Innovations in Government Responses to Catastrophic Risk Sharing for Agriculture in Developing Countries[*]

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1 Introduction

Markets for transferring catastrophic risk in agriculture are woefully lacking in developing countries. Even in developed countries, markets for transferring the risk of crop losses caused by natural hazards generally exist only with large government subsidies. However, such subsidies can be expensive, inefficient, and have detrimental implications that make future catastrophes even worse (Barnett, 1999). In developing countries fiscal constraints limit the degree to which governments can subsidize markets for agricultural risk-sharing. Nonetheless, there are specific things that governments can do to facilitate the development of these markets. This paper addresses the role of government in agricultural risk-sharing for natural disasters that impact crop yields or livestock mortality.

Governments that are concerned about economic efficiency should be extremely cautious about making public investments in agricultural risk-sharing markets. International experience demonstrates that, through rent-seeking activities, market participants can continue capturing public resources well beyond the start up phase of these markets. To the extent possible, government investments in developing agricultural risk-sharing markets should also have minimal impacts on resource allocation decisions of farmers and rural decision-makers.

Many countries have invested public resources in developing and maintaining insurance products that protect farmers against yield, price, or revenue risks. However, governments should only choose to invest public resources in developing agricultural insurance if it is perceived that the social costs of inefficiencies caused by the lack of such insurance products outweigh the social costs of government intervention. These social costs would include not only the opportunity costs of public resources required to create and maintain the agricultural insurance products but also any resource allocation distortions that result from farmers and rural decision-makers responding to incentives created by the insurance products.

Governments often consider investments in agricultural insurance markets as an alternative to ex post free disaster assistance. Often times, these government investments include significant premium subsidies for insured farmers. In principal, insurance products with ex ante structured rules have many advantages over ex post disaster assistance that is subject to budget constraints and the politics of the day. However, if premium subsidies are very high, an insurance product can generate many of the same perverse incentives as ex post disaster assistance. Further, the details of how any premium subsidy is structured are critical.

In general, there is no "one-size-fits-all" policy recommendation for the role of government in agricultural risk management. We assume that most governments consider at least three criteria when considering alternatives for addressing agricultural risk management needs. These are: 1) fiscal constraint; 2) social relief for serious catastrophes; and 3) a desire to facilitate more market-oriented risk transfer. To that end, we stress the importance of identifying risk layers and constructing appropriate government roles for each of those risk layers. In so doing, governments can attempt to segregate social welfare programs that use public funds to respond to low probability, high magnitude events from more market-based insurance programs that can be facilitated with less government fiscal exposure, making certain that these two forms of government intervention are complementary and not working at cross purposes.

In assessing proper roles for government, one must first consider the economic benefits that can be created by risk management tools, the characteristics of risks faced by farmers in the area, and the challenges associated with creating and maintaining risk management tools such as insurance.

2 The Case for Insurance Markets

Risk-averse decision-makers are willing to purchase risk transfer instruments (such as insurance) even when they have to pay more for the instrument than they expect to receive in payouts. Those who can transfer some portion of their risk exposure, through mechanisms like insurance, are more likely to engage in productive activities that promise high returns but also high risk. Thus, effective risk transfer markets encourage investment in productive activities with subsequent economic benefits for producers and local communities (Arrow, 1964; 1996).

However, beyond the market growth arguments that can be made for risk transfer, it is also likely that risk markets can help the poor. Climatic risks present major problems for poor farmers around the world. Not only do they retard growth by discouraging investment, but they can also trap individuals in poverty as a major weather shock can disrupt progress being made by individual households that are just beginning to escape the grips of poverty. The literature that describes the link between risk and poverty traps is growing (e.g., Dercon's edited book *Insurance Against Poverty*).

Farmers face crop losses due to drought, pests, floods, frosts, fire, and other hazards. Of these, drought and other weather-driven risk are the most dominant. Dercon (2002) reports that nearly 80% of Ethiopian farmers cited harvest failure due to drought, floods or frost as their most common concern. Dercon (2005a) has numerous chapters that demonstrate a strong link between shocks and poverty. Increasingly studies are finding that many of the poor in developing countries are a transitory group that move in and out of poverty on a regular basis. Shocks from a wide range of risk related events stop progress and send households who are making progress back to the poverty ranks. These poverty traps justify some type of public intervention using both equity and efficiency criterion. As Dercon concludes "social protection may well be good for growth." [page 2, Dercon (2005b)].

3 Agricultural Risk and Risk Management

Agricultural producers are susceptible to a variety of risks. Among these are variations in market prices for agricultural commodities and production inputs. Agricultural producers are also exposed to production risks associated with adverse weather conditions and pests. The primary focus of this paper is crop yield risk (rather than price risk). Much of the discussion is also applicable to situations where extreme weather events, such as drought or very harsh winter conditions, result in high rates of death loss for livestock.

Farmers use a variety of strategies to address the financial implications of risk. In general, these strategies can be classified in three categories: risk mitigation, risk transfer, and management of retained risk. Common risk mitigation strategies include irrigation, integrated pest management systems, the adoption of risk-reducing technologies such as pesticides or improved seed varieties, and diversification across commodities, regions, and/or off-farm enterprises.

In developed countries farmers often have access to risk transfer mechanisms such as futures market contracts (or derivatives thereof) to help manage price risk and crop insurance to help manage yield risk. In the developing world, the availability of risk transfer mechanisms is generally much more limited and informal. Share tenancy is perhaps the most commonly used risk transfer mechanism in many developing countries.

Even if they utilize available risk mitigation and/or risk transfer mechanisms, farmers still retain some degree of risk exposure. Thus, they must utilize strategies for managing the financial implications of serious loss events. Typically, this involves mechanisms for smoothing inter-temporal consumption across low and high income periods. In developed countries this is often accomplished by maintaining credit reserves with formal lending institutions. Individuals in some developing countries have access to formal lending institutions though often traditional local money-lenders are more common. Consumption smoothing can also occur through the assistance of extended family and community networks.

In developing countries, spatially correlated risk exposure creates a significant challenge since participants in consumption smoothing mechanisms often come from the same region or even the same village (Anderson, 1976). In the wake of a spatially correlated loss event, such as a drought, the demand for credit will increase dramatically driving up interest rates in rudimentary, highly localized, credit markets. In many cultures, villages are organized along extended family networks so a spatially correlated loss event will simultaneously impact all individuals and put tremendous strains on informal assistance networks. If the risk associated with spatially correlated loss events can be transferred out of the region, local consumption smoothing mechanisms will function more effectively.

4 Risk Transfer and Insurability Conditions

In some economic sectors, insurance is a commonly used risk transfer mechanism. Throughout the developed world, and in many developing countries, insurance is available to protect against the financial implications of events such as automobile accidents, theft, and property damage caused by fire or wind. When purchasing an insurance policy, individuals choose to accept a relatively small, consistent stream of losses (the insurance premiums) rather than face the risk of a large loss that is unlikely but possible.

Not all risks however, are insurable. Insurance experts have identified at least five ideal conditions for a risk to be considered insurable.

Determinable and Measurable Loss. It must be possible to determine clearly when a loss has occurred and the magnitude of the loss. If this is not the case, claims settlements will tend to be highly contentious. Purchasers will lose faith in the insurance product. Claims settlements will frequently require costly litigation. This will dramatically increase the cost of providing insurance.

Accidental and Unintentional Loss. Indemnities should only be paid when a loss has occurred due to a random event over which the insured has little or no control. If insureds can engage in hidden actions (including, but not limited to, fraud) that increase the probability of loss and/or the magnitude of loss, indemnities will be higher than anticipated. Insurers often call this the “moral hazard” problem. Insurers can attempt to address this problem through increased monitoring of policyholder behavior. However, this can be very expensive. Deductibles and co-payments can also be used to reduce the incentive for moral hazard.

Calculable Expected Frequency and Magnitude of Loss. To develop a premium rate, the insurer must be able to estimate accurately both the expected frequency and expected severity of loss. Of course, insurers understand that no estimates of expected frequency and severity of loss are likely to be perfect. For that reason, insurers often load premium rates to account for uncertainty in estimating these factors. If the uncertainty is minimal, the load will be rather small. However, if the uncertainty is large, the load can be so high that the insurance becomes unaffordable.

Potential Insureds Can Be Accurately Classified. Insurers typically do not develop premium rates on an individual basis. It would be very expensive to calculate the expected frequency and magnitude of loss for each individual insurance applicant. Instead, insurers attempt to classify applicants into roughly homogeneous risk pools and develop a premium rate for everyone in that pool. This is why automobile insurance applications often ask questions about the type of car being insured, the distance that the automobile will be driven from the home to the work place, and the number of teenage drivers in the household. These questions are among those used to classify potential insureds into risk pools. Problems occur if applicants recognize that the insurer has not classified them accurately. Within a given risk pool, the higher risk applicants will be more likely to purchase the insurance while the lower risk applicants will be less willing to purchase the insurance because they consider the premium cost to be excessive. Thus, while the insurer based the premium rate on the expected performance of the entire pool, in reality only the highest risk individuals purchased the insurance. As a result, indemnities will likely exceed what was expected when the premium rate was set. If the insurer responds by increasing the premium rate, more low-risk individuals will cease to purchase insurance, further compounding the problem. This "adverse selection" problem can only be corrected by better classification methods that typically involve collecting more information from applicants. This, however, may significantly decrease insurance purchasing due to the higher transactions costs.

