Conceptual and Practical Considerations for Sharing Catastrophic/Systemic Risks

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Catastrophic or systemic risks are a major challenge for the farm and food system and rural communities. Private sector markets for sharing catastrophic risks are limited, but less so than in the past. This article presents a conceptual base for understanding why markets for sharing catastrophic risks may be incomplete and/or inefficient. Next, federal efforts to address catastrophic risk losses are reviewed. Finally, new capital market developments are presented and an alternative is introduced where the government would write risk options for specific perils.

T his article examines issues related to catastrophic risk sharing with an emphasis on the farm and food system and rural communities. Policy makers, researchers, educators, and private sector interests need a better understanding of how society can develop institutions that will facilitate market-based solutions for sharing catastrophic risk. For our discussion, catastrophic risks are characterized as low-frequency, high-consequence loss events that are correlated across space. The term systemic risk can also be used. Examples of catastrophic risks include natural disasters such as droughts, hurricanes, floods, earthquakes, pervasive freezes, major snowstorms, etc. First, we describe why risk-sharing markets for catastrophic risks may be incomplete and/or inefficient. Next, federal efforts to address catastrophic risk losses are reviewed followed by a discussion of new capital market instruments for securitizing catastrophic risks. Finally, we suggest an alternative federal role that could improve efficiency in catastrophic risk-sharing markets for the farm and food system and rural communities.

Federal financial assistance frequently follows in the wake of catastrophic disasters. Economists are rightly concerned with the incentives in such a system (An-

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derson; Dacy and Kunreuther; Freeman and Kunreuther; GAO 1980, 1989; Kaplow; Kunreuther 1973, 1993, 1996; Rettger and Boisvert). Free disaster assistance becomes self-perpetuating because individuals never get proper signals about their loss exposure (Kaplow). If individuals expect government compensation to offset natural disaster losses, they will take on additional risks. If decision makers do not bear the consequences of risky decisions, they will continue to do the things that expose them to the risk. Many have argued that well-intentioned federal relief encourages further development along geologic fault lines and hurricane-prone coastal areas (Epstein; Noll; Rossi, Wright, and Weber-Burdin). Others have suggested that federal agricultural disaster assistance encourages crop production in environmentally sensitive marginal areas (Griffin). Disaster relief becomes self-perpetuating because individuals never get proper price signals about their exposure to losses from natural disasters. To break the cycle, economists argue that risks must be internalized. People must be held responsible for the risks they take. Part of that responsibility can come through participation in contingent claims markets that allow for more complete risk sharing.

In a market economy, individuals have a number of alternatives for managing risks. Among these are diversification, self-insurance, credit reserves, investments in loss mitigation, or use of market-based risk-sharing arrangements. However, risk-sharing contingent claims markets for catastrophes may be incomplete due to the special characteristics of the low-frequency, high-consequence events that create widespread losses over a large geographical area.

Failure of catastrophe risk-sharing contingent claims markets is used as justification for federal government involvement in markets for flood insurance and multiple-peril crop insurance. Hail crop insurance has a long history of private sector involvement because hail losses are more independent than multiple-peril crop insurance losses. The federal government has become the sole insurer of flood risk for U.S. homeowners. Multiple-peril crop insurance is provided through a risk-sharing partnership between the federal government and private insurance companies. Problems exist with each of these models.

The current decade provides many examples of how catastrophic risks affect the farm and food system and rural communities. Crop losses in 1993 from flooding, excess rain, and limited photosynthesis amounted to nearly $4 billion. Despite the availability of federally subsidized crop insurance, the federal government provided nearly $2.5 billion in direct disaster payments for crop losses in 1993. In March of 1997, flooding in the Ohio River Valley caused losses totaling nearly $1 billion (NOAA). Several communities in rural Kentucky were devastated. Federal disaster assistance to individuals totaled $116 million (FEMA). By the late spring of 1997, the Red River was threatening Grand Forks, North Dakota. Despite early warnings that flooding would occur and the availability of federally subsidized flood insurance, the federal government eventually paid $89 million in disaster assistance to victims of the flooding (FEMA).

Conditions for Insurability
Rejda (pp. 23–24) presents idealized conditions for a risk to be insurable.

- "There must be a large number of exposure units." Pooling involves the group-

ing of a large number of roughly homogeneous, independent exposure units so that the law of large numbers can provide an accurate prediction of average future losses. If a classification system cannot be found that results in relatively similar risk exposure units, adverse selection will result, and only the higher risk members of the classification will participate in the pool.

