Managing unknown risks: the future of global reinsurance

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It has been said that insurance is the last of the financial services to accept radical change (Denney [1995-1996]). Yet there has been a fundamental shift in the geographic location and in the organization of the reinsurance industry in the last six years (Chichilnisky [1996b]). Global environmental risks are partly responsible for this change; increased weather volatility and catastrophic risks are difficult to diversify using traditional insurance practices.

To provide a map to the future, we need a realistic appraisal of how we got where we are. This is the story of how humans have hedged risks. There are two basic and distinct approaches: statistical and economic. The former is typical of the insurance industry; the latter typifies the securities industry. Both are needed to manage today's catastrophic risks. Neither alone will do. We show how a combination of both leads to efficient outcomes, and is the way to the future (Chichilnisky [1996a, 1996b, 1996d]).

The volatility of weather, taken together with population movement to warm coastal areas and changing property prices, has made catastrophic risks highly unpredictable. Many scientists believe that climate change could be the source. A recent report by the Intergovernmental Panel on Climate Change (IPCC), charged by governments with investigating global warming, says that humans have a "discernible" influence on global climate.

In May 1996, insurance executives confronted the energy industry over global warming, and took their

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case to the United Nations Geneva meeting on climate change in June 1996 (Boulton [1996]). Their case was heard, and for the first time the United States took a leading position in supporting the developing countries' calls for hard targets in the reduction of greenhouse gas emissions in the industrial countries. Environmental markets that trade countries' rights to emit have been proposed and loom large on the horizon.[1]

FINANCIAL RISKS

Although the data on climate change are not conclusive, the financial challenge is already real. In the last few years the property/casualty insurance industry has experienced record claims of about US$43 billion connected with climate volatility. In the United States alone, there was the 1988 Midwest drought, the 1993 Midwest floods, and 1995 flooding along the California coast. Hurricane Andrew in 1992 produced about US$18 billion of insured losses and total losses greater than US$25 billion (Chichilnisky [1996a]).

Andrew was the most devastating natural catastrophe ever recorded. It also led to a wave of financial catastrophe; the hurricane affected almost every insurance company in the United States. Not knowing how to hedge unpredictable risks adds the risk of financial catastrophe on top of that of the natural catastrophe, a one-two punch that could lead to a societal disaster. The year after Andrew, thirty-eight non-U.S. and eight U.S. reinsurers, with names as familiar as Continental Re and New England Re, either withdrew from the business or ceased underwriting catastrophe reinsurance (Chichilnisky [1996b]).

Facing an impossible challenge, many reinsurers left the market. Worldwide reinsurance capacity dropped more than 30% between 1989 and 1993, and it appears that over 20% of that is due to Andrew. This naturally led to changes in the marketplace. Insurance companies could not buy enough catastrophe reinsurance, no matter how hard they tried. As supply dried up, prices of course increased dramatically; the rate on line went from 8.2% in 1989 to 21.4% in 1994.

Higher prices then attracted new capital. This led to a major geographic shift of the industry. Continuing doubts about the future existence of Lloyd's of London led to a drop in the U.K. market share, from about 56% in 1989 to 23% in 1995. Since 1993 Bermuda's reinsurance industry evolved from practically zero to its current position of 25% of the market. Investment banks are now betting heavily on the reinsurance market. They are the owners of most of the businesses created since 1992.

REVOLUTION IN GLOBAL FINANCE

Together with the geographic shift, there has been a substantial shift in the industry's strategy. The insurance derivatives that have been recommended for several years are starting to play a role.

In 1992, we recommended the creation of an instrument to bet on the frequencies of catastrophes, which the Chicago Board of Trade (CBOT) introduced under the name Catastrophe Futures in 1993 (see Chichilnisky and Heal [1993]). In 1997, Morgan Stanley started marketing a similar instrument: a bond issue whose returns are linked to hurricane frequency and severity in the current U.S. season. Recently, Merrill Lynch structured a transaction for USAA, the country's largest direct marketer of home and car insurance, offering US$500 million in bonds on the U.S. capital markets that are tied to the company's losses from hurricanes (see Waters [1996]).

Financial innovation in reinsurance markets is slowly developing, but the underlying pressure is relentless. Everyone knows that access to more liquid capital markets is essential to the reinsurance industry. The derivatives market is the key to liquid and flexible trading of weather risks.

UNKNOWN RISKS

Unknown risks are risks whose frequencies we do not know, and for which we are aware of our ignorance (Chichilnisky [1996d]). You could think of these as risks for which we have more than one actuarial table, each equally likely. There is more than one prior estimate of the frequency of the event (see Cass, Chichilnisky, and Wu [1996]).