Large Number of Independent Exposure Units. Insurers invest in a portfolio of insurance policies. The variance in returns on the insurer's portfolio can be reduced by diversifying over a large number of insurance policies if the indemnities paid on those policies are independent or, at least, not highly positively correlated. If indemnities paid on the insurance policies are highly positively correlated, the variance in net returns from the portfolio will be quite large. Insurers seek to manage this portfolio risk by purchasing reinsurance and/or maintaining financial reserves. Note, however, that each of these risk management strategies comes at a cost. Insurers must pay a premium for reinsurance. Financial reserves must be maintained in a liquid state in case they are needed to pay indemnities. These funds would likely earn a higher rate of return if they were invested for longer periods of time.

In reality, most insurance products deviate somewhat from these ideal conditions. However, violations of these ideal conditions must be recognized and addressed when insurance products are being designed. Failure to do so may destroy the long-term viability of the product. Risks characterized by extreme violations of these ideal insurability conditions are likely not insurable.

5 Independent versus Correlated Risk

When considering the potential functionality of any risk transfer instrument, a major consideration is the degree of correlation in financial losses caused by the risk. Insurance is based on the basic principles of diversification. Aggregating uncorrelated risks into a single insurance pool reduces the variance of loss. In other words, when considering a pool of uncorrelated loss events, the mean of the individual variances is always greater than the variance around the mean loss of the pool. This result follows from the statistical property known as the "law of large numbers." Society benefits from insurance markets that pool uncorrelated risks since the risk faced by the pool is less than the pre-aggregated sum of individual risks (Priest, 1996).

Agricultural production losses tend to be characterized by some degree of positive spatial correlation. The degree of positive correlation is often inversely related to the size of the region under consideration. Thus, relatively small (large) countries are likely characterized by more (less) positively correlated agricultural losses. Positive spatial-correlation in losses limits the risk reduction that can be obtained by pooling risks from different geographical areas. This increases the variance in indemnities paid by insurers. As a result, it also increases the cost of maintaining adequate reserves or reinsurance to fund potentially large indemnities caused by systemic loss events. In general, the more that losses are positively correlated the less efficient insurance is as a risk transfer mechanism.

Other risk transfer markets are better suited for risks that are highly positively correlated. For example, well-developed futures exchange markets exist for sharing risks associated with commodity prices, interest rates, and exchange rates. In recent years, various capital market instruments have developed for transferring highly correlated weather risks or risks associated with natural disasters.

In general, agricultural production losses are typically neither uncorrelated nor highly positively correlated. They are what we have referred to elsewhere as "in-between" risks (Skees and Barnett, 1999). This implies that, if used exclusively, neither insurance nor capital market instruments are well-suited to transferring agricultural production risks. However, a careful blending of these instruments can foster further development of agricultural risk transfer opportunities. This implies an important and appropriate role for governments in developing countries.

6 Implications for Agricultural Insurance

Based on the previous discussion of agricultural risks, risk management strategies, and insurability conditions, one can draw a number of implications for agricultural insurance products.

- Relative risk varies by crop and region and these differences in relative risk must be reflected in insurance premium rates. Failure to do so will create inequities among insureds and inefficient allocation of resources.
- Agricultural producers employ many different risk management strategies. Insurance products should be developed so as to complement effective existing risk management strategies.
- Risk management is always costly.
- Not all perils are insurable.
- For perils that are potentially insurable, insurance products should be tailored to address the risk characteristics of the peril.
- Because agricultural producers employ many different risk management strategies, some producers will not want (or need) insurance.
- When developing insurance products one must be aware of the potential for adverse selection. Effective risk classification (sometimes called "underwriting") is critical to the long-term success of insurance products.
- When developing insurance products one must be aware of the potential for moral hazard. It is critical that insured producers not be able to engage in activities that increase the likelihood or magnitude of indemnity payments.
- When developing insurance products, one must have sufficient data to calculate premium rates. The more uncertainty about the nature of the underlying risk, the more that insurers will load premium rates.
- Insurance products are best suited to protecting against losses from independent perils. Capital market instruments are best suited to protecting against losses from correlated perils. When perils are neither completely independent nor completely correlated, some combination of insurance and capital market instruments may be required.

7 Crop Insurance Experience in the United States and Canada

The Unites States and Canada have long established multiple-peril crop insurance programs. Over the past twenty to thirty years, both countries have made significant changes in their crop insurance programs. In both countries the crop insurance programs are subsidized by the federal (U.S.) or federal and provincial (Canada) governments.

At least two major differences exist between the U.S. and Canadian crop insurance programs. These differences involve the delivery system and the extent of product uniformity across the country. In the United States, crop insurance is sold and serviced (including claims adjustment) by private sector insurance companies. In Canada, crop insurance is sold and serviced by provincial government entities. In the United States, the Risk Management Agency (RMA) of the United States Department of Agriculture is responsible for approving any new insurance products and maintaining existing crop insurance products (including setting premium rates). As a federal agency, the RMA ensures a large degree of product uniformity across different geographic regions of the United States. In Canada, provinces have some degree of autonomy to tailor insurance products that better fit regional needs. The provincial government entities that sell and service crop insurance have a relationship with the Canadian federal government whereby the federal government provides some subsidy and reinsurance capacity under the broader umbrella of Canadian agricultural safety net policy.

Both the United States and Canada have expanded their insurance offerings beyond farm-level yield insurance. Both now offer farm-level revenue insurance products. Revenue insurance products now account for approximately three-fourths of U.S. agricultural insurance premiums. U.S. revenue insurance products are crop-specific.[1] Canada has moved aggressively to offer multi-crop, whole-farm revenue insurance. Both the United States and Canada have also experimented with agricultural insurance products that trigger indemnities based on area-level (rather than farm-level) yield or revenue shortfalls.

[1]See Glauber (2004) for a review of U.S. revenue insurance products and their growth.

7.1 The United States

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

Policies are available for over 100 commodities but in 2004 just four crops—corn, soybeans, wheat, and cotton—accounted for approximately 79 percent of the $4 billion in total premiums. Excluding pasture, rangeland, and forage, approximately 72 percent of the nation's 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.[2]

Most FCIP policies trigger indemnities at the farm (or even sub-farm) level.[3] Yield insurance offers are based on a rolling 4–10 year average yield known as the Actual Production History (APH) yield. The federal government provides farmers with a base, catastrophic (CAT), yield insurance policy, free of any premium costs.[4] Farmers may then choose to purchase, at federally subsidized prices, additional insurance coverage beyond the CAT 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.

Area-yield and/or area-revenue buy-up insurance policies are offered through the FCIP for some crops and regions. The areas for these policies are defined along county boundaries. 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 (within certain bounds) determine 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

[2]The remaining 2 percent of premium is for a variety of other insurance products.

[3]Under certain conditions policyholders can choose to divide farms into smaller units that are insured separately.

[4]The CAT policy only covers yield losses in excess of 50 percent of the APH yield. The rate of indemnity is only 60 percent of the expected market price.

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.

There are four components of federal costs associated with the U.S. program:

- Federal premium subsidies range from 100 percent of total premium for (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 the 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, is allowed to be called 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.

7.2 Canada

The newly reformulated Canadian Production Insurance (PI) scheme offers producers a variety of multiple-peril production or production value loss insurance products that are similar, in many ways, to products 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 in tailoring products to fit their regions and in offering new products.

Production insurance plans are offered for over 100 different crops, and provisions have been made to include plans for livestock losses as well. Crop insurance plans are available, based on 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. However, federal subsidies as a percentage of premium costs vary from 60 percent for catastrophic loss policies to 20 percent for low deductible production coverage. Combined, 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 United States program. Provincial authorities are responsible for the solvency of their insurance portfolio. In Canada, the federal government competes with private reinsurance firms by offering deficit financing agreements to provincial authorities.

8 Common Elements of U.S. and Canadian Crop Insurance

There are several common elements between the U.S. and Canadian crop insurance programs. Each of the programs:

- Attempt to address both social welfare and economic efficiency objectives;
- Offer core, farm-level, multiple-peril insurance products;
- Employ government premium subsidies that are a percentage of total premium;
- Use government funds and/or government agencies to absorb the administrative and operating costs of the program;
- Require significant government expenses; and,
- Involve a major role for government in pooling and holding some of the most catastrophic risk exposure.

The following sections address each of these common features in more detail. Any countries rethinking their existing approaches to agricultural insurance programs, or attempting to design new insurance products, should critically assess the U.S. and Canadian experience with respect to each of these common features. Our discussion of these features informs much of our later recommendations on designing agricultural insurance programs that must also cope with catastrophic risk exposure.

8.1 Covering Individual Farm Yields for Multiple Perils

It is very difficult to provide multiple peril insurance coverage against shortfalls in individual farm yields (or revenues). Farmers will always know more about their risk exposure and their behavioral responses to insurance purchasing than will the insurer. This information asymmetry creates both risk classification and moral hazard problems. Efforts to address this information asymmetry can be quite expensive. In the U.S. crop insurance program, premium rates are conditioned on crop, practice, and geographic region. The primary mechanism used to underwrite risk at the individual farm level is a requirement that farmers provide documentation of their previous yield history (up to ten years). Many farmers and insurance agents complain about the transactions cost associated with even this limited attempt at farm-level underwriting. In addition, monitoring of policyholder behavior is necessary to control moral hazard problems. But policyholders often resent the implied suspicion of wrongdoing if the insurer attempts to monitor their farming activities. The transactions cost of monitoring is also quite high.