- "Accidental and Unintentional Loss." Losses must occur as a result of chance— an "act of God" rather than an "act of management." If, as a result of purchasing insurance, management decisions are made that significantly alter the probability of loss and/or the extent of loss, moral hazard will exist. Moral hazard occurs when insured individuals change their behavior after they purchase insurance. The behavioral change increases the likelihood that policyholders will collect insurance indemnities and ultimately results in prohibitively high insurance premiums.
- "Determinable and Measurable Loss." Loss must be determinable and measurable within an acceptable level of reliability. "This means the loss must be definite as to cause, time, place, and amount" (Rejda, p. 23).
- "No Catastrophic Loss." If losses are positively correlated across insurance units (i.e., the underlying risk is systemic) the law of large numbers does not apply. Annual losses for the insurance pool will be extremely variable. The loss in any given year may be large enough to threaten the solvency of the insurance pool. Two techniques for insuring correlated losses are reinsurance and geographical spreading so that catastrophe insurance exposure is limited in any given geographical market.
- "Calculable Chance of Loss." To develop a premium rate, one must be able to estimate both average frequency and average severity of loss. Low-frequency, high-consequence catastrophic risks present serious challenges in premium rate-making.
- "Economically Feasible Premium." Premiums must be affordable. The chance of loss must be in a range that does not result in extremely high premiums. At some high level of probability, the loss becomes a standard business expense instead of a risk to be transferred. When a risk has a high frequency and low severity, the transaction costs will be so high that the insurance premiums will not be economically feasible.

Different Risks Require Different Risk-Sharing Markets

All risks are not the same. Certain institutions are better suited for managing certain types of risk. Risks that are highly positively correlated—so that everyone faces the same occurrence at the same time—can be effectively managed using exchange markets. Well-developed futures exchange markets exist for sharing risks associated with commodity prices, interest rates, and exchange rates.

Insurance markets are better suited for sharing uncorrelated risks. Examples include automobile accidents, property damage due to fire or wind, and crop damage due to hailstorms (Miranda and Glauber). By purchasing an insurance policy, individuals choose to accept a relatively small, consistent stream of losses (the insurance premium) rather than face the risk of a large loss that is unlikely but possible. In the classic sense, crop yields are not insurable because losses are cor-

related. Many risks with catastrophe components violate the independence condition of insurance.

If decision makers are risk averse, they are willing to pay more in insurance premiums than they can expect to receive in indemnities. Because they can share part of their risk exposure with others, insured individuals are more likely than noninsured individuals to engage in productive activities that promise high returns but also high risk. If the purchase of unsubsidized insurance allows individuals to engage in productive activities when otherwise they might not, local communities and the entire nation reap economic benefits (Arrow 1964, 1996).

Insurance markets work best when independent risks are aggregated to take advantage of the basic principles of diversification. Aggregating similar independent risks into a single insurance pool reduces the variance of loss. In other words, when considering a pool of independent loss events, each represented by an identical probability distribution, the mean of the individual variances is always greater than the variance around the mean loss of the pool. This result derives from the classic statistical property known as the "law of large numbers." Society benefits from the pooling of independent risks because the risk faced by the pool is less than the preaggregated sum of individual risks (Priest). In this sense, insurance markets are said to reduce the risk faced by society and thus the aggregate cost of managing risk.

"In-Between" Risks and Conditions for Insurability

Many natural hazard risks are neither highly independent nor highly correlated. We refer to these as "in-between" risks. In this section we describe characteristics of in-between risks that violate the conditions for insurability listed above. Theoretically, these violations increase the marginal cost of insurance for in-between risks and reduce the market supply. This may lead to incomplete markets in the sense that the socially optimal quantity of risk sharing will not occur.

No Catastrophic Loss

As policy makers struggle with choices on how to deal with catastrophes, they must understand more about some of the problems of insuring catastrophes. It would be incorrect to suggest that insurance markets cannot exist unless loss events are completely independent. Standard property and casualty policies cover losses caused by wind damage from hurricanes. In many areas, earthquake insurance is available as a rider to property and casualty policies.

International reinsurance markets have been willing to take some in-between risks and provide the needed capacity to support insurance offers. Reinsurance is insurance purchased by primary insurers to offset the risk present in their book of business. Although these contracts can take many forms, two basic models dominate: (*a*) a quota share arrangement where both parties share premiums and risk in some fashion; and (*b*) a stop-loss arrangement where the insurance company pays a premium and the reinsurer agrees to take all losses beyond some level. By purchasing reinsurance, the insurance company protects policyholders and stockholders against years of unusually high loss that could threaten the company's solvency.

Reinsurers are typically multinational firms that obtain diversification by cre-

ating an extremely large and varied insurance pool. The pool may include automobile insurance in Africa, health insurance in South America, and multiple-peril crop insurance in the Great Plains of the United States. By creating a large insurance pool that spans various geographic areas and lines of insurance, reinsurers reduce the year-to-year variability in losses from their portfolio. All of the principals of portfolio management apply. Walter reports a compound growth rate of 16% in the international reinsurance industry. Furthermore, international reinsurance premiums exceed $100 billion.