Examples of unknown risks are environmental health risks of new and little known epidemics, or risks induced by scientific uncertainty in predicting the frequency and severity of catastrophic events such as nuclear reactor and satellite risks. These risks are driving major changes in the insurance and reinsurance industry today (see Chichilnisky and Heal [1998]).

Take a simple example. One reliable source gives a 2% annual chance of the occurrence of a hurricane of a certain type, and another a 12% chance. Monte Carlo simulations and other procedures can be used to attempt to tease from all models a unique statistical approximation to the true frequency. But what if there *is* no true frequency?

How could this be? Easily. There may be two possible climate patterns, both equally likely. This is typical of complex and chaotic systems such as the climate (see Chichilnisky [1998]).

Many climate experts view climate as a fundamentally non-linear phenomenon in which chaotic patterns emerge easily. Such systems can have two "attractors," or two distinct overall patterns of behavior, each significantly likely. Each of these attractors describes a weather pattern, a reasonable statistical inference of the frequencies of a major event. In such a chaotic system, it is scientifically impossible to predict from the initial conditions which of the two patterns the climate will take: a pattern with two hurricanes a year, or the other with a dozen. Because we cannot predict, we face a risk. We call it a chaotic risk because it emerges from the chaotic nature of the climate system.

The first statistical reaction is to construct a new actuarial table by taking an average; assuming the two states, 2% and 12%, are equally likely, this is 7%. But taking an average does not help. It only ensures that one is wrong 100% of the time: 50% of the time we are overinsured (the pattern with two hurricanes per year), and the other 50% we are underinsured (the pattern with a dozen a year). Both have major financial costs. If each hurricane leads to US$2 billion in losses, the averaging method leads to a US$10 billion shortfall 50% of the time and US$10 billion overinsurance the other 50% of the time. Hardly a measured way to manage risks.

Is there a solution to this problem? The good news is that there is. It is possible to hedge such unknown risks successfully and efficiently. To do so, however, one needs a careful and customized approach that blends both insurance and securities approaches to hedging risks.

TWO WAYS TO HEDGE RISK

Insurance: The Statistical Approach

The *statistical* approach to hedging risks, which relies on the law of large numbers, is the traditional foundation of the insurance industry.

For this to work, risks must be reasonably independent across individuals or groups, and the frequencies must be known. Loss of life and car accidents are typical examples. Here the law of large numbers operates.

There is safety in numbers; with a large enough population, the number of those likely to be affected is known with considerable accuracy. The sample mean is highly predictable if the distribution for each person or group is known. This is the standard principle on which insurance operates.

Reinsurance is simply a way to augment the pool of those affected so that the law of large numbers operates better. All that is needed is a reliable actuarial table describing the incidence per person or group, and a large pool of insureds to distribute the risk (see Chichilnisky and Heal [1993]).

If the numbers are not large enough, it is standard to spread risk through time. The number of people affected by a hurricane over a ten-year period is at least ten times that affected in one year. This requires that the risks be independent through time, eliminating irreversible risks such as once-and-for-all shifts arising from global warming.

Hurricanes such as Andrew (1992) and Opal (1995), however, defy the law of large numbers. They affect large areas all at once, both in physical and in financial terms, and their frequency and severity seem to be changing. The actuarial table itself has become the risk. Insurance does not work. What are the alternatives?

Derivatives: The Economic Approach

An alternative is the *economic* approach. This works best for correlated risks, in which the same event occurs for many people all at once. A drop in the value of the dollar is an example; the event is the same for everyone in the U.S. economy. There is no way to *pool* this risk, although, as we all know, we can hedge it by using derivatives (currency futures or options). The principle used here is negative correlation. One hedges by taking a position that is highly correlated with the risk, except with the opposite sign.

For example, an investor with a dollar-based portfolio who fears a drop in the value of the dollar can buy a futures contract in yen, or a dollar put. If the dollar drops in value, the investor is covered by the increase in the value of the derivative. Bear funds have been constructed on this principle.

The economic procedure is radically different from the insurance approach in that it does not require a large number of people. Nor does it require knowing the frequency of the event or the actuarial table. This fundamentally different method is the way the securities industry operates. Instead of *pooling* risks, one *trades* risks.

Securities markets are, however, notoriously complex. For example, the procedure of trading risks just outlined makes no sense for individual risks, such as death. How would we describe the death of one single person within a large economy as one event on which all of us can trade? To do so would require an unrealistically high number of securities, indeed 2^x, where x is the number of people in the economy. In a world with five billion people, the number of securities could exceed the number of all known particles in the universe (see Chichilnisky and Heal [1998]).