In the U.S. experience, adverse selection and moral hazard problems have contributed to excess losses (Hazell, 1992; Skees, 2001a). As a result, premium rates have been increased to attain actuarial soundness targets. But without better risk classification, higher premium rates simply cause lower risk farmers to quit purchasing insurance. To keep these individuals participating in the insurance program, policy-makers have over time increased premium subsidies - most recently in 2000 (Glauber and Collins, 2002). Higher premium subsidies keep lower risk farmers in the insurance pool and thus, improve the actuarial performance of the insurance program. But premium subsidies are a very blunt tool. Higher risk farmers or those who tend to abuse the program also receive the benefit of higher premium subsidies (Skees, 2001a). Thus, premium subsidies have become a very expensive mechanism to mask the risk classification and moral hazard problems that occur when trying to provide multi-peril insurance coverage against individual farm yields. This outcome raises concerns about both equity and economic efficiency.

8.2 Subsidies as a Percent of Premium

Government premium subsidies for crop insurance are almost always calculated as a stated percentage of the unsubsidized premium. Since premium rates are higher for more risky crops and more risky regions, this method of calculating premium subsidies effectively generates larger government transfers to riskier crops and regions. In other words, the government premium subsidies create disproportionate economic incentives for farmers to produce more risky crops in more risky regions. Thus, the premium subsidies work at cross-purposes with other government programs that attempt to mitigate risk exposure in agricultural production. Often, more risky production regions are also more environmentally sensitive. This implies that the government premium subsidies may also work at cross-purposes with government environmental protection programs. Over the long-run, the incentives generated by the premium subsidies create more risk exposure in agriculture, higher losses when the next disaster occurs, and more environmental degradation.

Persistent free government disaster assistance can be thought of as ex post insurance with a 100 percent premium subsidy. Unless it is very carefully structured, free disaster assistance will have the same impacts as highly subsidized crop insurance (Milete, 1999). Some argue that government disaster assistance is not equitable as taxpayers compensate for losses that individuals chose to assume (Rossi et al., 1982). This argument perhaps has less credence when one is concerned that the poorest of the poor may be forced to concentrate in disaster prone areas. Nonetheless, if governments insist on providing free disaster assistance, the programs should be carefully structured so as not to encourage additional risk-taking.

8.3 Government Funds and/or Agencies Absorb Administrative and Operating Costs

Government agencies often directly provide at least some of the administrative functions associated with agricultural insurance programs. In the United States, the government directly provides some of the administrative functions. Delivery costs and other administrative costs incurred by the private insurance companies that sell and service the insurance products are also reimbursed by the federal government.

With private sector insurance products, premium rates must be set at levels that are sufficient to cover not only expected losses but also any administrative and operating costs (Hazell, 1992).[5] If the government absorbs the administrative and operating expenses for agricultural insurance, premium rates need only cover expected losses. By covering administrative and operating expenses, governments effectively provide another premium subsidy to agricultural insurance purchasers.

The costs of selling and servicing an agricultural insurance policy are roughly the same regardless of the size of the policy. Given this, a private sector insurance market would probably add some fixed administrative charge to each policy to cover these costs. Thus, the administrative charge would be a larger (smaller) portion of the overall premium for small (large) policyholders.

The U.S. experience suggests that governments should think very carefully about how to absorbing administrative and operating costs. For simplicity, the United

[5] Premium rates on private-sector insurance products must also cover other factors such as a catastrophic load, reserve load, and a required rate of return on invested capital.

States provides administrative and operating cost reimbursements to private insurance companies as a percentage of unsubsidized premiums. As premium subsidies have increased over time, insurance purchasers have gravitated to more expensive insurance products. Though there is no evidence that these products generate higher administrative and operating costs, the private insurance companies receive larger administrative and operating cost reimbursements simply because the unsubsidized premiums are higher for these products.

In years when prices are expected to be high, the dollar amount of insurance coverage in force will also be higher. At a given premium rate, the higher the dollar amount of coverage in force, the higher the unsubsidized premium. This, in turn, generates higher administrative and operating costs reimbursements though there is no evidence that these costs change with expected market prices.

If governments feel compelled to absorb the administrative and operating costs of private sector agricultural insurance companies, they should do so on a per policy basis rather than as a percentage of unsubsidized premium. However, we will argue later that there are likely even better ways for governments to incur some of the development and administrative costs of agricultural insurance programs.

8.4 Significant Government Expenses

Government expenses for agricultural insurance programs can be quite high. This is often masked in the way that actuarial performance is presented. Governments typically report loss ratios, or cost to premium ratios, as indemnities paid divided by total premiums collected. There are two problems with this. First, because of government premium subsidies, farmers pay only a fraction of the total premium. Second, governments typically absorb most of the administrative and operating costs. When calculating loss ratios for private sector insurance products these costs are also included in the numerator. Thus, both the U.S. and Canadian crop insurance programs have, in recent years, reported loss ratios around 1.0. They then cite this as evidence that the program is actuarially sound. But if 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, the loss ratios are about 3.6 for the United States and 2.9 for Canada.[6]

Policy-makers often suggest agricultural insurance programs as an alternative to free ex post disaster assistance. In principal, insurance programs have many advantages over ex post disaster assistance. For example, it is often argued that disaster

[6]These are the authors' estimates. The estimated Canadian loss ratio is based on data from Pikor (2004).

assistance programs 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 another vehicle for transferring wealth from the public sector to agricultural producers. Nor is there much evidence that agricultural insurance programs have been successful in forestalling free ex post government disaster assistance. In the United States, more and more costly crop insurance programs have co-existed with disaster payments for well over 20 years (Glauber, 2004).

This experience is not unique to the United States. New thinking is needed about how to accomplish both the social welfare and economic efficiency objectives of agricultural insurance programs, in a manner that is fiscally responsible.

8.5 Using Government to Pool and Hold Catastrophic Risk

Another common feature of most agricultural insurance programs is some procedure for pooling catastrophic loss risks within the country. In large, spatially heterogeneous, countries, there are obvious diversification benefits to pooling catastrophic risks. In smaller countries, where catastrophic losses are more spatially correlated, diversification benefits from pooling catastrophic losses are more limited. Nonetheless, facilitating catastrophic loss pools can be an important role for governments. In some cases, after facilitating pooling within the country, the government may also need to facilitate the transfer of the remaining catastrophic risk to investors outside the country.

8.6 Implications: Market Failure or Logical Market Response?

Is the lack of effective private sector agricultural insurance markets the result of a market failure, or is it simply a logical market outcome? High transactions costs preclude many markets from emerging but this does not necessarily mean that government should intervene. For example, insurance products for high frequency, low magnitude losses are seldom offered because the transactions costs associated with loss adjustment would make the insurance cost-prohibitive for most potential purchasers.

In general, farmers probably don't need insurance that will cover high-frequency, low-magnitude agricultural production losses. They use other risk management mechanisms to cover these losses. They likely do need insurance that will protect against low-frequency, high-magnitude loss events. However, research suggests that many decision-makers tend to underestimate their exposure to low-frequency, high-magnitude losses. Thus, they are unwilling to pay the full costs of an insurance product that would protect against these losses. Those who do buy insurance against low-frequency, high-magnitude losses often cancel the policy if they do not receive an indemnity for an extended period. Thus, it seems that, if they are to be successful, agricultural insurance products must be constructed so they will make indemnity payments at a reasonable frequency (say, 1-in-10 years).

The cognitive complexity and ambiguity surrounding any assessment of low-frequency, high-magnitude events may merit some special considerations. Low-probability events, even when severe, are frequently discounted or ignored altogether by producers trying to determine the value of an insurance contract. This happens because forming probability assessments over future events is complex and often entails high search costs. On the other side, insurers will typically load premium rates heavily for low-frequency and high-magnitude events when there is considerable ambiguity surrounding the actual likelihood of the event. 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 form empirical distributions are incomplete or of poor quality. 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 fail to materialize or, if they do materialize, cover only a small portion of the overall risk exposure.

This type of market failure is commonly used to justify government intervention to supply products or services that are not provided (or not provided in sufficient quantity) by private markets. However, the lack of a functioning private-sector agricultural insurance market is not sufficient to justify government intervention. 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. Asking if there is true market failure is a critical first step before governments embark upon what could be an expensive proposition.

When risk transfer markets fail to materialize or are incomplete, it is important to carefully diagnose the cause of the problem. Only then can one consider whether government is better positioned to address the problem than private entities. For example, governments may have no inherent advantage over markets in trying to facilitate the provision of individual, farm-level, yield or revenue insurance products. These products are rarely provided in the private-sector typically due to information asymmetries that cause moral hazard and adverse selection problems. It is hard to see how a government provider would have any inherent advantage in addressing these information asymmetries. Nor would government provision contribute much to reducing the effects of cognitive complexity that limit the demand for agricultural insurance. On the supply side, government may have an impact in that when setting premium rates it may be less sensitive than private insurers to risk ambiguity.

