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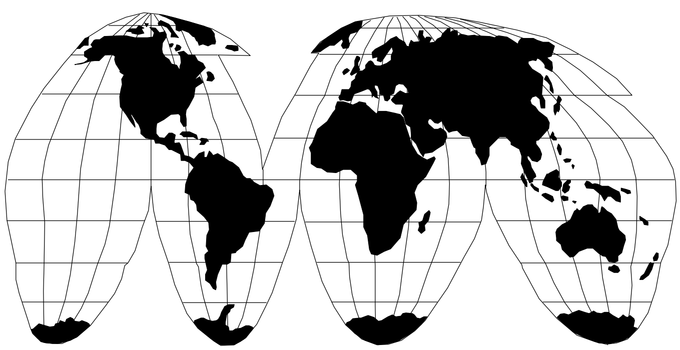

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A Role for Capital Markets in Natural Disasters: A Piece of the Food Security Puzzle

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Introduction

Agricultural development is the key to food security in many countries around the world. Natural disasters reduce domestic food supplies in the short-run and retard agricultural development in the longer-run. Natural disasters are a major source of risk for production.[1] And while many alternatives are used to cope with this type of risk, careful consideration of the consequences of these alternatives is essential.

This paper evaluates the consequences of alternatives to cope with natural disasters by first developing a conceptual frame for understanding these risks and then reviewing some alternatives. The challenge for introducing market-based solutions is evaluated by focusing on one source of natural disaster risk – drought. Market-based policies that pay when there is a shortfall in rain offer some promise for coping with many of the problems identified. Such 'index-based' policies could be applied to many natural disasters. Risk-sharing using these methods will require an active participation from capital markets. New developments in capital markets give reason for optimism. Still, there may be a role for government in developing the market for risk-sharing for natural disasters.

The Role of Risk-Sharing in Agricultural Development

In a market-based economy risk must be internalized. Farm managers have many means for coping with risk. Diversification in enterprise mix or in use of family labor for both on and off-farm jobs is a common and dominant choice. Diversification does not come without a cost. The benefits of specialization in production are well-documented in economics (Debreu). When farmers diversify they give up the higher expected income that would come with specialization to reduce the variation in income. In effect this can be thought of as an insurance premium. Another means of managing risk involves use of credit reserves. If the firm decides to limit the use of credit below a level that may be optimal, the opportunity to borrow funds will be open in the event of a major disaster. Again, there is an opportunity costs associated with maintaining a credit reserve for major disasters. This competes with desires to maintain credit reserves that would allow the firm to take advantage of unforeseen opportunities.

Possibly more significant, if farmers do not have the means to manage catastrophic risk from natural disasters, bankers will be forced to internalize these risk in some fashion. When bankers

[1] By natural disasters I am referring to risks that cover a wide area at the same time. For example a major drought, excess rain, hurricanes, or volcanoes can inflect wide-spread damage to production agriculture. In small countries, these types of disasters also create short-term food security problems.

recognize that loan defaults are tied to natural disasters they will either 1) ration credit or 2) build in a credit premium to cover these risks (i.e., charge higher interest rates). There are no free lunches. Agricultural risks are an impediment to fully developed financial markets in many developing countries. Access to affordable credit is a key to development. With affordable credit farmers can adopt new technologies and take more risk in developing improved farming systems. There is a catch twenty-two – if farmers had access to credit they could mange agricultural risk better – if bankers did not have to worry about loan defaults from agricultural risks they wold provide more access. In many countries, the financial markets are incomplete. Effective risk-sharing markets for natural disaster risks are largely lacking the world over. If such markets existed, one might expect the following: 1) more access to affordable credit; 2) more rapid adoption of new technologies; 3) more specialization in production; and 4) a more adaptive and flexible agricultural sector.

Most economists agree that using insurance allows decision makers to engage in new productive activities with benefits for the entire economy (Arrow 1964, 1996). However, great care must be taken. Farmers must pay for the risk protection and the market contract must be structured so that it cannot be abused. These two conditions are fundamental to a sustained risk sharing program and to one that results in welfare gains to society. If farmers are given risk protection via various subsidies, significant inefficiencies will follow, and some of these inefficiencies may have negative environmental consequences. If the contract is subject to abuse, the losses must be added to future premiums and soon there will be no private interest in either purchasing or supplying insurance.