Yet, traditional reinsurance markets have limited capacity. Kunreuther et al. review these limits, pointing to recent experience. Short memories tend to dominate, causing disruptive price cycles. As time passes and no major loss events occur, the market softens as premium rates are bid ever lower (Stipp). After a catastrophe, reinsurance becomes very expensive. A number of property and casualty insurers attempted to pull out of Florida and California following Hurricane Andrew in 1992 and the Northridge California earthquake of 1994. Both Florida and California were forced to develop state reinsurance pools in an attempt to stem the outflow of primary insurers (Jaffee and Russell, Noonan).

Calculable Chance of Loss

Some simple equations will facilitate this discussion.

(1) $$\text{loss cost} = \frac{\text{indemnities}}{\text{protection outstanding}}$$

(2)   additional cost = reserve load + cat. load + adm. costs + return on equity

(3) $$\text{premium rate} = \text{expected loss cost} + \frac{\text{additional cost}}{\text{protection outstanding}}$$

(4)   premium = premium rate × protection outstanding

(5) $$\text{loss ratio} = \frac{\sum \text{indemnities}}{\sum \text{premiums}}$$

Expected loss cost

Loss cost is the starting point for rate-making. For insurance products that have been in existence for a significant period, the historical loss cost of the product is used as an estimate of expected future loss cost. For example, if over time, an insurance product typically has paid $20,000 in indemnities for every $1 million in coverage sold, the expected loss cost would be 2%. For independent risks, the variance around the 2% expected loss cost would be low. Under these conditions, the loss cost will be a major component of the rates. However, for in-between risks, variance around the 2% expected loss cost would be higher and skewed to the right with very low probabilities of very high loss costs in the extreme right tail of the probability distribution. A classic example where the variance of loss cost is high is with insurance against widespread natural disasters such as drought. If the disaster does not occur, the loss cost is very low. If the disaster does occur, the loss cost is very high.

Reserve load

Premium rates contain a reserve load because of the variance around expected loss costs. Insurance companies build and maintain financial reserves that can be accessed in the event that indemnities exceed premiums in any given year. The higher the variance around expected loss cost, the greater the need for financial reserves (Doherty). Thus, reserve requirements for insurance against in-between risks are higher than for insurance against largely independent risks. If an insurer's reserves are drained to pay unusually high indemnities in a given year, the reserve load typically is increased to replenish the reserves.

Catastrophic load

For in-between risks, historical loss costs may not provide an accurate estimate of expected loss cost. This is true even if the historical loss cost is calculated from a relatively long time series of historical data. Low-frequency, high-consequence loss events easily can be underrepresented (or even overrepresented) during the historical period used to develop loss costs.

In 1989, Hurricane Hugo struck the coast of South Carolina and caused $4–$5 billion in damage (Kleinfield). It was the worst natural disaster in U.S. history up to that time. Many felt that it was a highly unusual loss event. Within the next five years, three different natural disasters each generated property damage over three times that of Hurricane Hugo. The damage from Hurricane Andrew in 1992 was estimated at $18 billion (Jehl). Had Andrew moved about thirty miles north into Miami, damage would have exceeded $50 billion. The 1993 Midwest floods caused losses estimated at $15–$20 billion (Tolchin). Losses from the 1994 Southern California earthquake were estimated at $20 billion (Reich). Is the rash of natural disasters experienced during this decade a statistical anomaly? Or were earlier decades unusually benign?

Kunreuther et al. document how actuaries load premiums when risks are not well specified (see also Hogarth and Kunreuther 1989, 1992). In-between risks are not well specified because the historical loss cost may not accurately reflect future expected loss cost. Thus, actuaries add catastrophic loads to premium rates. "Never say never" must be the motto of anyone attempting to price in-between risks.

Administrative load

It is common practice for insurance companies to load premium rates for administrative expenses. Typical administrative expenses would include salaries and sales commissions, equipment and supplies, advertising, and office space. Insurers incur additional administrative costs related to asymmetric information. The insureds typically know more about their expected loss exposure than the insurers. For this reason, insurers put elaborate information systems in place that attempt to balance this inherent information asymmetry. Failure to do so will result in adverse selection and/or moral hazard problems.

Adverse selection occurs when insurers make a classification mistake and potential insureds recognize that the mistake is to their benefit (i.e., the actual risk faced by the potential insureds is greater than the risk reflected in the premium rate being charged by the insurer). Moral hazard occurs when insureds change their behavior after purchasing insurance. The change in behavior causes expected

losses to be higher than the insurance company anticipated when setting premium rates.

Information needed to accurately classify potential insureds (targeted at controlling adverse selection) and monitor the behavior of actual insureds (targeted at controlling moral hazard) comes at a cost. If the event being insured is not strictly the result of an "Act of God," then the information needs can become very significant (i.e., when management can affect the probability of losses or magnitude of losses).

Later we argue that the administrative costs for insuring in-between risks are higher than for insuring independent risks, principally because of the high transaction costs associated with organizing reinsurance and maintaining adequate reserves.