Asymmetric information, correlated loss risk, cognitive errors, and ambiguity, have all contributed to the lack of private agricultural insurance markets in most countries. Governments have responded to the lack of private agricultural insurance markets by either directly providing agricultural insurance or facilitating the provision of such insurance through private market channels. But these government interventions have been very expensive which begs the question of whether the costs of providing insurance outweigh the social costs of the risk exposure.

The remainder of this manuscript addresses alternative models for government intervention is agricultural insurance markets. The focus is on government facilitation of index insurance products. Gains in cognitive recognition and a lessening of the ambiguity problem may occur if the tail of the loss distribution - that segment containing the fewest observations, greatest uncertainty, and highest losses - can be layered out and transferred using indexed insurance products. Doing so would remove much of the justification for very high ambiguity loads on insurance products that cover losses throughout the remainder of the distribution.

9 Index Insurance Alternatives

Index insurance products are contingent claims contracts that 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 that is 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 that are exogenous to the individual policyholder—such as area-level yield, or some objective weather event 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 risk 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.

Because it protects against spatially correlated losses, index insurance facilitates risk trading locally among individuals who may expect to experience different levels of loss when the underlying loss event occurs. Index products also facilitate trading in more formal financial markets where investors may hold index contracts as another investment in a diversified portfolio. In fact, index contracts may offer significant diversification benefits since the returns should be generally uncorrelated with returns from traditional debt and equity markets.

Other Forms of Index Insurance

Weather events are not the only measures used to develop index insurance contracts. Any independent measure that is secure and highly correlated with agricultural losses can be used as a means of forming an index insurance product. Three examples are profiled below:

1. use of area-yield insurance
2. use of satellite vegetative images
3. use of widespread mortality rates for animals

Area Yield Insurance - While the idea of insurance based on weather is more contemporaneous, area-based insurance is an index-based insurance product that has been promoted for sometime. Chakravati wrote about area-yield insurance for India as early as 1920. Halcrow was writing about the usefulness of this approach for the United States as early as 1949. Area-yield insurance programs exist in the United States, India, Brazil, and Canadian province of Quebec (Miranda, 1991; Mishra, 1996; Skees et al., 1997). New thinking of how to use area-yield insurance is advancing the efforts in both the United States and India.

Satellite Vegetative Images - In Alberta, Canada, efforts are underway to pilot tests using satellite images of the vegetative cover to provide effective and affordable insurance for ranchers. Advances in technology may make such systems quite attractive as farmers and ranchers could provide the geographic coordinates, and an index to proxy the value of the pasture or crop on the surface could be created to make index payments.

Mortality Rates for Livestock - In Mongolia, the death rate of livestock is highly spatially correlated due to harsh winters. Mongolia performs a complete census of every species each year. Thus, a historic data set is available at the local level to estimate mortality rates. The World Bank is working with the government of Mongolia to introduce index-based livestock insurance that would pay based on the local mortality rates (Skees and Enkh-Amgalan, 2002).

9.1 Basic Characteristics of an Index

The underlying index used for an index insurance product must be correlated with yield or revenue outcomes for farms over a large geographic area. In addition, the index must satisfy a number of additional properties that affect the degree of confidence or trust that market participants have that the index is believable, reliable, and void of human manipulation, i.e., that measurement risk for the index is low (Ruck, 1999). The properties for a suitable index are that the random variable being measured is:

- observable and easily measured,
- objective,
- transparent,
- independently verifiable, and
- able to be reported in a timely manner (Turvey, 2002; Ramamurtie, 1999).

Publicly available estimates of weather and regional yield variables generally satisfy these properties. For weather indexes, the units of measurement should convey meaningful information about the state of the weather variable during the contract period, and are often shaped by the needs and conventions of market participants. Indexes are frequently cumulative measures of precipitation or temperature over a period of 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 locations where weather variables can be measured, as well as the types of variables it is possible to measure. Measurement redundancy and automated instrument calibration further increase the credibility of an index.

Index insurance contracts closely follow the model proposed by Martin, et al. (2001). The terminology used to describe features of index insurance contracts is often more like that used for futures and options contracts rather than other insurance contracts. For example, rather than referring to the threshold where payments begin as a "trigger," index contracts typically refer to it as the "strike." In an attempt to make things more straightforward, they also pay in increments called "ticks."

Consider a situation where a contract is being written to protect against deficient cumulative rainfall during a cropping season. The writer of that contract may choose to make a fixed payment for every 1 mm of rainfall below the strike. If an individual purchases a contract where the strike is 100 mm of rain and the limit is 50 mm, the amount of payment for each tick would be a function of how much liability is purchased. There are 50 ticks between the 100 mm strike and 50 mm limit. Thus, if $50,000 of insurance were purchased, the payment for each 1 mm below 100 mm 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. For example, if the realized rainfall is 90 mm, there are 10 ticks of payment at $1,000 each; the indemnity payment will equal $10,000. Figure 1 maps the payout structure for a hypothetical $50,000 rainfall contract with a strike of 100 mm and a limit of 50 mm. An example of an area-yield index insurance contract is given in the case examples to follow.

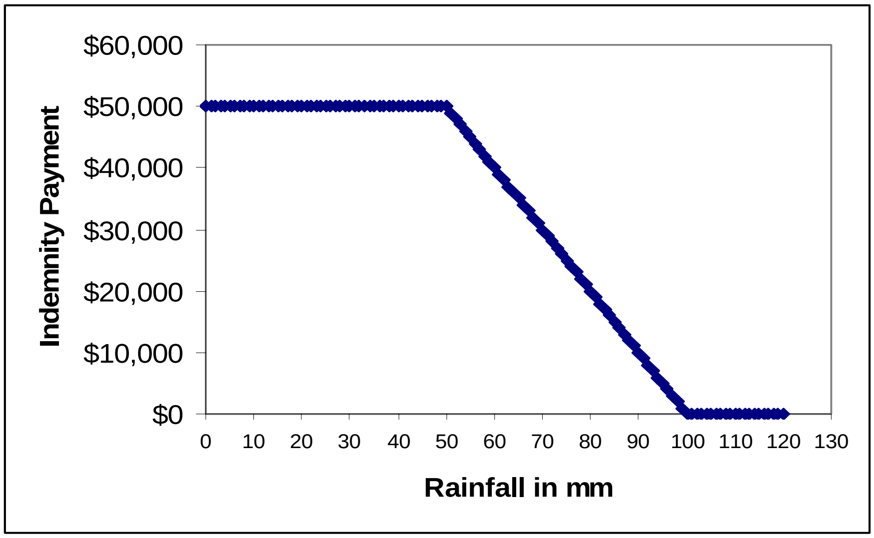

Figure 1: Payout Structure for a Hypothetical Rainfall Contract

Index contracts written to protect against unfavorable weather events have gained a lot of attention and are developed well enough in some markets for there to be standardized exchange traded products, primarily for use by the energy sector. However, the range of weather phenomena that can potentially be insured against appears to be limited only by imagination and the ability to parameterize the event. A few examples include excess or deficient precipitation either in the form of rain or snow during different times of the year, insufficient or damaging wind, tropical weather events such as typhoons, various measures of temperature, measures of sea surface temperature that are tied to El Niño and La Niña (ENSOs) and even celestial weather events such as disruptive geomagnetic radiation from solar flare activity. Contracts are also designed for a combination 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, 2001a).

A major challenge in designing an index insurance product is minimizing basis risk. "Basis risk" is a term most commonly heard in reference to commodity futures markets. In that context, basis is the difference between the futures market price for the commodity and the cash market price in a given location. Basis risk also occurs in insurance. It occurs when an insured has a loss and does not receive an insurance payment sufficient to cover the loss (minus any deductible). It also occurs when an insured has a loss and receives a payment that exceeds the amount of loss.

Since index insurance indemnities are triggered by an exogenous random variable 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 not experience a yield or revenue loss and yet, receive an indemnity. The effectiveness of index insurance as a risk management tool depends on how positively correlated farm yield or revenue 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 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.

The basis risk inherent in index insurance products has been widely discussed in the scholarly literature. Much less discussed is that basis risk also exists with 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 (e.g., 4–10 years in the United States). Given simple statistics about the error of small sample estimates, it can be easily 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 not 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 over-payments. Between the two sources of error (measuring expected yields and measuring realized yields), farm-level crop insurance programs also have significant basis risk.

Longer series of data are generally available for area-level yields or weather events than for farm-level yields. Further, the standard deviation of area yields is also lower than that of farm yields. Since the number of observations is higher and the standard deviation is lower, the square-root-of-n rule suggests that there will be less measurement error for area-yield insurance than for farm-yield insurance when estimating both the central tendency and the realization.

9.2 Relative Advantages and Disadvantages of Index Insurance

Traditional, multiple-peril crop insurance is often sold only with large deductibles. Because of this, index insurance can sometimes offer superior risk protection compared to multiple-peril crop insurance. Deductibles, co-payments, or other partial payments for loss are commonly used by insurance providers to mitigate adverse selection and moral hazard problems. Asymmetric information problems are much lower with index insurance because 1) a producer has little more information than the insurer regarding the index value, and 2) individual producers are generally unable to influence the index value. This characteristic of index insurance means there is less need for deductibles and co-payments. Similarly, unlike traditional insurance, there is little reason to place restrictions on the amount of coverage an individual purchases. As long as the individual farmer cannot influence the realized value of the index, there is no need to restrict liability. An exception occurs when governments offer premium subsidies as a percentage of premium. In this case, they may want to restrict liability (and thus, premium) to limit the amount of subsidy paid to a given policyholder.

