by Chris Barton and Graciela Chichilnisky

# A RADICAL SHIFT IN MANAGING RISK: PRACTICAL APPLICATIONS OF COMPLEXITY THEORY


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Complexity theory seeks windows of order out in a rough-and tumble world, something close to every insurance professional's or actuary's heart. Whether applied to physical systems in the laboratory or in a mathematical model, it can detect order in systems that may appear completely random. But in the real world it is just what its name says — theory. It may help us understand why things go one way or another, but it can not foretell those things with such certainty that an insurance company could, say, set its rates based on the knowledge that only one hurricane will strike Florida during the coming year. Yet we see a connection between complexity theory and risk management, which is the essence of insurance. In particular, from our different perspectives our research focuses on the risk management of complex systems. Admittedly, the detailed prediction of complex systems is inherently difficult, even impossible within many systems. But we take a position closer to analysts who say that you can sometimes discern patterns, even in chaotic systems. Often you can make predictions of the several different overall patterns that could emerge, providing you have the right models and instruments. Once you know what are the possible alternatives, even if you cannot predict which one of them will actually emerge, you can hedge future risks. In a nutshell, this is the approach we follow.

What is needed for better risk management is something in the nature of a gestalt shift and, in particular, financial innovation based on a new method of predicting overall patterns. Here the need is not to know the future (though people may tell you it is). In finance, analysts are not trying to predict the future (nobody can really do that); instead, they hedge against the risk of a downside future event. Whether we can predict the future is beside the point — it is a misunderstanding of the true nature of the problem. The challenge is knowing how to hedge effectively against an adverse event. After all, if the future were predictable, there would be no need for insurance in the first place. All that would be required is a steady accumulation of funds sufficient to pay the resulting losses, when a predicted event occurred, or better yet taking actions that mitigate losses beforehand based upon a clear cost/benefit analysis and an assessment of social impact.

Given that we can not predict events, to hedge effectively we must rely on a portfolio of mitigating actions and on financial innovation. We must focus on the management of risk in complex systems. They are most difficult, but they are frequently the best representation of how the world works today. With a bit more sophistication in decision making and financial innovation, we can deal with these systems. The approach suggested below will not do a perfect job — nothing can — but it provides a new way of managing and accounting for risk, and of dealing with apparent randomness.

## Order in Chaos

The key behavior of chaotic systems is that they exhibit order, and that order is expressed by what are called "chaotic attractors." Even though these systems are difficult to predict, and difficult to observe, they eventually settle into time-integrated patterns which constrain their future state for a period of time.

Think, for example, about the weather. Perhaps you have been told that a chaotic attractor defines two possible states into which the weather may settle. In one, there will be a high probability of 10 intense and destructive tornadoes. Conversely, in the other state, there are clear skies and an absence of intense storms.

In such a system, there are two corresponding actuarial tables for catastrophic storms, one with 10 such events and another with one. You are not predicting which will come to pass, only that one of two will happen and that they are equally likely. Given that you do not know which scenario will occur, the standard principles of insurance are not of any help in deciding what steps to take, based on the actuarial tables for the two scenarios. In one case, you decide to be very cautious and assume that 10 events will occur. Then you consider how much capital reserves are needed, given that assumption. If each of the events costs $1 billion, then you know you will need $10 billion. Of course, if there is only one event, the cost of carrying that collateral has been enormous, since you have been carrying 10 times the amount needed and the opportunity cost of that capital is not inconsequential.

On the other hand, if you decide there will be only one event, you will likely be under-protected. In that situation, the risk is financial catastrophe. What do insurers do in this case? They have several options; all, however, have accompanying downsides. One is to settle on something between the extremes of $1billion and $10 billion. If both patterns are equally likely, it could seem perfectly logical to divide the difference and choose $5.5 billion as the target. But by doing so they are guaranteed to be wrong 100 percent of the time — 50 percent of the time they will be overinsured and 50 percent of time they will be under-insured, by several billion dollars in both cases. If they are too low, and insuring themselves, they are making themselves liable for risks they can not cover. But if they set the target too high, they are forced to set unattractively high rates. They will likely end up losing their customers. In many instances, that is happening right now. If you want to insure property in the Caribbean for example, you must pay a premium that is roughly 33 percent of the value of the property. You know there is not a one-in-three chance of a catastrophic event. But because the possibility may, in fact, be one in 10, or one in two, insurers take something like an average. So we end up with 33 percent. As a result, most of the properties in the Caribbean are uninsured. Another option is self-insurance. Stanford University, for example, purchases no earthquake insurance. For many years, the university covered itself. Some may think of that as a solution, but it is not. In the end, regulators look at Stanford and say, "Okay — you are selling insurance to yourself. So all the usual state regulations about insurance apply to the university." Stanford, as a result, has the same burden of accumulating data, record-keeping, and reserves as any insurance company.

## Back to the Weather

Let us think again about those two possible weather patterns. What do they really mean? They qualify as a chaotic attractor with two possible states. One is associated with a certain type of weather; the other is associated with another type. Still, there is a lot of uncertainty with these two patterns; you can not make exact predictions. One pattern is associated with just one catastrophic storm, and the other with 10 storms. With chaotic systems, although you have identified the attractor, you can not predict whether you will settle into one state or the other.