Loss ratio and return on equity

The loss ratio is a measure of actuarial performance. For independent risks, if the expected loss cost is 60% of the actual premium rate, the insurer would expect a loss ratio of 0.60. Loss ratios above 0.60 would suggest inadequate earnings to make desired contributions toward reserves, administrative costs, and return on equity.

For in-between risks, the loss ratio for any given year (one random draw from the underlying distribution) does not contain much information about the long-run actuarial soundness of the insurance product. Many years of indemnity and premium data are required to calculate a meaningful long-run loss ratio. It is not at all clear how many years of data are required to measure the actuarial soundness of a product that insures against an in-between risk such as flood, earthquake, hurricane, or crop yield failure.

The more variable the return on an investment (i.e., the higher the risk), the higher the average rate of return demanded by investors. Because of the higher variability in losses, and hence net returns, insurers require a higher rate of return on equity for lines of insurance that protect against in-between risks.

Premium rates

The cost of insuring in-between risks is much higher than the cost of insuring independent risks. Positive correlation across loss events greatly reduces the risk-reducing properties of aggregation on which insurance depends. Insurers are forced to respond by increasing reserve loads and adding catastrophic loads. Administrative costs are higher and investors expect a higher average return on equity. All of these factors lead to reduced quantity supplied and premium rates that are much higher than those for lines of insurance that protect against largely independent risks.

In-Between Risks and Transaction Costs

Beyond the transaction costs of acquiring needed information on insureds, there can be significant transaction costs associated with obtaining reinsurance. Recall that because of the potential for huge losses, primary insurance companies almost always obtain reinsurance for in-between risks. The initial reinsurer may, in turn,

purchase reinsurance for some portion of the in-between risk acquired from the primary insurer. This activity may continue though several layers of reinsurance. Structuring multiple layers of reinsurance can be costly. Each reinsurer will make a "due diligence" assessment, both of the risk being obtained and of the company from which it is being obtained. Likewise, the company ceding risk will want to be sure that the reinsurer actually has the capacity to fulfill the reinsurance contract in the event a catastrophic event occurs. In markets for independent risks, the benefits of risk reduction more than offset the transaction costs of reinsurance. In markets where risks are correlated, exchange markets involve lower transaction costs than using traditional reinsurance.

Reinsurance contracts do not fully protect the insurer ceding risk. As with retail insurance policies, reinsurance contracts typically include deductibles, copayments (called quota-shares among reinsurers), and indemnity limits (stop losses). The insurer ceding risk must maintain capital reserves to cover the loss risk not ceded to the reinsurer. There are significant opportunity costs associated with reserves since they must be kept in a relatively liquid form. The potentially large loss exposure from in-between risks requires that insurers bear the opportunity cost of maintaining large reserves. Jaffee and Russell further argue that the presence of large liquid reserves could potentially make publicly traded insurers susceptible to unfriendly takeover attempts. Resources expended in fighting off such attempts could be considered another transaction cost of insuring in-between risks.

Additional transaction costs are imposed by the regulatory environment. Every state has a state insurance commission that regulates insurance products. Before being allowed to sell an insurance product, insurers must undergo a review by state insurance commissions regarding product design and premium rates. Furthermore, the insurer must provide assurances that it has the capacity to pay insureds in the event of worst-case scenarios (Klein).

Scientific disagreements often exist about the actual probability of occurrence for in-between risks. Disagreements also exist about the potential magnitude of loss. A conservative insurer who builds large reserves to cover expected losses from in-between risks may become susceptible to consumer activists who contend before the state insurance commission that the large reserves are evidence of overpricing (Jaffee and Russell). After reviewing proposed rate hikes based on computer forecasts of catastrophic losses, the state insurance commissioner in Florida recently said, "I will not let the consumers of Florida become hostage to a computer" (Stipp).

At the federal level, transaction costs include bans on practices that could facilitate improved financing of risk-sharing markets. An example is the current ban on off-exchange trades of agricultural options. Further transaction costs are imposed by federal tax law. Earnings set aside in reserve are taxed in the year they are earned. Interest earnings on accumulated reserves are also taxed. This further increases the opportunity cost of maintaining adequate reserves when insuring in-between risks (Jaffee and Russell).

In-Between Risk and Cognitive Failure

Cognitive failure likely reduces the demand for sharing of in-between risks. Individuals typically do not know the probability of, or the potential magnitude

of, catastrophic loss events (Kunreuther 1976; Rossi, Wright, and Weber-Burdin). They are typically unable or unwilling to imagine the potential devastation that could be caused by low-frequency catastrophic events (Kunreuther 1996, Kunreuther and Slovic, Tversky and Kahneman). Decision makers often forget bad loss events (Buzby et al.).

Insurers not only must remember bad events, they must also be aware that a future loss event could be more severe than any experience in the record books. As indicated earlier, insurers of in-between risks typically add a catastrophic load to insurance premiums to account for potentially large but yet-to-be-experienced events. No one anticipated how severe the losses could be from persistent rains through the Midwest in 1993.