Index contracts offer numerous advantages over more traditional forms of farm-level multiple-peril crop insurance. These advantages include:

Less moral hazard. Moral hazard arises with traditional insurance when insured parties can alter their behavior so as to increase the potential likelihood or magnitude of a loss. This is less possible with index insurance because the indemnity does not depend on the individual producer's realized yield.

Less adverse selection. Adverse selection is a misclassification problem caused by asymmetric information. If the potential insured has better information than the insurer about the potential likelihood or magnitude of a loss, the potential insured can use that information to self-select whether or not to purchase insurance. Index insurance, on the other hand, is based on widely available information, so there are few informational asymmetries to be exploited.

Lower administrative costs. Unlike farm-level multiple-peril crop insurance policies, index insurance products do not require underwriting and inspections of individual farms. Indemnities are paid solely on the realized value of the underlying index as measured by government agencies or other third parties.

Standardized and transparent structure. Index insurance policies can be sold in various denominations as simple certificates with a structure that is uniform across underlying indexes. The terms of the contracts would therefore be relatively easy for purchasers to understand.

Availability and negotiability. Since they are standardized and transparent, index insurance policies can easily be traded in secondary markets. Such markets would create liquidity and allow policies to flow where they are most highly valued. Individuals could buy or sell policies as the realization of the underlying index begins to unfold. Moreover, the contracts could be made available to a wide variety of parties, including farmers, agricultural lenders, traders, processors, input suppliers, shopkeepers, consumers, and agricultural workers.

Reinsurance function. Index insurance can be used to transfer the risk of widespread correlated agricultural production losses. Thus, it can be used as a mechanism to reinsure insurance company portfolios of farm-level insurance policies. Index insurance instruments allow farm-level insurers to transfer their exposure to undiversifiable correlated loss risk while retaining the residual risk that is idiosyncratic and diversifiable (Black et al., 1999).

There are also challenges that must be addressed if index insurance markets are to be successful. These include:

Basis risk. The occurrence of basis risk depends on the extent to which the insured's losses are positively correlated with the index. Without sufficient correlation, basis risk becomes too severe, and index insurance is not an effective risk management tool. Careful design of index insurance policy parameters (coverage period, trigger, measurement site, etc.) can help reduce basis risk. Selling the index insurance to microfinance or other collective groups can also pass the issue of basis risk to a local group that can develop mutual insurance at some level. Such a group is in the best position to know their neighbors and determine how to allocate index insurance payments within the group.

Security and dissemination of measurements. The viability of index insurance depends critically on the underlying index being objectively and accurately measured. The index measurements must then be made widely available in a timely manner. Whether provided by governments or other third party sources, index measurements must be widely disseminated and secure from tampering. Possible approaches for mitigating potential problems with the weather data include 1) more secure, tamper-proof stations and instruments, and 2) verification of measurements using comparisons with adjacent stations or with remote sensing data.

Precise actuarial modeling. Insurers will not sell index insurance products unless they can understand the statistical properties of the underlying index. This requires both sufficient historical data on the index, and actuarial models that use these data to predict the likelihood of various index measures.

Education. Index insurance policies are typically much simpler than traditional farm-level insurance policies. However, since the policies are significantly different than traditional insurance policies, some education is generally required to help potential users assess whether or not index insurance instruments can provide them with effective risk management. Insurers and/or government agencies can help by providing training strategies and materials not only for farmers, but also for other potential users such as bankers and agribusinesses.

Marketing. A marketing plan must be developed that addresses how, when, and where index insurance policies are to be sold. Also, the government and other involved institutions must consider whether to allow secondary markets in index insurance instruments and, if so, how to facilitate and regulate those markets.

Reinsurance. In most transition economies, insurance companies do not have the financial resources to offer index insurance without adequate and affordable reinsurance. Effective arrangements must therefore be forged between local insurers, international reinsurers, national governments, and possibly international development organizations. The insurer faces high risk because of the covariant nature of the insured risk. When a payment is due, then all those who have purchased insurance against the same weather station must be paid at the same time. Moreover, if the insured risks at different weather stations are highly correlated, then the insurer faces the possibility of having to make huge payments in the same year. To hedge against this risk, the insurer can either diversify regionally by selecting weather stations and risks that are not highly (positively) correlated, or sell part of the risk to the international reinsurance and financial markets.

Market Size. As with the introduction of any new product, the volume of insurance sold could be too small to be profitable. The insurance will only appeal to people whose economic losses are highly correlated with the insured weather event. If the index does not sufficiently approximate actual loss experiences then the insurance will not sell. Also, if the probability of loss is high, then the cost of the insurance could be prohibitive. To overcome these problems, the insurance might be limited only to truly catastrophic events that though infrequent, impose large losses. Collective action by agricultural cooperatives, microfinance groups, or farmer associations, offers significant promise for the use of index contracts and adds value by developing mutual insurance products whereby members have a vested interest in mitigating fraudulent behavior.

Weather Cycles. The actuarial soundness of the insurance could be undermined by weather cycles that change the probability of the insured events. It may be necessary to adjust the cost of the insurance whenever a specific weather event is confirmed, though this would require sufficient lead time between knowledge of the pending event and the time of selling insurance

As more sophisticated systems are developed to measure events that cause widespread problems (such as satellite imagery) it is possible that indexing major events will be more straightforward and accepted by international capital markets. Under these conditions, it may become possible to offer insurance in countries that traditional reinsurers and primary providers would previously have never considered. Insurance is about trust. New risk management opportunities can develop if relevant, reliable, and trustworthy, indexes can be constructed.

The value of index insurance is enhanced when it is blended with banking and credit services. The role of index insurance is to manage the correlated risk of widespread crop losses by shifting it to those willing and better able to assume those risks, generally financial and reinsurance markets. In turn, the local banking sector should be able to work with individual producers to help them manage idiosyncratic and basis risk; if a producer has an independent loss when the index insurance does not pay, it should be possible to borrow from the bank to smooth that shock. By combining insurance with banking in this manner, it is possible to remove one of the main concerns associated with index insurance: a producer may not receive payment when a loss is realized.

In principle, one might expect the private sector to take the initiative in developing weather-based insurance, but it would be advantageous for governments to:

- identify key catastrophic weather events that correlate strongly with agricultural production and income in different types of agricultural regions;
- educate rural people about the value and use of weather insurance;
- ensure secure weather stations;
- establish an appropriate legal and regulatory framework for weather insurance; and,
- underwrite the insurance in some way (perhaps through contingent loans) until a sufficient volume of business has been established that international reinsurers or banks are willing to come in and assume the underwriting role for themselves.

9.2.1 The Role of Technology in Providing Needed Information

In recent years, state-of-the-art methods to forecast food shortages created by bad weather have significantly improved. For example, the East African Livestock Early Warning System (LEWS) is now able to provide reliable estimates of the deviation below normal up to 90 days prior to serious problems. These systems use a variety of information: 1) satellite images, 2) weather data from traditional ground instruments, 3) weather data from new systems, and 4) sampling from grasslands to determine nutrient content. More important, these systems allow problems to be forecast at a local level using geographic information systems. Since many of the early warning systems have been in place for as long as twenty years, it is now possible to model the risk and begin pricing insurance contracts that match the risk profile.

9.2.2 Reinsurance and Weather Markets

Much can be said about the international reinsurance community and their resistance to entering new and untested markets. The use of capital markets for sharing "in-between" risks remains in the infant stage, leaving the issue of capacity and efficiency in doubt. This raises questions about the role of government in sharing such risk. For the United States, Lewis and Murdock (1996) recommend government catastrophic options that are auctioned to reinsurers. Part of the thinking is that the government has adequate capital to back stop such options and may be less likely to load these options as much as the reinsurance market. Skees and Barnett (1999) write about the role of government offering insurance options for catastrophes as a means of getting affordable capital into the market. However, the demand for catastrophic insurance will be limited where free disaster assistance is available.

Reinsurers have acquired many of the professionals who were trading weather. SwissRE acquired professionals from Enron and PartnerRE, and ACE acquired professionals from Aquila. *Reinsurers are now in a position to offer reinsurance using weather-based indexes.* This type of reinsurance should be more affordable since it is not subject to traditional adverse selection and moral hazard problems.

9.2.3 Mitigating Basis Risk with Market Solutions

Weather-index insurance products should only be used when there are specific weather events that create significant crop failures. Under these conditions, weather index insurance products will remove most catastrophic risks that involve correlated losses and present a major challenge for private sector financing of these types of losses. Once a weather index insurance product removes the largest risk, a host of private market efforts can be used to mitigate the basis risk. These efforts can be classified as follows:

- Self-retention of smaller basis risk by the farmer
- Supplemental products underwritten by private insurers
- Blending index insurance and rural finance

9.2.4 Self-Retention of Smaller Basis Risk by Farmers

Some people have argued that index insurance products are not worth considering because they leave farmers exposed to basis risk. But this conclusion is too simplistic. Surely there are many circumstances were farmers would be better off with an index insurance product than with no insurance product. An instrument that transfers catastrophic, covariate, risk should enhance the effectiveness of many of the risk-coping strategies that farmers already employ. If basis risk is not too high, farmers should be able to use index insurance products to transfer much of the catastrophic, covariate, risk and then use traditional risk-coping strategies to address the residual, largely idiosyncratic, risk.