With classic insurance, pooling independent loss events yields a mean loss for the pool that has a variance that is less than the mean of the individual variances. This result is derived from the classic statistical property of the “law of large numbers." Thus society benefits from pooling independent risks since the risk faced by the pool is less than the pre-aggregated sum of individual risks (Priest). In short insurance markets *reduce* the risk faced by society and thus the aggregate cost of managing risk.

Attempts to Manage Natural Disaster Risk

A variety of alternatives have been used to protect societies against the adverse effects of natural disasters. Free assistance is likely the most common. While such assistance may be necessary for humanitarian reasons, there are reasons to proceed with caution. Free assistance sends the wrong signals. Consider the response. Decision makers will soon value the free assistance and change their behavior in ways that will ultimately lead to more losses. If the government gives free assistance to farmers who lose their crops on a regular basis, the farmers will plant more crops and collect more disaster payments in the future. Such a decision creates a cycle that may be burdensome to the government budgets, the environment, and to the people taking the undue risks. There is a rich literature discussing the public policy problems created when free disaster assistance is provided (Dacy and Kunreuther; Kaplow; Kunreuther 1973, 1993, 1996).

Governments have also been active in providing government supported insurance. In many cases the government has been the direct retailer and risk-bearer of such insurance programs. For the US crop insurance program, the government uses the private sector to deliver subsidized crop insurance and share the risk of the crop insurance through a special reinsurance agreement with the government. Whether the government sells insurance directly or uses the private sector, there are problems. Most government insurance is subsidized as a percent of premium. Providing subsidies as a percent of premium still favors more risky areas more than less risky areas, sending similar signals as free disaster aid. Further, the transaction costs of providing individual insurance can offset any welfare gains for society. Finally, allowing the private sector to sell government insurance and share the risk creates rent-seeking behavior that can destroy the efficiency gains for society (Goodwin and Smith; Hazell, Pomareda, and Valdes; Mishra). Hazell does a nice job of developing reasons multiple-peril crop insurance programs have failed in developing countries.

Incomplete Risk-Sharing Markets for Natural Disasters

There are several reasons why private markets have not developed for risk-sharing from natural disasters that damage agriculture. First, it may be that government actions have crowded out such market development. Private insurance does exist for earthquakes and hurricanes in the U.S. Second, the transaction costs of insuring farm level yields are high because of information asymmetries. Third, the risk from natural disasters is widespread and correlated creating huge losses and requiring special forms of risk-sharing. In fact, this is a reason given by many for needing government involvement. Finally, it is possible that there is a cognitive failure problem on the part of many decision makers who undervalue insurance.

Government Crowding Out Markets

Governments may simply crowd out private sector interest. Many governments generally provide assistance to communities ravaged by natural disasters and operate highly subsidized public crop insurance programs. Such government activities have been blamed for competing unfairly with private insurers, stifling development of innovative insurance products. Governments also tend to regulate the insurance sector heavily creating another burden to innovation.

Information Asymmetries

Incomplete agricultural and rural risk markets also stem from information asymmetries. Farmers will always know more about their yield risks than the government or any private company. Thus the classic problems of adverse selection and moral hazard can create serious problems for any multiple peril crop insurance program. There is an extensive literature on these problems (Goodwin and Smith; Ahsan, Ali, and Kurian; Skees and Reed). If individual risks are not properly classified prior to selling insurance, then high risk growers may be the only ones to participate. Such adverse selection will create losses that are greater than the insurance premium rates creating a need to continually raise rates. By the same token, if insureds change their behavior after they purchase insurance in ways that create more losses because they are insured, rates will need to be increased on a regular basis. This is moral hazard. Controlling adverse selection and moral hazard requires investments in information. Investing in information will add to the transaction costs of delivering insurance. This increases premiums and reduces demand for insurance.