Consider how these factors may affect insurance markets for in-between risks. Buyers' willingness to pay is restricted by cognitive failure. Sellers are willing to supply insurance for in-between risks only at prices that have been loaded to account for the lack of information on true underlying loss distributions and the high administrative (transaction) costs associated with acquiring reinsurance and maintaining adequate reserves. It is very likely that these imperfections cause markets for insuring against in-between risks to clear at less than socially optimal quantities of risk sharing.

Traditional Government Involvement

There have been at least three federal government responses to incomplete risk-sharing markets for in-between risks: (*a*) free federal assistance; (*b*) private sector retailing of subsidized government insurance with no private sharing of loss risk; and (*c*) private sector retailing of subsidized government insurance with private sharing of loss risk.

Free Disaster Assistance

Political incentives encourage government financial assistance to victims of widespread natural disasters. In the wake of human suffering, any tough-mindedness tends to give way to an emotional desire to see the effect of the loss reduced. Two former members of Congress have argued that in a postdisaster political environment there are essentially no incentives for members to vote against disaster assistance (Downey and Weber 1994). This is particularly true if the spending can be designated as "emergency supplemental appropriations." This designation means that the appropriations are exempt from spending limits imposed by the federal budget process and therefore do not have to be offset by corresponding spending cuts or tax increases. As a result, disaster assistance appropriations bills become "vehicles" for appropriating funds for many unrelated programs. The disaster assistance legislation passed in the wake of the 1994 Northridge California earthquake contained spending for Pell education grants, rebuilding of a highway damaged by the 1989 San Francisco earthquake, and U.S. peace-keeping efforts in Somalia, Iraq, Haiti, and Bosnia (Malkin 1994).

Between 1980 and 1996, the federal government provided approximately $19 billion in free disaster assistance grants to individuals. Over 70% of this went to farmers who suffered crop losses. Over the same period, the federal government initiated over $26 billion in low-interest disaster loans. Almost 50% of these loans

were for farmers. Barnett estimates the total federal cost of these programs over the period at almost $30 billion.

Free disaster assistance is seen by some as an equitable way of transferring small amounts of money from many taxpayers to the few who have been damaged. Others argue that government disaster assistance is inherently inequitable because those who assumed risk, through their choices, have shifted it to all taxpayers (Rossi, Wright, and Weber-Burdin). Evidence of inequities is found in Farm Service Agency (FSA) disaster payments to farmers. During the seven years between 1987 and 1993, 107,042 farmers received disaster payments in four or more years. Although these farmers were only 8% of the total number who received disaster payments over the time period, they received almost 29% of the total payments disbursed (Hoffman, Campbell, and Cook).

The incentives created by disaster assistance generally cause society's scarce resources to be misallocated. This is especially true if decision makers recognize the expected value of the assistance and incorporate this value into their decisions. Resources that would yield higher social benefits if used elsewhere are used to rebuild homes on flood plains and fault lines and to compensate farmers whose crops routinely fail—stimulating yet another cycle of losses and relief payments.

Government as Primary Insurer

Based on arguments of insufficient reinsurance capacity, policy makers have created programs where the U.S. government functions either as an insurer or reinsurer for various types of insurance. A classic example is the Federal Deposit Insurance Corporation (FDIC). Because private insurance markets are unable to accept the highly correlated risk of bank failure in the United States, the federal government insures bank deposits through the FDIC. In the last several sessions of Congress, legislation has been introduced that would create a federally facilitated, national property and casualty insurance pool. These efforts are driven by concerns over the correlated risk inherent in natural disasters such as earthquakes and hurricanes (GAO 1994, 1995).

In the national flood insurance program, federal flood insurance policies are sold through private insurance companies. The private companies receive a commission but retain no loss risk. The policies provide insurance to residents of communities that adopt specified flood mitigation requirements. Premium rates are subsidized until completion of a flood insurance rate map.

Special flood hazard areas (SFHA) are defined as areas with at least a 1% chance of flooding in a given year. Federal law requires that buildings in SFHA must be covered by a national flood insurance policy if financing is provided by a federal agency or if financing is provided by a lender that is regulated by a federal agency. However, Kunreuther (1996) reports evidence that many purchase flood insurance policies at the time their mortgages are initiated but at some point in the future, after experiencing no losses, cancel the policies.

Public–Private Partnerships with Government Reinsurance

Correlated risk arguments also are used to justify the federal government's role in U.S. multiple-peril crop insurance markets. Private insurance companies sell and service subsidized federal multiple-peril crop insurance policies. The policies are

reinsured through standard reinsurance agreements (SRA) with the Risk Management Agency (RMA) of the USDA. The SRA contains both quota share and stop loss provisions. Quota share provisions specify what percentage of premiums and loss exposure the private company will retain, with the remainder being passed on to the federal government. Stop loss provisions specify the maximum dollar amount of loss that the company will have to cover before the government steps in to cover all additional losses.

