
59. This information was provided by RMS, who worked with Agroasemex on the initial project.
 60. The Sharpe Ratio method is presented in Appendix 1.
 61. The unorganized sector in India corresponds to the informal or *submerged* economy, such as small-scale nonregistered businesses, found particularly in the rural areas.
 62. www.basixindia.com.
 63. BASIX Annual Report 2003–04.
 64. The BUA is a project of the Andhra Pradesh Government; it subsidizes 85 percent of the cost of community bore wells dug for irrigation of lands belonging to multiple village households. The remaining 15 percent of the bore well cost is met by the individual BUA members, in proportion to the land they irrigate.
 65. BSFL is another BASIX subsidiary company. Launched in 1998, BSFL is the "flagship" company of the group and is registered with the Reserve Bank of India as a nonbank financial company engaged in microcredit and retailing insurance and the provision of technical assistance. Source: www.basixindia.com.
 66. This section is from Hess et al. 2005.
 67. As of 2003. The source of this information is the World Development Indicators database, August 2004.
 68. Information on SHR is from Adamenko 2004.
 69. See Appendix 1 for details regarding the pricing of weather insurance contracts.
 70. The information for this section is from AFSC 2005.
 71. The NOAA satellite system was used because historical satellite images were readily available. To be effective, however, any nonpastureland had to be excluded from the satellite images. With the square kilometer resolution of the satellite image, pastureland outside the pilot area is situated in smaller land parcels and within other crop and forested land. Moving beyond the pilot area, with this resolution, would dictate the exclusion of many pixels that do not meet the minimum pasture content criteria. Without a minimum number of pixel images, the sample size for a township production estimate is not credible.