Correlated Risk

Independent risk is a classic pre-condition for insurance (Rejda; Vaughan). When risks are not independent, markets may be incomplete. The widespread nature of natural disaster losses undermines the ability of insurance companies to pool risks and offer affordable insurance coverage. Although crop losses are often widespread, they may not be completely correlated. General price movements for a bulk agricultural commodity are generally correlated. Such correlated risks can be managed with futures exchanges. In many ways, crop and natural disaster risks are "in-between risks." They are neither completely correlated nor independent (see figure 1). New ways of thinking are required to introduce markets for such "in-between risks." When insurance is offered for natural disaster risks the rates must be loaded for catastrophes because of the nature of the risk. In effect, the potential seller must overestimate the pure risks.

Figure 1: Independent versus Correlated Risk

0 correlation	In-between risk	100% correlated
AutoAccidents	Natural Disasters	Commodity Prices
Heart Attacks	Rainfall/ crop yields	Interest rates
Insurance Markets	Government/ ? ?	Futures Markets

Cognitive Failure by Decision Makers

Cognitive failure problems may also contribute to the problem of incomplete risk-sharing markets (Kunreuther 1996 Tversky and Kahneman; Kunreuther and Slovic). If decision-makers underestimate the risks they face, they will be less willing to purchase risk-sharing products. Interestingly, decision makers seem to underestimate risks from natural causes and overestimate risks from man-made causes (Camerer and Kunreuther; Kunreuther 1976). If potential purchasers of insurance underestimate the risk and potential sellers overestimate the risk, a market will not evolve.

Insuring Natural Disasters

Insurance is available for natural disaster risk in developed economies. Homeowners can insure against damage from hurricanes and earthquakes. These risks are clearly different than most insurable risk. Unlike automobile insurance where the risks are largely independent, natural disaster risk are correlated with some low probability of very high losses as a widespread area is damaged by a single event. This requires special arrangements to share these risks in the capital markets. Primary insurers pass on certain levels of risk to an international reinsurance market (Miranda and Glauber; Cutler and Zeckhauser).

The simplest form of reinsurance is a stop loss where the primary insurer pays a premium to get protection if their losses exceed certain levels.[2] For example, if an insurance company has a book of business that is concentrated in a hurricane prone area they would likely need such reinsurance. If they have $100 million of property value insured with an average premium rate of 10 percent, they would collect $10 million in premiums. While this company may have another $10 million in assets to cover significant losses, they cannot cover losses beyond the combined $20 million level or beyond a loss ratio of 2 (indemnities / premiums). They may decide to buy a stop loss where the reinsurer pays for all losses above the $20 million level.

The reinsurer has an interesting problem – how does one rate a policy for a low probability high-loss event? While there are very sophisticated models used to address this problem, most wise reinsurers will load the risk beyond levels experienced in the past (Anderson; Hogarth and Kunreuther 1989, 1992). Things can always get worse. Or as anyone in the risk management business will say "just because it has never happened, that doesn't mean it won't." The other problem is intertemporal. Suppose the big hit comes in the first year. This will require capital reserves to pay large losses. Rate makers load to build these reserves quickly for early losses. Finally, keep in mind that all of the issues of asymmetric information apply for the principle-agent relationship between the primary insurer and the reinsurer. Reinsurers must invest in monitoring and information systems to balance the information. This increases transaction costs. In the end, all of these costs must be summed together with the pure risk of the contract to develop a premium rate.

(1) Premium Rate = Pure premium rate + Catastrophic Load + Reserve Load
+ Charge to cover transaction costs + Return on equity

It is little wonder that premium rates can exceed the expectations of decision makers who tend to forget bad events from natural disasters. These arguments are used to justify government involvement. Efficiencies are needed. Large international reinsurers can spread risks around the world -- applying all of the principles of portfolio theory. If the portfolio of reinsurance is large enough, what may be low-probability high catastrophic events for a small company become a largely independent and diversifiable risk for the large reinsurer. There has been significant growth in the international reinsurance markets. Walter reports a compound growth rate of 16% and estimates that, in 1997, all premiums from reinsurance may be greater than $100 billion.