Furthermore, the SRA specifies three reinsurance funds, each with different quota share provisions: (*a*) a commercial fund for business representing sound underwriting risk, (*b*) a developmental fund for business representing unknown underwriting risk, and (*c*) an assigned risk fund for business representing unsound underwriting risk. Company premium and loss risk retention is highest in the commercial fund and lowest in the assigned risk fund.

A private reinsurer would not allow an insurance company to identify policies that they expect to be profitable and policies that they expect to be unprofitable and then selectively pass on more of the unprofitable business to the reinsurer (GAO 1995), so why does the federal government allow this? There are two reasons. First, historically, private insurance companies have not been allowed to establish premium rates. These are established by the RMA. If the RMA establishes premium rates that the company feels are too low for certain policies, then it only makes sense that the RMA should have to take most of the risk on those policies.

The second reason that private companies are allowed to assign business to different RMA reinsurance funds is that politicians view federal multiple-peril crop insurance as both an insurance program and a government social program. They want everyone to be able to purchase multiple-peril crop insurance at reasonable premium rates. Yet, by nature, insurance is discriminatory. Well beyond the rate differentials charged to different individuals, insurance underwriters can actually refuse to insure certain individuals. If coverage is offered, the underwriter will attempt to determine the risk exposure associated with the policy so that an appropriate premium rate can be charged.

For federal multiple-peril crop insurance policies, underwriting is carried out by a government agency that faces strong political incentives to provide reasonably priced coverage for all who desire it. Because the private companies do not conduct the underwriting, they do not want to retain risk for policies that might be misclassified.

Recently, private companies have created new crop revenue insurance products that are subsidized and reinsured by the RMA. The companies develop rating, underwriting, and loss adjustment procedures on these new products. Because the products are reinsured through the SRA, the RMA insists that the policies and procedures be thoroughly reviewed. These reviews have been a continual point of friction between private insurance companies and the RMA. The insurance companies argue that the reviews are a costly and seemingly endless bureaucratic entanglement. The RMA argues that the reviews are necessary to protect taxpayer interests.

Private sector innovation is further hampered by the lack of an exclusive claim to intellectual property rights. New crop yield and revenue insurance products cannot compete with existing federally subsidized products unless they too are subsidized and reinsured by the RMA. But once a product is subsidized and re-

insured by the federal government, the developing company loses its exclusive claim on the product. Every company selling the federal product gets immediate access. The inability to earn exclusive rents for a period of time severely limits incentives for new product development.

The federal multiple-peril crop insurance program has also proven to be quite susceptible to rent-seeking activity. Changing the rules during the growing season has been common, as those at risk seek yet more government subsidies. Political decision makers have frequently altered program provisions to benefit farmers and private insurance companies.

New Innovations in Private Sector Risk-Sharing

The market for sharing catastrophic risks is changing. Recent developments may lower the transaction costs of securing the capital needed to insure against large catastrophes (Doherty, Lamm, Skees). Insurers and reinsurers are utilizing a wide variety of contingent claims instruments to securitize catastrophic risk exposure. The most striking examples are catastrophic bonds (CAT bonds) and the catastrophic insurance options (CAT), which are now traded on the Chicago Board of Trade (CBOT).

CAT bonds are new debt instruments that provide capital contingent on the occurrence of a disaster. More than thirty such bonds providing over $10 billion of "synthetic reinsurance" have been sold since 1994. Those purchasing CAT bonds receive a relatively high rate of return if there are no catastrophes. They may lose some or all of their investment if a catastrophe does occur. Fund managers are attracted to CAT bonds because the returns on the bonds are uncorrelated with traditional equity markets.

The CAT insurance options traded on the CBOT are based on Property Claim Services (PCS) catastrophe loss indices for nine geographic regions in the United States. This exchange market provides an exposed insurance company the opportunity to share large amounts of loss risk from either earthquakes or hurricanes with market speculators. Trading of these contracts can occur even as the event is developing. For example, insurers can use CAT options to purchase extra coverage as a hurricane approaches an exposed market. Open interest on CAT insurance options has consistently exceeded 4,000 contracts for a few years now.

Similarly, the CBOT also trades Crop Insurance Yield contracts. These cash-settled contracts are based on USDA estimates of state crop yields for major crop-producing states. Both futures and options contracts are available. Unlike the CAT contract, which has experienced increased open interest since its introduction, there has been limited trading interest in Crop Insurance Yield contracts. The federal government provides subsidized reinsurance for multiple-peril crop yield insurance, thus crowding out some of the potential demand for these contracts. In contrast, the federal government currently does not provide reinsurance for the property and casualty insurance industry—although legislation that would develop a federal property and casualty reinsurance pool has been introduced in the last three Congresses.

Capital market innovations show potential for increased financing of catastrophic risk, but these markets are in infant stages (Doherty, Lamm). Together, CAT bonds and CAT insurance options currently account for less than 5% of national

reinsurance capacity. Although fund managers like the high expected returns and diversification benefits from holding CAT bonds, they also recognize the potential for having to report large losses to investors. For this reason, some call CAT bonds the "ultimate junk bond."