Insurance, instead, deals with such risks expeditiously. If all individuals are in a similar risk class, one insurance contract would suffice. The contrast is stark, but it makes a point. In a world of unknown risks, neither securities nor insurance methods work in isolation.

THE IDEAL HEDGE: CATASTROPHE BUNDLES

We see that insurance does not work when the frequency of a risk is unknown, and securities do not work when the risks are individual. If neither of these two approaches works on its own, what does work?

The ideal hedge is a combination of insurance and securities; this can achieve efficient allocation of risk-bearing. We call this a *catastrophe bundle* because it bundles together two types of instruments. It consists of an insurance instrument with a novel derivative security for betting on the frequency itself (see Chichilnisky and Heal [1993]).

The latter type of security has emerged and is now traded on the CBOT. As we have mentioned, related securities have recently emerged also in the form of bonds floated by Morgan Stanley and Merrill Lynch.

The combination of both instruments ensures that no financial catastrophe will occur, since the reinsurer is not exposed to more risks than it can afford. At the same time, this approach can be used to provide nearly full coverage for the insured at a minimal cost.

We show elsewhere that such instruments lead to an efficient allocation of risk-bearing (see Chichilnisky and Heal [1993, 1998] and Cass, Chichilnisky, and Wu [1996]). They require a carefully customized approach to hedging risk. This gives the traditional face-to-face insurance approach an edge over raw technology.

HOW DO CATASTROPHE BUNDLES WORK?

Catastrophe bundles work best in the hands of an experienced reinsurer or broker who can customize the instrument to the client's needs. In a way, the reinsurer is selling a package that consists of insurance, a security, and a risk management/consulting tool.

The broker must first identify with the client the set of possible descriptions of the risk. This crucial part of the process involves new techniques of risk management. It is best handled on a face-to-face and customized basis. A mathematical formula is then brought to bear in customizing catastrophe bundles to customer needs. This formula works very well when there is more than one pattern of risk and therefore more than one "possible" actuarial table, each table being substantially likely.

After this is achieved, derivative securities whose payoffs depend on which description of the risk is correct are introduced. These securities serve to hedge uncertainty about actuarial tables. Finally, one structures insurance contracts that establish a compensation arrangement in a way that depends on which description of the risk is correct.

Catastrophe bundles are proprietary, and their use in a particularly simple case is illustrated in Exhibit 1.

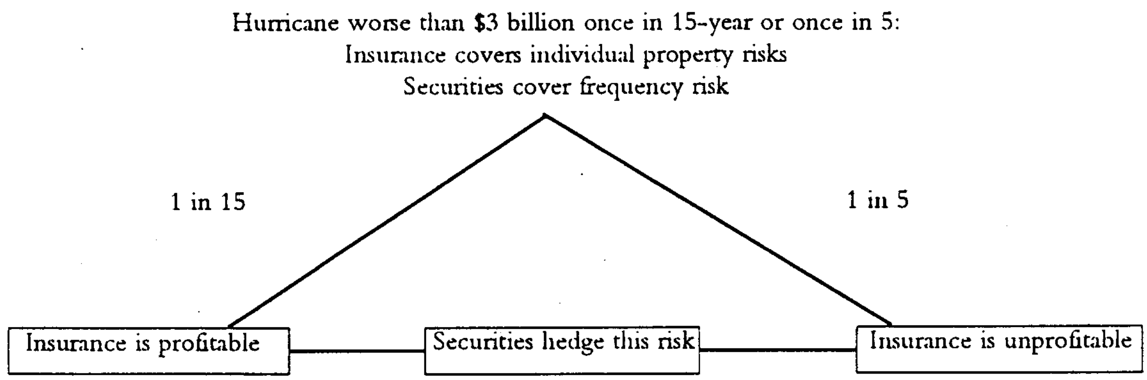
PRICING AND OPTIMAL PORTFOLIOS

Fund managers can look at the flip side of this picture and seek a combination of insurance and securities that offer an optimal portfolio in insurance and investment markets. A part of this instrument is what Merrill Lynch and Morgan Stanley have floated recently. Securitizing such instruments is, of course, the next step.

Through the use of catastrophe bundles, the reinsurance broker can access a large pool of managed funds while offering its clients a customized reinsurance service that manages risks optimally, and at very competitive prices.