Yet, reinsurance markets are thin with few large international firms and limited capacity. Kunreuther (1996) and Stipp review some of the problems with reinsurance markets. Reinsurers have short memories. After a major catastrophe reinsurance prices increase greatly or the reinsurer simply pulls out of the market. This happened in Florida after Hurricane Andrew and in California after the Northridge earthquake. State reinsurance pools were created in both Florida and California to offset these problems (Noonan; Jaffee and Russell).

Improved efficiencies are needed in reinsurance markets. The transaction costs of putting together large sums of capital can be high. There are new developments that hold promise for reducing the transaction costs (Doherty; Lamm). There is some promise that exchange markets can

[2] Other forms of reinsurance are also common. For example, quota-share arrangements involve simply sharing both premiums and indemnities.

be used as risk-sharing institutions for disasters. The Chicago Board of Trade (CBOT) trades a Catastrophic Insurance Options Contract (CAT). Property Claim Services (PCS) catastrophe loss indices are traded for nine geographic regions in the U.S. As such, the contract allows those at risk from large property and causality losses due to hurricanes or earthquakes to share some of that risk with a larger community of traders in an exchange market. The contract has grown a good deal in recent year but still comprises only about two percent of the total market.

Another important development is the emergence of catastrophic bonds. This is truly using of capital markets to share catastrophic risk. These take on a variety of structures. In essence, they represent contingent capital should the disaster occur. Some have called the CAT bonds the ultimate junk bond – you have a very high probability of getting a high rate of return on your money or you have a very low probability of losing everything. Since catastrophes are not correlated with other market equities, they should be a good diversification strategy for portfolio managers.

The use of the capital markets for sharing "in-between" risk remains in the infant stages, leaving the issue of capacity and efficiency in doubt. This raises questions about the role of government in sharing such risk. For the U.S., Lewis and Murdock 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.

Using Index Contracts to Insure Natural Disasters

There are serious questions about trying to insure individual crop risks. Potential societal welfare gains can quickly disappear when there are high transaction costs for monitoring the micro level problems of adverse selection and moral hazard or if extra resources are needed by rent-seekers to keep subsidies. Without investments in monitoring, actuarial performance will almost certainly be poor (Hazel). The nature of the systemic risk also presents major challenges in reinsurance. When a significant systemic risk component is present, index contracts may be optimal. In other words, if most potential insureds face losses from the same events, then offering a contract that pays when those events occur can offer significant risk protection. Crop insurance that pays indemnities based on yield shortfalls from normal area yields is a case in point (Miranda; Skees, Black, and Barnett; Mishra).

The problem with index contracts is that an individual can have a loss and not be paid because the major event trigging a payment has not occurred. In futures markets this type of risk is referred to as basis risk. With index contracts it is also possible for an individual to be paid when they suffer no losses. While traditional insurers think this is a problem it is this very aspect that makes index contracts attractive. The insured paid the premium based on the underlying risk of the index so that is not an issue. Most importantly the insured's management decisions after planting a crop will not be influenced by the index contract. There is no moral hazard. The insured farmer (in this case) still has the same economic incentives to make a crop as the uninsured farmer.

The most serious aspect of basis risk for an index contract is that a farmer can have a loss and not get paid. If the basis risk is not too high, this issue is also not as serious as many make it to be.

First, consider that an index product should be more affordable than individual insurance. Second, if it protects against most of the risk, it can be better than having no other alternatives. Third, keep in mind that offering an index contract that takes most of the risks out and leaves only independent risks opens the possibility that an insurance company can offer an insurance contract for the independent risk. Such a wrap-around contract would still be subject to the same problems of high transaction costs due to monitoring and information needs by the insurer. If buyers are not willing to pay for the transaction costs then maybe a market should not evolve.

In short, index contracts tradeoff basis risks for transaction costs. Transaction costs of index products are generally much less than for individual insurance. Everyone should have access to the same information. Asymmetric information is not a problem. Again, with lower premiums because there is lower transaction costs a market might evolve. Still one must be concerned about the level of loading that may be necessary for an index contract. When one is writing index contracts on natural disasters, the degree of systemic risks can be significant. More will be said about this issue as alternatives ways to offer reinsurance for index contracts is discussed below.