Exchange-traded CAT insurance options must cover geographic areas large enough to stimulate sufficient open interest but small enough to generate acceptable basis risk—that is, the individual losses must be sufficiently correlated with the index that triggers the payment to provide risk protection. Viability is almost totally dependent on sufficient interest from speculators. It is hard to imagine a firm that would need to hedge against the possibility of a catastrophe not occurring. As with standard reinsurance, the market for these instruments is likely to be characterized by myopic behavior that leads to exaggerated short-term shifts in supply and demand. The resulting erratic prices could further limit market development.

Current levels of government assistance to disaster victims will limit demand for these instruments (Barnett). Private markets simply cannot compete against free *ex post* insurance. In the farm and food system, the 1998 disaster payments to crop farmers is the most recent example of government assistance. These payments explicitly violated the commitments of the 1994 Crop Insurance Reform Act to provide no more disaster aid.

A New Role for Government

Violations of insurability conditions, transaction costs, and cognitive failure create incomplete risk-sharing markets for in-between risks. The federal government has responded with free federal assistance and public–private partnerships that deliver subsidized government insurance. Free federal assistance creates perverse incentives that may lead to a self-perpetuating cycle of increased risk taking. Existing public–private partnerships are plagued by inconsistent objectives, transaction costs associated with bureaucratic behavior, little incentive for innovation, and opportunities for rent seeking. New private sector innovations for sharing catastrophic risk hold promise; yet, questions remain about the viability of these markets. More importantly, no private market can compete against a government determined to provide disaster programs for the farm and food sector and rural communities.

Our policy proposal rests principally on five assertions developed earlier. First, the supply of risk sharing for in-between risks is greatly reduced by violations of insurability conditions and transaction costs associated with reinsurance, regulation, and taxation. Second, cognitive failure is a real phenomenon that reduces the demand for sharing of in-between risks. Third, free disaster relief is inefficient and self-perpetuating. Fourth, traditional government natural disaster insurance programs have been plagued by adverse selection, moral hazard, high transaction costs, disincentives for innovation, and rent-seeking activity. Fifth, absent government involvement, private markets for sharing in-between risks will clear at low quantities that are socially unacceptable. Resulting political incentives will guarantee some form of government response—disaster assistance, subsidized loans, subsidized insurance, etc. Thus, the relevant question for economists is not Should the government be involved in markets for sharing in-between risks? but rather Are there more efficient ways for the government to be involved in these markets?

We suggest government provision of natural disaster index options as a second-best policy solution that would be far more efficient than current disaster assistance and subsidized insurance programs. These options would be based on either objective measures of events or statistical estimates of area yields. First, we introduce flood level options as a method for protecting rural communities from flooding. Next, we suggest options based on USDA estimates of state crop yields as a means to reinsure the multiple-peril crop insurance program. Finally, we explore options based on either rainfall or soil moisture measures.

The examples presented share some common traits. Each provides an objective and independent source of information for measuring the occurrence of an event. It is possible to statistically estimate the distribution of outcomes. Historical data either already exist in the public domain or could be made available, allowing for complete transparency. The options conceivably could be sold through a competitive bidding process (Lewis and Murdock). The ability to use these options to transfer catastrophic risk could facilitate more private sector risk-sharing activity. Creative insurance firms that use government options to protect against catastrophic losses could then develop tailored insurance products to meet the specific needs of their customers. After using government options to shed catastrophic risk, the remaining residual risk contained in tailored individualized insurance products should be largely independent and, hence, inherently insurable. In contrast to current government natural disaster insurance programs, there is no reduction in insurers' incentives for maintaining actuarial soundness.

Government Options on Floods

Because many natural disasters are triggered by events that can be measured and quantified, the government could simply write options on events and auction them (presumably with a reservation price) to insurance and reinsurance interests. For example, the government could write options on flood levels for rivers as a mechanism to protect against catastrophe risks. When the river exceeds a certain level selected by the insurance or reinsurance company (the strike) the government would make a payment. To illustrate further, consider a case where an insurance company has written $10 million in insurance liability for a community. The company knows the hydrology of the river (this information is typically available from the Army Corp of Engineers), and they know their exposure. By using geographic information systems, the insurance company can map the likely magnitude of losses at different flood levels. This will not be a perfect match because other variables, such as speed of the water flow or time of year, will also influence losses, but flood level is a major variable that contributes to losses. If the insurance company starts incurring significant losses when the river exceeds 10 feet above flood stage, they may choose to purchase a call option with a strike at that level. Payment would be based on the percentage above 10 feet until the percentage reaches 100. These percentages would be multiplied by the value of the option. For example, if the water level reached 15 feet above flood stage (50% above the strike), payment would be equal to 50% of the face value of the option.