## The Securities Component

The securities industry has a different approach to this dilemma than the insurance industry. The insurance industry knows that you can not predict when and where a specific event will hit, so it relies instead on actuarial tables to provide broader (statistically based) predictions inherent in the law of large numbers. This is the principle behind insurance – safety in large numbers. You can not predict precisely who will be hit, but you can predict how many people, overall, will be hit. Even if a given system is chaotic, you still have enough information to say something about it. What you say takes the form of one, two, or three possible scenarios and, with them, one, two, or three actuarial tables. Selecting from among them is the problem. The remedy is to use principles from securities markets. These markets do not rely on the sort of statistically based information the insurance industry uses. What they do is hedge. They operate by seeking patterns and, armed with that, hedge against probable downside risks. They hedge, for instance, when they use bonds and equities to provide a cushion against interest-rate changes — without looking for the statistical safety in numbers that characterizes insurance procedures. They search for factors that are correlated. Securities companies, then, hedge against correlated events, not by using the law of large numbers or insurance principles, but by using inverse correlation. The obvious question arises: "What I have is not stocks and bonds; it is two equally probable actuarial tables. What am I supposed to use as a hedge?" The answer is — use the same principles that have proved so successful in the securities markets. You hedge the risks in one of your actuarial tables against the risks in the other. You need to look at the risk not as something you are trying to predict statistically, but as the development of different scenarios. Then you, in effect, insure yourself by using insurance policies within each of the scenarios. In each case you assume the scenario that is going to occur. Insurance goes as far as possible – because it is a very efficient method – in dealing with one of the scenarios. But when dealing with multiple scenarios, where you have no way of deciding between them, you have to use a different financial instrument. This instrument is a security contract, one that is contingent not on interest rates but on actuarial tables instead. In risk management, the key is to think of the future as a combination of two factors. The first is a statistical factor, which is what you are familiar with — the actuarial table.

But if you are insecure, as you should be about what triggers insurable events, your only option is to protect against the various outcomes, covering all of them and in each case betting on the probability that each will actually occur . If there is one sort of outcome, and you are protected for that, you will have a shortfall, and if the other scenario happens, and you are protected for that, you will have too much insurance and the carrying cost will be too high. For example, what you do is buy securities that pay more in one weather pattern and less in another. Thus, by transferring money between the two possible states — or taking other protecting measures — you are protected. In more concrete terms, it is a combination of a modified reinsurance package, which diversifies the risk and protects the insurer against unknown financial risks, and a security, which captures correlated risks that can not be diversified in any way. So the fact that you can not make predictions becomes irrelevant — as long as you have a chaotic attractor, which gives rise to patterns. While behavior within the pattern is not predictable, if you can distinguish a finite number of states within the pattern, you are positioned to take effective action and hedge the risk by reverse correlation. Thus, chaotic systems can be used for practical purposes. We live in a world where we need to know what could happen, having used a rational approach to classifying risks. And the risk may well take the form of one of several states, with correspondingly different actuarial tables. Once you have understood that risk, take action. Take out a hedge against the risk.

## Some Pieces in Place

While this concept has yet to be fully implemented, pieces of it, have been coming onto the market. The Chicago Board of Trade is now selling catastrophe futures, for example. They are a piece of the total puzzle described here, since they help protect against different actuarial tables governing a given exposure time. But the market for these instruments to date has been very thin, because the same people who buy them — insurers — are the people who report how much a given instrument should pay, thereby potentially creating a conflict of interest. Meanwhile, during the summer of 1996, Merrill Lynch and Morgan Stanley floated new instruments, such as catastrophe bonds, with exactly the same structure. This is a bond with a coupon that, in addition to the standard terms, includes a factor that pays differently depending on the frequency of catastrophic events. In addition, there have been attempts to adapt the fundamentals of securities to fit the insurance industry — in a word securitization. There are companies that carry insurance contracts as their main asset (but of course, there are also liabilities); they sell shares in the company, thereby accessing the capital market. Much like Ginnie Maes, you take a large number of risks, pool them, cut the pool into small portions (shares) that are put on the market, and let people invest in the company. This procedure lets companies access capital markets from an insurance base, and that is good, given the potential for losses from a major catastrophe. It is nearly impossible to put aside enough reserves for a "Big One," and the associated cost of doing so is tremendous. So different pieces of the approach advanced here have been implemented, but not the whole thing. The bottom line, then: You cannot predict one particular outcome using complexity theory, but you can look for the relevant chaotic attractors. Then, if there turns out to be more than one potential state you can use securities as hedges between them. An optimal financial instrument has been developed at the Program on Information and Resources of Columbia University, and is in the process of being implemented commercially. It protects against financial as well as natural catastrophes in the most cost-efficient way. The social value of these instruments covers a variety of circumstances. It covers individuals against losses when it is too late to alter their behavior, for example, because people have already built a house in a hurricane-prone area. A hurricane can lead to major losses for entire populations, and the social value of providing funding for reconstruction of the affected area can be enormous.

In the recent Hurricane Mitch, the loss included 10,000 human lives in Central America. For such human losses, the social value of our financial instruments is to produce incentives to redistribute human settlements away from the highly risky areas in the first place, thus avoiding repeated losses. Such strategies were recently advocated by James Lee Witt, Director of the Federal Emergency Management Agency in his address at the National Press Club in Washington D.C. of November 10, 1998. In this sense, the economic instruments developed at Columbia's PIR are akin to prevention rather than cure. They provide an effective way to convey signals to the population about the true costs to society of unsafe buildings, or building on dangerous sites, and are as such one of the most effective ways to prevent future social losses.

You cannot use complexity theory to predict hurricanes or other climatic events, but you can use it to hedge against future risk and to create incentives to prevent future losses.

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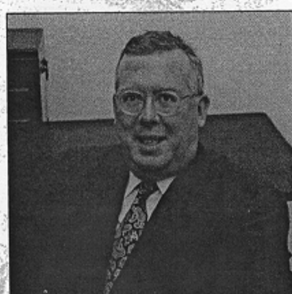

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