Besides being largely free of adverse selection and moral hazard problems, index contracts can be made widely available. Traditional farm-level crop insurance is made available to farmers only. In reality many individuals are at risk when there is a natural disaster that does severe damage to crops. For example, the lender is clearly at risks if a large number of their borrowers suffer serious financial losses from the same event. Further, agribusinesses selling inputs to farmers or purchasing the final product are at risks. In particular an agribusiness that earns revenues based only on throughput of a basic commodity might find an area-based index contract attractive. Finally, individual consumers of basic food stuffs could purchase the index contract that would indemnify them when there is a food shortage in their area. There is no reason to limit who can purchase an index contract that pays when a natural disaster damages a crop. Farmers are not the only ones at risk.

Rainfall Index Contracts

One index contract that merits consideration for many developing countries is a rainfall index. While an area-yield contract may be preferred to a rainfall contract in many cases, there are a number of reasons why a rainfall contract may be better. First, many more countries likely have a better history of measuring rainfall with a government meteorological agency than the countries with quality statistics on crop yields. Second, it is less costly to set up a system to collect rainfall for specific locations than to develop a reliable yield estimation procedure for small geographical areas. Third, in some cases rainfall shortfalls or excess rain will influence income and not crop yields. Finally, either shortages or excess rainfall are the major source of risk for crop losses in many regions. Drought causes low yields and excess rainfall can cause either low yields or serious losses of yield and quality during the harvest. For irrigated farms, a drought can also cause increased costs as the cost of irrigation may be tied to the level of water needed. Hazell mentions the possibility of developing rainfall insurance in his review of crop insurance for developing countries.[3]

For purposes of discussion some terms need to be defined:

Liability – the face value of the contract or the most you could ever be paid.
Pure premium rate – the expected losses in percent of liability terms
or frequency of loss x severity of loss
Strike – the level of rainfall where payments begin (usually as percent of average)

An area-based rainfall contract can be quite simple or complex. In order of complexity, there are three basic alternatives that merit consideration: 1) a zero-one contract that pays all liability when cumulative rain is at or below the strike; 2) a layered contract that pays an additional fixed amount of the liability as each layer is penetrated; 3) a percentage contract that pays based on percentage below the strike. While the simple contracts may be more attractive as they are easier to understand, the more complex contracts are more likely to offer the best risks protection.

The Zero-one Contract

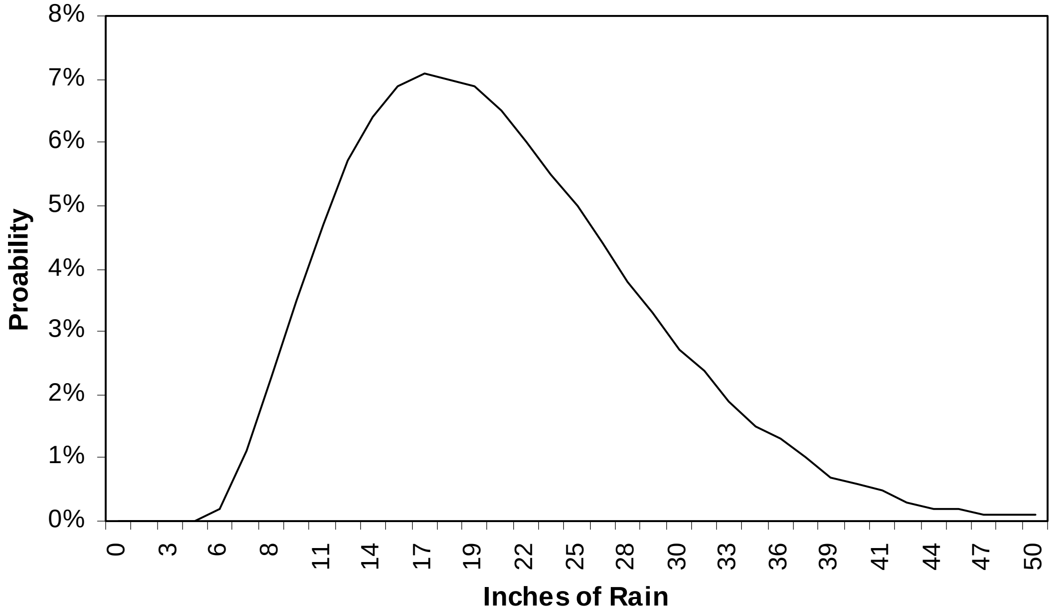
In it's most simple form, a rainfall contract would simply pay the full face value anytime there were a rainfall shortfall in a specific location. For example, let's say that the most critical period for rainfall is the first two months after planting. One could design a policy that would pay when rainfall is below a specific percentage of the average rainfall during that period. The payment schedule would simply be the face value (liability) of the contract.