Pricing, of course, is a crucial issue. What is needed here is to separate two parts of the risks and to push each as far as it will go. The contingent insurance part of the instrument should be applied as far as possible, covering the independent part of the risk for which it is optimally suited. Securities are then used for the purpose for which they are best: the correlated part of the risk. A mathematical formula used to construct the catastrophe bundle separates and prices both parts.

EXHIBIT 1
CATASTROPHE BUNDLE EXAMPLE



CONVERGENCE OF INSURANCE AND SECURITIES MARKETS

It is no secret that the securities industry is making inroads into the reinsurance business. By itself, however, it cannot succeed, because the individual parts of the risks cannot be handled efficiently by securities markets; they are too cumbersome for individual risks. Insurance, based on the law of large numbers, has an important place in simplifying financial transactions and hedging known individual risks.

Catastrophe bundles offer one approach to computing the limits of each instrument, and blending them optimally to achieve the most competitive pricing of a catastrophe reinsurance portfolio.

The future of the industry is in the hands of those who achieve the optimum balance, through integrating derivative securities with contingent insurance contracts, and integrating technology with customized face-to-face know-how.

HURRICANE RISKS AND EL NIÑO: AN EXAMPLE

How exactly would catastrophe bundles work? We answer that question with a simple but typical example, drawn from hurricane insurance. Hurricane incidence is conditioned by the ENSO cycle, so we consider, instead of hurricane bonds of the type that have recently been issued, a tradable ENSO index.[2] This index would achieve everything one needs from hurricane bonds, but in a more general and simple fashion.

A tradable ENSO index is a contract that pays an agreed amount contingent on the value of a physical index. It is similar in concept to the catastrophe futures traded on the CBOT, and is an example of a security conditional on the incidence of the insured peril, that is, on which risk description is correct.

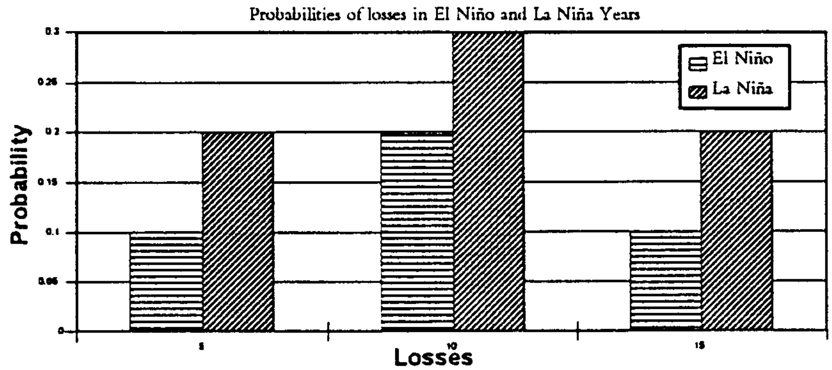
There are two extreme states of the ENSO cycle, known as El Niño and La Niña. In El Niño years, hurricane incidence in the southeastern U.S. is below average; in La Niña years, it is above.

Exhibit 1 shows possible probability distributions of damage due to hurricanes conditional on El Niño or La Niña years.

As an example, assume that, in an El Niño year, there is a 10% chance of a $5 billion loss, a 20% chance of a $10 billion loss, and a 10% chance of a $15 billion loss. The expected value of the damage is therefore $(0.1 \times \$5) + (0.2 \times \$10)+(0.1 \times \$15) = \$4$ billion. In a La Niña year, the probabilities are 20%, 30%, and 20%, respectively, giving an expected loss of $7 billion. Assume that there is a 40% chance of an El Niño year, and a 60% chance of a La Niña year.[3] The total value of insured property is taken as $30 billion, so that in a worst case scenario — when the hurricane damage is at its maximum of $15 billion — half of this value is at risk.

In an El Niño year, the expected loss is 13.33% of the insured risks, and in a La Niña year, it is 23.33%. It follows that the rates on line (i.e., premiums as a percentage of the insured amount) conditional on being in El Niño and La Niña years would need to be at least 13.33% and 23.33%, respectively, to break even in expected value terms.

EXHIBIT 2
HURRICANE PROBABILITIES AND THE ENSO SYSTEM



As we have already noted, expected losses are different, depending on what type of year we are in. Before we know what kind of year will occur, we therefore have an expected loss due to El Niño equal to the expected loss in an El Niño year times the probability of such a year, i.e., (0.4 × \$4) = \$1.6 billion. For La Niña, the equivalent calculation is (0.6 × \$7) = \$4.2 billion. Hence, ex ante, before we know which year we are or will be in, the expected losses in El Niño and La Niña years are, respectively, \$1.6 billion and \$4.2 billion, giving a total of \$5.8 billion as the annual expected loss altogether.