What is Needed to Make the Innovations Work?

There are market makers who are keenly interested in offering rainfall index insurance in developing countries. For example, PartnerRE New Solutions presented the following list of items that are needed to get them interested in offering such contracts.[a]

- Historic weather data
- Prefer 30+ years of data, especially to cover extreme risk
- Limited missing values and out of range values
- Prefer less than 1% missing
- Data integrity
- Availability of a nearby station for a "buddy check"
- Consistency of observation techniques: manual vs. automated
- Limited changes of instrumentation / orientation / configuration
- Reliable settlement mechanism
- Integrity of recording procedure
- Little potential for measurement tampering

[a] Brian Tobben presented these items at the Annual Meeting of the International Task Force on Commodity Risk Management, Jointly Sponsored by the FAO and the World Bank at the FAO, Rome, 5 and 6 May, 2004.

9.2.5 Supplemental Products That Are Underwritten by Private Insurers

Developing tailored insurance products for individual farm yields is complex. Index insurance products could be used as a starting point for the development of more sophisticated products. Again, to the extent that index-based insurance products remove much of the spatially correlated risk, they can effectively serve as a form of localized reinsurance. A private sector insurance provider may then be able to offer a companion product that transfers the residual risk.

To some extent, even multiple-peril crop insurance could be offered to a select group of farmers. For example, if an index insurance product is offered with a relatively low deductible, a multiple-peril crop insurance product with a higher deductible could be offered alongside that product. The combined insurance product could simply be designed to pay the higher of the two indemnity calculations. Under such conditions, the private insurance provider would effectively be offering insurance on events not covered by the index insurance contract, thus eliminating the major source of basis risk. With proper underwriting such contracts could cover only risks that are much more independent - precisely what an insurance company should be able to do. The challenge of effective underwriting would still be an issue, but one that is left to the private sector to address.

9.2.6 Blending Index Insurance and Rural Finance

Progress has been made in designing and offering index insurance products for a variety of correlated risks in developing countries. Index insurance can shift correlated risk out of small countries into the global market. To the extent that the index is based upon a secure and objective measure of risk, this approach provides an important risk transfer innovation for developing countries where legal structures for more sophisticated insurance products are often lacking. Index insurance contracts involve significantly lower transaction costs and can be offered directly to end users from companies that operate in a global market, particularly if the end user is positioned to aggregate large amounts of risk—as is the case with many microfinance entities (MFEs).

In developing countries, insurance offerings are often constrained by problems with governance, macroeconomic policies, and legal frameworks. These problems can be circumvented if index insurance is offered directly to MFEs. To the extent that the writer of the index insurance is a reputable global partner, the MFE could pay premiums in dollars and be paid indemnities in dollars as well. This would mitigate the effects of inflation risk within the country. The legal framework needed to allow MFEs to purchase these contracts from a global writer should be much more straightforward than the legal framework needed to offer traditional insurance. The major challenge for developing countries is determining whether or not the global partner has the reputation and the resources to pay indemnities. Should the International Finance Corporation of the World Bank Group become more involved in partnering the writing of index insurance contracts many of these concerns could be eased.

The issue of basis risk has been of some concern if one is selling index insurance contracts to individuals. However, if these contracts are sold to MFEs, the MFE should be in a position to mitigate basis risk in a number of creative ways. It is useful to illustrate some potential arrangements that could emerge between global sellers of index insurance contracts and rural finance entities. Consider a small MFE, with members having household activities in the same neighborhood. While this group of individuals may use many informal mechanisms to pool risk and assist individuals who experience losses, they are unable to cope with a catastrophic, spatially correlated event, such as drought, that adversely impacts all members at the same time.

If the group could purchase an index insurance contract that would simply make payments based upon the level of rainfall (an excellent proxy for drought), the group would be in a much better position to cope when everyone suffers a loss at the same time. The MFE would need to develop ex ante rules regarding how indemnity payments from index insurance would be used. Three examples of how those ex ante rules may be developed are presented.

Indemnity Payments Could be Used to Forgive Debt

Since making loans is a major activity of most MFEs, the ability to repay the loans will likely be in jeopardy when there is an event that adversely impacts everyone. Having loan defaults from a large number of borrowers at the same time is likely to put the MFE at some risk. Thus, indemnity payments from index insurance can be used to offset defaults that occur due to natural disaster. Effectively, indemnity payments become a form of credit default insurance. The MFE would still need to implement rules regarding debt forgiveness for individuals.

Indemnity Payments Could be Used to Facilitate a Form of Mutual Insurance

The indemnity payment from index insurance could be directly distributed to members of the MFE via insurance-like rules that are determined by the members. Given that only actual indemnity payments received would be distributed, a common problem among mutual insurance providers in developing countries would be avoided—inadequate cash to pay for indemnities that are specified in insurance contracts (McCord, 2003). To the extent that the MFE is relatively small and members know one another, the asymmetric information problems discussed earlier would be minimized. This, of course, is the advantage of mutual insurance.

Indemnity Payments Could be Used to Facilitate Better Terms of Credit

Since lending is an excellent means of smoothing consumption when there are unexpected cash flow problems, the MFE could tie the index insurance directly into the loan arrangements. Loans that are made immediately following a good season where no indemnity payments are made could be higher than normal to collect premiums that would pay for the index insurance. Interest rates could be lowered using indemnity payments directly, immediately after a major event. Interest rate reductions could be tied directly to the severity of the event (Parchure, 2002).

9.3 Where Weather Index Insurance Is Inappropriate

Weather index insurance contracts will not work well for all agricultural producers. There are many places in the world where agricultural commodities are grown in micro-climates. For example, much of the coffee in the world is grown up and down the sides of small and large mountains. Fruit such as apples and cherries will also be commonly grown in areas that can have very large differences in weather patterns within 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 localized and/or if it can be written so that it protects only against the most extreme loss events.

Some regions of the world also have strong negative trends in variables (such as precipitation) that could potentially be used as the basis of an index. This negative trend can compound both the complexity of index insurance products and the potential mistakes that can be made in writing these offers. There are also significant crop production regions in the world that suffer from frequent and significant droughts (e.g., 1-in-3, or 1-in-5 years). Even under the best of circumstances, it is difficult to envision creating a sustainable index insurance product given such frequent and significant crop failures. Other solutions are needed in these circumstances.

Over-fitting 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 sample can lead to complex contract designs that may or may not be effective hedging mechanisms for individual farmers. Typical procedures that assume liner relationships simply may be the wrong models to use. Extreme events that are generally accepted by a wide range of decision makers as events that create large losses may offer a better starting point. While scientists are tempted to fit complex relationships to crop patterns, interviews with farmers may reveal more about what type of weather events concern them the most. 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, many crops will be adversely impacted. Likewise, if it rains for an extended period of time and there is significant cloud cover because of persistent rain during a critical photosynthesis period, a number of crops will also be adversely impacted.

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 an indemnity than does the insurer. Endogenous forecasts of weather by farmers are many times quite good. Potatoes farmers in Peru forecast El Niño better than many climate experts. In 1988, a major company offered drought insurance in the U.S. Midwest. As the sales closing data neared, the company noted that farmers were increasing the purchase of these contracts in a significant fashion. 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 had a major failure and rainfall insurance for agriculture in the United States suffered a significant setback. The lesson learned is that if one is going to write insurance based on weather events, it is critical to be diligent in following and understanding weather forecasts. 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 the farmer about conditional weather forecasts. Otherwise, adverse selection will render the index insurance product unsustainable.

10 Developing Policy Prescriptions

Given the discussion above a few key points merit re-emphasis:[7]

- Cognitive failure is common for infrequent and severe natural disasters.
- Natural disasters involve correlated risks whereby many individuals can experience large financial losses at the same time.

[7] This section is developed using concepts that are similar to those being proposed for the Mongolian livestock insurance pilot program. A number of individuals have been involved in the development of those recommendations. From the World Bank insurance side, Rodney Lester and Olivier Mahul have provided significant input into these designs. Jerry Skees has been the primary consultant working with these professionals and others involved in the Mongolian pilot program. Nathan Belete is the task manager and Richard Carpenter is the legal consultant.

- Monitoring individual farmer behavior involves high transaction costs and, without proper consideration for incentive compatibility issues, government attempts to offer individual crop insurance should be avoided.
- Properly designed index insurance products can clear the way for other more efficient market-based solutions to handle idiosyncratic or basis risk.

10.1 Layering Catastrophe Risk

To focus the discussion, Figure 2 presents the probability distribution function for August rainfall in Andhra Pradesh, India. Figure 2 was developed using historic data from the period 1871 to 2000 from the coastal region of Andra Pradesh using nonparametric kernel-smoothing procedures that smooth out the long tail of the distribution. In reality there are few observations above the 2,500 mm level. For sake of exposition, assume that rainfall in excess of 2000 mm creates crop losses. A private insurance provider could write a contract that would that would use 2000 mm as the strike and 2500 mm as the limit.[8] It is common for insurance providers to place limits on their exposure as they do not want open-ended exposure for extreme rainfall events that represent true catastrophes. The index insurance contract could be quite straightforward. The insured would select the amount of insurance (the liability) and the payment rate per tick would be calculated as follows:

$$\text{Payment per tick} = \frac{\text{liability}}{\text{limit - strike}}.$$

Assume that a farmer has a crop with an expected value of $15,000. Should rainfall reach the 2500 mm level, it is estimated that the farmer will lose two-thirds of the value of the crop. Thus, the farmer purchases $10,000 of liability and the payment rate for each tick (each mm of rainfall) would be $20 ($10,000 divided by (2500-2000)). For example, at 250 ticks (or 2750 mm of rainfall) the indemnity would equal 250 x $20 = $5000.