The insurance company cannot adversely select on the government. Everyone knows the relevant government statistics on the natural phenomenon of interest and everyone has the same opportunity to purchase the government option. By

making the system completely transparent, the government has reduced the asymmetry in information and reduced the incentives for rent-seeking based on complexity.

By providing a relatively low-cost mechanism for shifting uninsurable catastrophic risk, government disaster options would facilitate private sector market development. Either the primary insurance company would purchase the government options or the reinsurance company may purchase the options and give more direct and traditional reinsurance to the primary company. Ideally, the government options would be sold with strikes set to protect against only the most serious catastrophes (i.e., far out of the money). By purchasing such options, insurers or reinsurers could shift the uninsurable correlated loss risk to the government and develop tailored insurance products to protect against the residual, largely independent, risk exposure.

Government Options on State Crop Yields

As another example, consider the federal multiple-peril crop insurance program. The government arrangement under the standard reinsurance agreement allows companies to adversely select which business they desire to share the risk on and which they choose to pass on to the government. Because federal multiple-peril crop insurance is available to anyone, this is considered a necessary arrangement. Nonetheless, the current system creates little incentive for fixing some of the fundamental problems that have plagued the federal multiple-peril crop insurance program and created very poor actuarial performance in some regions. One way to "start over" in the multiple-peril crop insurance program would be for the government to sell put options on state crop yields. These contracts could be patterned very much like the CBOT crop insurance yield contracts. However, they would be available for all major crops on a state by state basis. Development and delivery of specific crop insurance products to farmers could then be left to private insurance companies.

To demonstrate the degree of correlation between crop yield shortfalls and the historic loss ratio for the federal multiple-peril crop insurance program, a simple analysis was performed. We focused on the major crops that comprise over 90% of the exposure for the federal multiple-peril crop insurance program. First, state crop yields were trend adjusted. Next a percentage shortfall measure was calculated using the simple equation

if   actual state yield (ASY) $<$ trend-predicted state yield (TPSY),   then

$$\text{percent shortfall} = (\text{ASY} - \text{TPSY})/\text{TPSY}.$$

Nearly 80% of the insurance volume is in states where the correlation between percent shortfall and state crop insurance loss ratio (total indemnities/total premiums) exceeds 75% over the period 1981–1997. Iowa corn yield shortfalls are 99% correlated to the state loss ratio on corn insurance policies. If the government auctioned put options on state crop yields, there would be no need for a complex reinsurance agreement that offers significant barriers to entry and unique rent-seeking opportunities. Furthermore, the multiple-peril crop insurance companies could be creative in the products they developed, while being prudent to design products where the systemic risk would be covered by the state put options. Under

the current system, every federal multiple-peril crop insurance product developed by a private company must undergo scrutiny because these products may put the government at risk. If the government is only selling low-level put options on state yields, this would no longer be needed.

Government Options on Rainfall/Soil Moisture

As a final suggestion for event-based options, consider how the government could facilitate more development of private insurance by writing catastrophic options on rainfall or soil moisture. Many countries have good sources of historic rainfall data. These data can be used to develop reasonable estimates of cumulative rainfall distributions for specific periods. Given such distributions, it is a straightforward matter to write options on either too little rain or too much rain. The World Bank is investigating this concept in Nicaragua (Hazell and Skees; Skees, Hazell, and Miranda). Rainfall options can be used to protect against any number of economic losses that are highly related to either too much or too little rain. For example, an excess rainfall contract could be used to protect against the water-related problems that are created by tropical storms or hurricanes; rainfall shortfall contracts can be used to cover crop losses, unavailability of irrigation water, low river flows and disruptions of shipping, city water shortage, etc. Secure rainfall stations are a requirement. By the same token, objective measures of soil moisture could be used as the basis for catastrophic government options on specific low or high levels of soil moisture. For agricultural purposes, soil moisture may be a better index than rainfall as there should be a higher correlation between crop yields and soil moisture. For either rainfall or soil moisture, improved information systems that utilize satellite images hold significant promise to reduce the transaction costs of monitoring.

Conclusion

Society continues to struggle with appropriate means for protecting citizens from losses suffered due to natural disasters. Insurance markets for these low-frequency, high-consequence events are incomplete. Market shortcomings are used as justification for providing free assistance after disasters occur. Such assistance generates perverse incentives. When given free assistance, individuals take on more risks, making it almost certain that the next natural disaster will bring about even more losses and suffering. Direct government provision of subsidized insurance is fraught with problems as well.

To the extent that the government will be involved in natural disaster risk-sharing markets, we suggest that a more efficient means would be to auction government options on indexes that would facilitate reinsurance for low-frequency, high-consequence events. Under this system, private sector firms will be prudent in offering insurance that is sound. Furthermore, these firms will not become rent-seekers who have little incentive to fix problems that may be present in government-based insurance. Finally, if the government offered catastrophic options (with strikes available only well "out of the money") the way would be cleared for international markets to increase access to additional private capital for risk sharing from natural disasters.

Acknowledgment

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