Consider the probability distribution (pdf) represented in figure 2. In this pdf, the rainfall is positively skewed and has an average of 20 inches of rain with a standard deviation of 8 inches. If an individual purchases a $100 contract that pays if rainfall drops below 50% of the 20 inch average rainfall for the two month period, the strike is 10 inches. All $100 of liability would be paid for rainfall at or below 10 inches. For this pdf, such an event will occur 8.3 percent of the time. Since all liability is paid for rainfall at or below the strike, the pure premium rate would also equal 8.3 percent.

While the simplicity of the zero-one design is attractive, there are some shortcomings. First, the loss function is rarely bimodal. The relationship between rainfall and income is more likely a linear or curvilinear since the degree of damage is likely a function of how much below average the rainfall actually is. Second, making things so precise gives undue pressure for individuals to try to manipulate the system in some fashion. As the rainfall gets close to the strike, a fraction of an inch of rain either way can make the difference between paying all or nothing. Third, either premium rates would have to be very high or some very low levels of rainfall would need to be insured. Again, consider the pure premium rate of 8.3% for the distribution in figure 2. To complete the rating all

[3] Peter Hazel and I proposed such a program in Nicaragua as part of a World Bank credit project (Hazel and Skees). Mario Miranda and I are now working on this project (Skees and Miranda). Much of what is written here comes from these experiences.

Figure 2. Distribution of Spring Rain



factors introduced in equation (1) would need to be added to the pure premium rate. This may double that rate. Rates in excess of 10% are generally not attractive to potential purchasers of these type of contracts. Therefore, a zero-one contract may have to be written for very low and infrequent events – say one in twenty years or a 5% chance. If purchasers are not indemnified any more frequently than this, they are not likely to stay with the contract. Receiving some level of payment frequently is important because of some of the cognitive failure problems discussed above.

A Layered Contract

To address some the shortcomings of the zero-one contract consider a layered contract with multiple strikes paying a fixed additional amount when each layer is penetrated. Again consider the distribution in figure 2. We can design a policy that would pay one third of the face value (liability) for three levels of rainfall. For a $100 policy, consider the following payment schedule that starts paying for rain below 60 percent of the average:

If rain > 8 inches but <= 12 inches pay $33.33 odds of rain below 12 inches=15.8%
If rain > 4 inches but <= 8 inches pay $66.66 odds of rain below 8 inches = 3.0%
If rain <= 4 inches pay $100 odds of rain below 4 inches = 0%

To rate this policy, sum frequency x payouts (severity) for each layer:

.158 x $33.33 = $5.3 /$100 of liability
.030 x $33.33 = $1.0 /$100 of liability
.000 x $33.33 = $ 0 /$100 of liability

Total pure premium = $ 6.3/$100 of liability or a pure premium rate of 6.3 %[4]

A Percentage Contract

The third way to structure these contracts is to develop payouts as a function of rain below a strike level. Using percentages below the strike and multiplying those percentages by the liability selected is the most straight-forward functional relationship. Using the same strike rainfall of 12 inches, one would pay as follows:

(2) Payment = [(12 – actual rain) / 12] x liability

The rate is simply the average of the percentage shortfalls below the strike. For the distribution in figure 2 at the strike of 12 inches, the pure premium rate is 3.2%. Now it is possible to offer protection at higher levels. For example, offering coverage at 70 percent of the average or a strike of 14 inches has a pure premium rate of 5.6%.