We can now compute the premiums that would have to be charged for cover in each type of year before the type of year is known, in order to break even on average. These would have to be the premiums contingent on being in each year — seen above to be 13.33% and 23.33% for El Niño and La Niña — multiplied by the probabilities of each type of year. Thus the ex ante rates on line (before it is known whether we are in an El Niño or a La Niña year) have to be at least (0.4 × 13.33%) = 5.33% or (0.6 × 23.33%) = 13.99%, respectively.

If insurers follow the obvious and traditional procedure of charging premiums based on the overall expected loss and not distinguishing between the two climate patterns, they will charge premiums that will bring in their overall ex ante expected loss of \$5.8 billion, implying a rate on line of 5.8/30 = 19.33%. This is unsatisfactory because in El Niño years they are overcharging (expected claims are \$4 billion; the rate on line need be only 13.33%); La Niña years, they are undercharging (expected claims are \$7 billion; a rate on line of 23.33% is needed).

In the former case, the insurers are charging premiums in excess of expected losses by \$1.8 billion, hardly a competitive strategy, and in the latter case, premium income falls short of expected claims by \$1.2 billion, clearly a dangerous and unsustainable position. Neither case is satisfactory. To match assets to liabilities properly, insurers need to shift income from El Niño to La Niña years.

This is where securities conditional on incidence, on description of the risk, come into the picture. They can be used to transfer income between El Niño and La Niña years so that the surplus in the former cover the deficit in the latter. We need a security whose value depends on the incidence of hurricanes; for the purposes of this example, we take this to be a tradable ENSO index. This would be a contract whose value depends on the value of the ENSO index and in which traders can take long or short positions. By trading this security, the insurer in our example can in effect trade income in El Niño years for income in La Niña years.

The odds work out nicely. The insurer wants to sell \$1.8 billion in an El Niño year, its surplus of premium income over expected claims, which occurs with a 40% chance. Correspondingly, it needs to buy \$1.2 billion of income in La Niña years, to cover the shortfall between premium income and expected claims. In our example, this happens 60% of the time.

The prices for ENSO index contracts delivering \$1 in El Niño and La Niña years will be proportional to the probabilities of these events, and so will be in the ratio of 0.4/0.6 or 2/3. But \$1.2 billion/\$1.8 billion = 2/3, so that at such prices the sale of surplus income in El Niño years will exactly finance the purchase of income to cover the deficit in La Niña years.

Overall, then, we have a pattern of transactions as follows:

1. Issuing insurance contracts which provide cover against damage in either El Niño or La Niña years.
2. Selling \$1.8 billion of contracts contingent on the ENSO index having a value corresponding to an El Niño year, at a price of \$0.40 per dollar.
3. Buying \$1.2 billion of contracts contingent on the

ENSO index having a value corresponding to a La Niña year, at $0.60 per dollar.

This specific combination of trades in securities and insurance policies described in these steps is what we refer to as "catastrophe bundles." Through trading catastrophe bundles, insurers can arrange complete cover for themselves and their clients at minimum cost, in spite of not knowing what the odds of loss will be. They achieve this by a specific tailor-made combination of insurance contracts and securities. All these contracts are conditional on the incidence of the insured risk.

How different is this approach from the practice today? The securities issued today securitize insurance or reinsurance risks, and therefore bring more liquidity to the reinsurance market. This is an improvement. But these securities still leave open the possibility that the insurer is either offering non-competitive rates or taking on a dangerous exposure. Today's securities do not tackle the essence of the problem.

The key to catastrophe bundles is to recognize that when there are several possible actuarial tables, all reasonably likely, we have to supplement insurance introducing and trading securities dependent on them. A specific combination of insurance and securities, and an equally specific pricing policy, are required for an optimal allocation of risks on competitive terms.

ENDNOTES

[1]Chichilnisky [1996c] advances a proposal for a global market on greenhouse gas emissions and an International Bank for Environmental Settlements to handle executions, clearing, and settlements as well as regulate borrowing and lending rates.

[2]ENSO stands for the El Niño-Southern Oscillator, the name given to the weather pattern that originates in the equatorial Pacific and influences rainfall and storm incidence from Australia to southern Africa. An indicator of the state of the ENSO cycle is a sea surface temperature (SST) index for the equatorial Pacific.

[3]This is a simplification. There are also years that are neither, so-called neutral years. The numbers we use in this example are purely illustrative.

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