The insurance provider has limited the losses beyond 2500 mm for this insurance product. Without setting this limit, the contract would be extremely expensive since it would protect against losses in the extreme upper tail of the probability distribution. Because there are few empirical observations in this upper tail of the distribution, insurance sellers would say that the “ambiguity” is quite high. If an insurance product were to cover events in this upper tail of the distribution, the premium would be heavily loaded for this ambiguity. On the other hand, buyers are

[8] The example could just as easily focus on shortfalls of rainfall. However, in this case, the purpose of the limit is clear. The lower bound on rainfall is zero. The upper bound on rainfall is unknown.

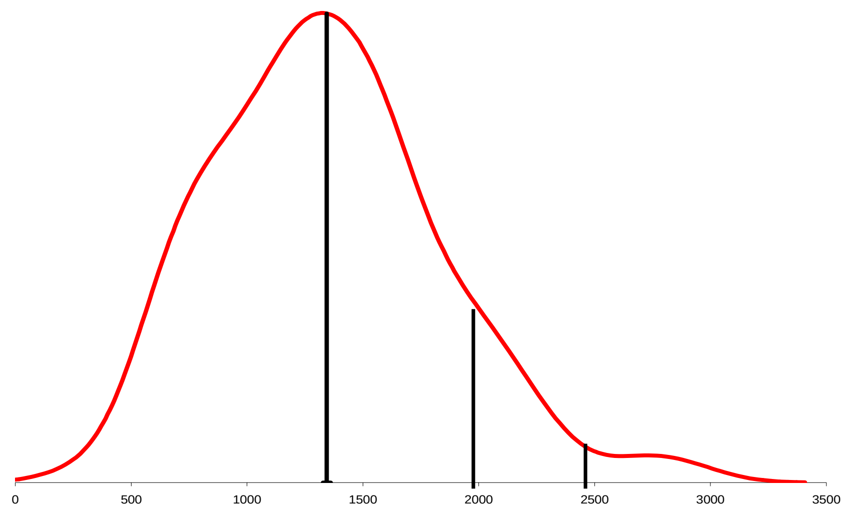

Figure 2: Distribution of August Rainfall for Andhra Pradesh

more likely to experience cognitive failure regarding events in the extreme upper tail of the distribution. Thus the wedge between sellers' willingness to accept and buyers' willingness to pay is largest for insurance that covers extreme events in the tail of the distribution. As a result, markets will often fail to transfer socially optimal amounts of risk in the extreme tails of probability distributions.

The story of layering risk does not end here. Even if a local insurance company offers a number of "layered" rainfall insurance contracts in the region in such a fashion that each one has a limited exposure, the portfolio of these contracts would very likely have a long tail of extreme losses. This is relatively easy to understand given that extreme rainfall in even an expanded region would likely be highly correlated—if the rainfall is close to 2500 mm in Andhra Pradesh, it is likely to be very high in a number of states in that area. To illustrate this point, an estimate of the loss function for the reinsured companies selling crop insurance in the United States is presented in Figure 3.[9] This distribution suggests that a company with a national book of crop insurance and the benefits of the U.S. standard reinsurance agreement could still suffer losses in excess of premiums. More specifically, the distribution

[9]These are the authors' estimates and include all of the very complex rules of the standard reinsurance agreement in the United States. This agreement allows companies to select the business they wish to keep and the business they wish to pass on to the government. In addition, the government offers a stop loss agreement for every state at the loss ratio of 500 percent.

indicates that the company could lose more than the premium approximately 13 percent of the time. Without the benefits of the special reinsurance agreement, the level and severity of net losses would be much higher.

The loss function presented in Figure 3 is very typical of any insurance product that attempts to insure against losses that are correlated. Once again, layering the risk of the losses is a critical means of financing these large losses. Reinsurance is used to accomplish this task. The easiest way to consider the role of reinsurance is to consider that the insurer of events that create a loss function (as presented in Figure 3) would purchase insurance on these losses. For example, insurers may decide that they could build adequate reserves that would cover losses beyond 105 percent of premiums; however, they would be unable to cover losses beyond that point. They could purchase what is called a "stop loss" contract to pay for all losses beyond 105 percent of the premium. More complex arrangements allow for quota shares, whereby the local insurance provider shares both premiums and losses with a global reinsurance market.

Just as with any insurance product, one can estimate the premium rates of a simple stop loss on the insurance losses using the information in Figure 3. The area above the stop loss is the first estimate for such reinsurance. Thus, as one works to sell more contracts across a wider region (i.e., a more diversified portfolio), the area above the stop loss will become smaller. However, as a company expands into new areas and new products, the likelihood of making mistakes may also increase.

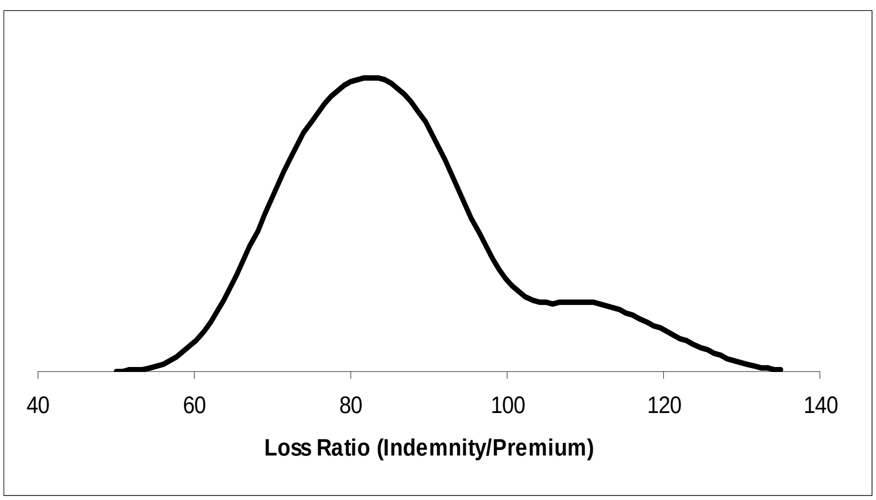

Figure 3: Estimate of Loss Function for the U.S. Crop Insurance Industry

For that reason, concentrating in known markets may be a good strategy at some level. Still, the more concentrated the portfolio of the insurance company, the more skewed the loss function (i.e., there is both a higher likelihood and severity of large financial losses).

With index insurance it may be that pooling losses among a number of insurance companies within a country can offer diversification benefits to companies that sell policies only in limited areas. However, insurance companies would be ill-advised to pool more traditional insurance contracts without excellent knowledge of the underwriting companies and their actuarial procedures. With relatively standard index insurance contracts, this type of concern is lessened considerably, making pooling among insurance companies a much easier proposition. Nonetheless, rules for pooling and some government involvement may be needed to facilitate this activity.

10.2 Structured Disaster Response to Complement Private Products

Given that ambiguity loading and cognitive failure are more problematic for extreme tail risk, governments and non-government organizations (NGOs) could be involved in facilitating transfers of these risks through appropriate layering of index insurance contracts. Such systems could be designed for either put option risk (e.g., severe shortfalls in the underlying index) or call option risk (e.g., severe excesses in the underlying index). A key would be to make certain that the transfers do not involve risks that are more frequent. If such risks are removed without the individual bearing some cost, the cognitive failure argument breaks down and one can imagine that the same problem of undue risk-taking in more risky regions will become a concern (Milete, 1999).

Returning to the example in Figure 2, the government could design a structured disaster response product (DRP) that would pay for losses beyond the 2500 mm level. The indemnity structure could be the same as that used for the insurance product that protects against losses in the layer between 2000 and 2500 mm. Government could select the thresholds for the DRP, based upon statistical properties. The idea would be to select thresholds likely to be in the realm of cognitive failure. The approach should attempt to develop thresholds that reflect relatively rare events (e.g. at least 1-in-15 years). Furthermore, as more advanced statistical methods are developed with the data, one can imagine government attempting to set the thresholds and payout rules so that the implicit transfer is roughly equal across different regions. This would be more equitable and create fewer incentives for taking on more risk in higher risk regions.

Simple rules that encourage farmers to purchase the insurance product for the 2000–2500 mm layer can be considered. For example, if farmers select only to sign up for the DRP, they should be required to pay a relatively small administrative fee. If they purchase the insurance for the 2000–2500 layer, they could be given the DRP for free. Such a tie would reduce the problems associated with government disaster programs that crowd-out private insurance products (PIP).

For the case in Figure 2, there would be three layers of risk and three different entities involved in holding these risks:

1. For rainfall below 2000, farmers would retain the risk either on their own or with other bank and non-bank entities.
2. For rainfall between 2000–2500, the risk would first be transferred to a local insurance company via a private insurance product (PIP).[10]
3. For rainfall levels above 2500, the government would provide insurance with the disaster response product (DRP).