Obtaining Risk Protection from A Rainfall Index

Extensions of portfolio theory are needed to evaluate the utility of a rainfall index. For the farm manager, the rainfall index simply becomes another enterprise in the portfolio of choices. In some cases, the rainfall index enterprise may offer a better portfolio than adding another crop, especially if better terms of credit are available when the rainfall index is purchased. While the full evaluation of these choices is involved and requires good data, there are some important considerations that will give some indication about the utility of using a rainfall index. Formal models have evolved from the original portfolio work by Markowitz. Capital asset pricing models, hedging models and contingent claims models all use the same basic constructs and principles: expected values of the alternatives; variance of the alternatives; and the covariance of the alternatives.[5]

For a rainfall index, the degree of correlation between net receipts from the index and farm income will play a large role in the effectiveness of the risk protection offered. With higher correlation there will be less basis risk. Understanding income-rainfall correlation requires crop yield modeling. Further, it is possible that a set of rainfall indexes may fit best for different farming systems. Farm income risks for certain crops may be most sensitive to rainfall shortfalls at different times during the season (e.g. planting and blooming). Income may also be at risk during harvest if there is excess rain (the designs described above can be applied to excess rainfall contracts as well).

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[4] If the same procedures are used with a starting coverage level at 60% of average and 5 layers, the pure premium rate drops to 5%.

[5] In the final version of this paper, the equations will be developed to demonstrate these properties.

CAPM type models can be used to determine the optimal level of these contracts once the income-rainfall relationships are understood (Miranda does this for an area yield contract). One advantage of CAPM type models is they also help sort out the independent risk and the systemic risk. This is critical as systemic risks are the "in-between" risk that concern the insurer and reinsurer. Therefore, index products are a bit different than traditional insurance in that the very presence of high levels of systemic risks improves their attractiveness. To the extent that there is high spatial correlation between rainfall stations in a region, the exposure for an insurance company would be even higher. The reinsurance issues must be resolved. Before moving to that issue, it is useful to summarize the advantages and potential difficulties of the rainfall contract.

The advantages of a rainfall contract include:

1) Low moral hazard and adverse selection.
2) Low administrative cost since no on-farm inspections are needed and no individual loss adjustments are required.
3) There is no need to track yields or financial losses (one need only measure rainfall). The insurance can be sold to anyone who has income that is correlated to the rainfall event, including bankers, agricultural traders and processors, farm input suppliers, shopkeepers, consumers of basic commodities, and agricultural worker.
4) The contracts could be sold as a simple certificate at low denominations.
5) To the extent that these contracts cover a large systemic risk component, they can facilitate development of other kinds of insurance to handle independent risk.
6) Since the insurance would be sole as certificates, a secondary market could emerge enabling people to cash in the tradable value of a standard unit contract at any time.

The potential difficulties include:

1) The need to have reliable and secure rainfall measures for a large geographical area
2) The need to model intertemporal weather events such as El Nino.
3) Mistakes could be made in selection of the critical rainfall periods and in other contract design features.
4) The difficulty of potential purchasers in understanding how to use the contracts.
5) The high degree of correlated risk making it necessary to have reinsurance.

Using Government to Address the Potential Difficulties

To the extent that the government helps in development of rainfall contracts it will lower the transaction and start up costs. Some government assistance would be needed in most developing countries. There is a public good in developing research needed to understand the critical periods for rainfall (i.e., those periods that are most highly correlated with income). Public research to model El Nino events is needed. Investing in the infrastructure for secure and reliable rainfall stations also has some public good dimensions. Governments may also engage in the educational efforts needed to help potential users know how to evaluate purchase decisions. These public investments help assure transparency in information, an important condition for efficient markets.