The example can be generalized. Let x be a measure of the loss needed to be hedged and let $f(x)$ be the probability density function of claims in an individual region. The payment functions for three decompositions can be represented by a truncated function. *Strike* is the attachment point of the contract, i.e., the point on the index at which indemnity payments would begin. *Cap* is the maximum limit of the insurer's liability. The *Cap* greatly reduces the insurers' exposure to catastrophic losses.

If $x < Strike$, the loss is retained by the individuals or communities.

If $Strike \leq x \leq Cap$, the losses are protected by the local insurance company.

If $x > Cap$, the insurer pays an indemnity that is equal to the full liability and claims in excess of *Cap* are paid by the disaster response product provided by the government.

A major motivation for this arrangement is that the extreme risk at the local level is taken on by the government. Many proposals would have the government removing the extreme risk only after the insurance has been pooled, as with the U.S. standard reinsurance agreement. The arrangement proposed here would institutionalize the social role of government in removing extreme risk events at the local level. This would significantly lower premium rates as the tail risk, characterized by high ambiguity, would not need to be priced. Furthermore, by organizing these types

[10]Even though the local insurance company provides the PIP, it is very likely that it will still have to use other means to transfer the tail risk associated with selling a concentrated portfolio of correlated risk.

of contracts at the local level, isolated severe events that do not capture the attention of the national policymakers could still have some structured assistance in the form of a structured disaster response. Again, only infrequent-high consequence risks should be included in any DRP design.[11]

To summarize the major advantages of offering a structured DRP that uses weather index contracts:

- Structured rules allow for better planning than ad hoc disaster payments;
- Structured rules can account for low probability events explicitly, attempting to address the ambiguity loading and cognitive failure problem, and provide for a structure that provides more equity in expected payouts;
- Governments can set *Cap* levels and rules that complement the development of private insurance products;
- Governments can estimate their own exposure associated with the DRP, and plan for the fiscal costs accordingly;
- Having localized DRPs can provide for some level of catastrophic protection when events are not widespread enough to command national attention that results in ad hoc disaster payments.

10.3 Pooling the Risk Within the Country

Even with a layered PIP as developed above, there will be insurance loss functions that are at least as skewed as the one in Figure 3. The correlated risk problem remains a constraint for domestic insurance companies wanting to write PIPs. Nonetheless, international reinsurers may still be more willing to offer reinsurance to a local company offering index insurance because there are less asymmetric information problems (i.e., moral hazard and adverse selection should be lower).

One final role for government could be to develop the regulatory structure to allow companies selling PIPs to pool their contracts within the country first before going to the global market. Such activity would make index insurance contracts more affordable as the tail of the loss distribution would be less formidable than it would be for any individual insurance company that was unable to diversify its portfolio. Numerous structures can be envisioned to facilitate pooling index insurance

[11]One can also envision using the government to facilitate better pricing for these extreme tail risks. Lewis and Murdoch (1996) and Skees and Barnett (1999) write about this solution. The problem is that writing these contracts at a local level and attempting to provide support via auctions that are supported by government would involve very high transaction costs.With discipline, the government can provide this layer at a local level at a nominal fee and facilitate the development of base insurance products that complement the mid-layer of risk.

contracts among insurance companies. Again, to the extent that the contracts have used information that is of similar quality and have also used similar procedures for rate-making, insurance companies should be able to pool these risks without the same concerns that they would have if pooling more complex insurance products subject to moral hazard and adverse selection.

One structure could be to create a syndicate relationship among insurance providers. Each could deposit the premiums into the pool. They could arrange to have a stop loss on the pool either from government or from a major reinsurer. For example, if they chose to purchase a stop loss of 110 percent of all premiums, they would receive the benefits of pooling by having a lower reinsurance premium rate than they could obtain on their own if they went to the reinsurance market. The simple fact that the companies worked together to aggregate a significant volume of risk would also enhance their chances of getting an international reinsurer interested in the business.

To elaborate on a structure that could be implemented, each insurance company would be required to pay reinsurance that was consistent with the profile of risk they bring into the pool. They would also be required to estimate the total premium they would sell. Thus, the insurance companies who participate would prepay an amount equal to the stop loss layer (10 percent in this case) and the reinsurance cost for the business they anticipate bringing into the pool. The pool would purchase the reinsurance stop loss from either the government or the global reinsurance market. Once the reinsurance is purchased, the benefits of pooling could be passed on to each insurance provider via discounted reinsurance premiums to the pool. The idea would be to leave enough premium in the pool (110 percent in this case) to fully pay for all indemnities. Once the insurance cycle is complete, the underwriting gains would be distributed to each participating insurance provider, based on their share of the premiums sold. Of course, the pool would also earn interest over the insurance cycle. Thus, there would always be something to share at the end of the insurance cycle, even if losses exceeded the 110 percent level.

Again, the concept of layering risk can be used for this pooling arrangement. Governments may decide that they wish to spur the insurance market. They could offer a layer of stop loss reinsurance at a pure premium rate that would be significantly lower than the premium rate charged by the global reinsurance firms. For example, they could offer the pool a stop loss at 130 percent. This would effectively make the insurance to the end user more affordable and be a superior way to introduce a subsidy, as it would again be working with extreme, catastrophe-type risk. If the government offered a stop loss at 130 percent, the pool would still likely need to go to the global market to obtain a stop loss at a lower level.

The real advantage of the pooling arrangement for these standardized index insurance contracts is that the individual insurance company's share in the pooling arrangement could be treated as an asset. If a company had a 25 percent share in a pool, that share could ultimately be sold to any other member of the consortium or to a global reinsurer. For example, an easy arrangement would be to have a 50/50 percent sharing between the local company and a global reinsurer (this is similar to a quota share). More fundamentally, one could envision an exchange-traded market emerging to dynamically trade shares of the pool as the crop year progresses. Such an arrangement should result in more efficient pricing.

The other strong advantage of the pooling arrangement just described is that it would guarantee farmers would be paid for losses but with far less regulation than what is often required to assure that insurance companies have the financial wherewithal to pay indemnities. Companies would effectively be prepaying for losses below the stop loss. The major concern would be to assure that the reinsurance above the stop loss would be fully protected.

11 Conclusions and Implications

Insurance for natural hazard risk is indeed complex. For this reason, government involvement to facilitate markets for crop insurance has typically been unsuccessful and/or quite expensive. This paper has reviewed some of the problems with attempts to provide crop insurance in the United States and Canada. The problems of correlated risks, cognitive failure, and high transaction costs have been introduced to explain why true markets for these risks have not emerged. Index insurance products offer some hope for dealing with problems associated with monitoring and high transaction costs to mitigate moral hazard and adverse selection problems that plague traditional multiple-peril crop insurance. However, as was discussed, one must still consider further developments and other institutional arrangements to mitigate the basis risk that may accompany index insurance products.

More work is still needed on the basis risk in index insurance products. The conceptual thinking to date focuses on the use of risk aggregators who could, in turn, develop both formal and informal mechanisms for addressing basis risk. These mechanisms may involve mutual insurance companies. They might also involve banks that offer contingent loans to individual who suffer hardships when the index insurance does not pay. The notion of blending index insurance with lending instruments merits more serious consideration. Once again, banks should be well suited to handle small event risks that are generally associated with basis risk.

Numerous innovations can emerge from the concepts associated with index insurance. For example, ongoing work in Mexico examines the extent to which index insurance contracts can be used to hedge the inflow of water from the stream that feeds an irrigation reservoir. This could be a quite important means of using both engineering solutions and market-based solutions to plan for the size of dams and the rules for allocating water. The conceptual goal is to have contracts with water users that guarantee either water delivery or some combination of water and indemnity payments when the water is not available (Skees and Zeuli, 1999). Such capital market solutions could accelerate the movement towards more efficient water markets in many developing countries.

Finally, as promised, this paper closes with specific policy recommendations that build on the use of weather index insurance. The recommendations presented in Section 9 explicitly recognize the social goals of government to cover extreme catastrophic events via what is termed a Disaster Response Product (DRP). This approach provides structure to disaster response in a fashion that should not create significant market distortions. It also explicitly recognizes that markets are expensive for extreme event risks and that decision makers are limited in their cognitive assessment of these types of risks. Finally, the structure facilitates markets rather than crowding them out.

Even with a DRP program, insurers of less extreme layers will still have a correlated risk problem that can cause extreme losses for their portfolio of insurance products. To address this problem Section 10 develops recommendations for a unique pooling arrangement to retain as much risk within the country as possible before going to the international reinsurance markets. Once such pooling arrangements have been organized, the consortium of insurance companies who participate in the pool can more effectively approach the global reinsurance market for stop loss reinsurance coverage. Should governments decide they want to provide more support for the overall insurance program; the government can also select various stop loss levels to protect the catastrophic risk of the pooled risk. Government stop loss reinsurance coverage could presumably be sold at something approaching an actuarially fair premium rate. The ability to purchase this reinsurance coverage at premium rates that are below market levels would allow insurance companies to discount their insurance premium rates.

The concept of layering risk that is written on a standard measure, using the same rate-making producers opens many possible avenues for securitizing weather risks. Some of the ideas presented are only the beginning. Should the structure that is suggested prove viable one can envision many possible ways to trade correlated risk dynamically; ultimately improving the pricing and efficiency of a weather market that is currently underdeveloped globally.

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