Secure and reliable rainfall measures are critical for all parties. New technologies hold significant promise. One company in the US offers a rain gauge operated by a battery with a five year life. Tiny buckets trip the measuring device so that rainfall at .01 of an inch can be recorded. No rain is collected. By using a data jack with windows based software, a worker simply plugs into the rainfall measuring device and downloads the data. This can go as long as one month between intervals. A complete system of 50 such gauges, software and data jack cost about $240 each. This is affordable and offers the opportunity to densely populate a region with rain gauges. Finally, geographically smoothing can be used with a heavily populated set of rain gauges to provide point estimates for rainfall. This has great promise for reducing opportunities for any individual to tamper with a single gauge and to reduce the basis risk of offering a contract on a rain gauge that is several miles form the crop. Security can be enhanced by placing the rain gauges on telephone poles with shields around them from below.

To give companies the comfort needed to insure rainfall in a developing country, the government may consider writing low probability insurance contract on individual rainfall stations. Primary insurers and reinsures would determine how many and what mix of such contracts to purchase from the government. These contracts could be simply rated at the historical break-even rate, or they could be auctioned to the highest bidder. The World Bank or others in capital markets could back up these contracts with a contingency loan so that the government would have sufficient capital to pay all losses if the bad year came early in the pilot test. In effect, the capital markets would be offering a stop-loss type contract to the government.

To make this clear, consider a hypothetical scenario. A primary insurance company in decides to offer several drought contracts to farmers, bankers, and others for limited test market. To make this simple, let's say that only one contract is available at each station. That contract pays when cumulative rainfall in the months of May through July is less than 75 percent of the average rainfall at each station. Between 75 and 50 percent, the contract pays 1/3 the face value. Between 50 and 25 percent of the average, the contract pays 2/3's the face value and for rainfall that is 25 percent of the average the contract pays the full face value. Again, assume that the primary insurer sells $1 million of these with a face value of $10 million. In the worst case, if each rainfall station had rainfall of less than 25 percent of average, the insurer would pay $10 million. For these three stations such an event has never occurred. However, that does not mean it is not possible. Such a possibility would be priced by a reinsurer and this would likely make the reinsurance more expensive for the primary insurer.

The host-country government could sell individual rainfall contracts to reinsurers to prevent this. For example, the government may sell a rainfall contract for each station that pays in two stages: 1) 50 percent of the face value for rainfall below 40 percent of the average; and 2) 100 percent of the face value for rainfall below 20 percent of the average. There are many possible contracts. The government would sell very low level coverage for each station. The reinsurer would have to purchase the mixture of these that would best protect their risk. As the government sells these, they must have the capital to pay if the bad year comes early. For small countries this could be a problem The World Bank, an international reinsurer, or a financial entity that is ready to write CAT Bonds could offer simple 'stop-loss' coverage via a contingency loan. For example, if the government sold premium of $500,000 for these contracts, at premium rates of 5 percent, the maximum possible loss would be 20 times the total premium or $10 million. While the expectations are that the government would break-even over the long run, they could have the bad event early. The World Bank or the international capital markets would cover such an event with a loan. As things are phased in, the government may want to offer these contracts in a limited number via an auction to move the market to an insurance market. Or the government may be able to build a reserve fund and offer the contracts without outside capital after some time. A system needs to be established to consider the alternatives as things develop. The primary objective should be to move to a market-based system with little or no involvement in reinsurance from the government.

Conclusion

Food security has many dimensions. Natural disasters challenge food security in the short-run with food shortages and in the long-run with underdevelopment of the agricultural economy if there are incomplete risk-sharing markets. Attempts to introduce multiple peril crop insurance programs in developing economies have largely failed. This paper reviews some of the reasons for that failure. Based on this review and an introduction on international reinsurance markets for natural disasters and new capital markets, an alternative is presented.

The case for using a rainfall index in developing countries rather than traditional crop insurance is strong. Among the more important advantages is the absence of moral hazard and adverse selection and that an index can be sold to anyone at risk. Three major challenges must be addressed before effective rainfall contracts are introduced: 1) the critical periods rainfall and how correlated they are to income for those at risks; 2) the need for a secure and reliable infrastructure to measure rainfall; and 3) the role of government versus international reinsurers in protecting against the systemic risks embedded in a portfolio of rainfall contracts. If effective rainfall contracts are offered, they can take much of the systemic risk out of the equation and open the possibility for private efforts at insuring independent risk.

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