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► **To cite this version:**

| Robert Kast. Catastrophe risks: the case of seisms. 2010. hal-02821494

**HAL Id: hal-02821494**

**<https://hal.inrae.fr/hal-02821494>**

Preprint submitted on 6 Jun 2020

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Laboratoire Montpellierain  
d'Economie Théorique et Appliquée

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Unité Mixte de Recherche

# DOCUMENT de RECHERCHE

« Catastrophe risks :  
the case of seisms »

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DR n°2010-18

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# Catastrophe risks: the case of seisms<sup>#</sup>

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December 2010

## Abstract:

Catastrophes and risks have had a great influence on the evolution of human development. We analyze behaviors in front of risks, then we consider some basic principles that have guided private and public behaviors. Managing risks has become a specialty for finance and insurance, but they are not the only institutions that allow to confront them. We conclude on an example of how public funds, private insurance and reinsurance companies can work together and use financial markets in order to cover financial risks due to seisms.

**JEL classification n°:** G1, G22, H43, K32, N22, Q51, Q54

**Keywords:** Seism, catastrophes, risks, hedging instruments, cat-bonds.

## Introduction

The first time one talked about insuring seismic risk, it seemed like an earthquake in the world of Finance and Insurance!

However, Swis-Re, the world's biggest reinsurance company, and a firm that has managed financial instruments as well as insurance contracts for over a century, confronted the problem and recently arrived at practical solutions, notably for Mexico and the Mediterranean area.

I'll introduce the type of financial contracts proposed in the last section, but first I'll go over the history of risks management, then differences between collective and private approaches in front of risks, before I review different forms of management policies and instruments.

### 1. Risk management over history: Fighting the four enemies

Let me indulge in my old 68's culture to structure this first analysis on a then classical reference: *The way of the pacific warrior* by Carlos Castaneda, a strange teaching given to him by an old Mexican Indian sorcerer and related by the author as his Ph.D. thesis at the beginning of the 70's. There are four enemies that an ordinary man has to face and overcome in order to become a warrior (i.e. one pretending to become a proper human being and not just a particular animal).

The first one is **fear**, the second one is **clarity** (enlightenment, knowledge), the third one is **power** (wisdom) and the last one, the one that one can't completely vanquish, is old age, or the evidence of **death**.

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<sup>#</sup> Under the title: "Managing financial risks due to seisms (Gestion financière des risques provoqués par les séismes)", this paper was first prepared for: "Provence's 2009" - Seismic risk in regions of moderate seismicity: from hazard to vulnerability - what did we learn since the 1909 Lambesc earthquake? Aix en Provence, les 6, 7 et 8 Juillet 2009.

I think these four steps may help us to understand how risk has been approached during human history, as well as in each of our individual lives.

### **1.1 Facing risks**

Sicknesses, wild predators, harmful plants, geophysical phenomenon: e.g. earthquakes, are inspiring fear. How did and how do humans face it?

1.1.1 *Learning*: Gods are the names given to some dangers in order to make them familiar, magical and religious practices helped to face fears. Observing the regularity of phenomenon, places where they took place, cause-effects, memories of actions that worked ... all of these helped to give explanations and to be more confident in front of the risks so as to try and confront them ... and being less paralyzed by the fears they inspired.

However not being paralyzed doesn't mean that one can confront a danger if (s)he's not strong or armed enough.

1.1.2 *Getting together*: Sharing knowledge, strength or ruse when useful, and the damages after unfortunate outcomes. "L'union fait la force"! is the Belgian national devise.

However, getting together can be damageable to the whole: if everybody is stroke dead, then no one can profit from experience.

1.1.3 *Spreading the risk*: "Don't put all your eggs in the same basket"! is a wise popular say. As far as individuals are concerned, this implies that people share risks, preferably if they're little chance that everybody gets to face bad outcomes at the same time. At the social level, this say induces to specialize in risks: different groups will concentrate on some specific tasks, develop their know how about the risks at stake, but rely on social solidarity when their activity sector is stroked by bad luck or errors.

All these facets of human groups and individual behaviors help to get enough confidence to overcome fear in front of risks. So one can learn how to behave in front of hazardous phenomenon and overcome their inconveniences and/or damages: that's what leads to clarity (enlightenment).

### **1.2 Taking risks**

Once fear is overcome, individuals and their societies can try and deal with risks that they perceive with clarity.

1.2.1 *Using knowledge*: curing diseases, hunting and gaming animals, growing and selecting plants and animals for consumption, using geophysical resources: ores, streams, winds ...

1.2.2 *Working together*: clans, organizations, governments ...

1.2.3 *Specializing in skills*: hunters, cultivators, blacksmiths, carpenters, and other workmanships, organizers ...

However, in order to feel more strength from knowledge, and improve it, some part of it is better kept secret or shared only by initiates in unions, secret societies, magical or religious sects.

Taking risks is a facet of human behaviors once fear is overcome, and it is the secret to its success in surviving as a species, using its special brain capacities.

However clarity has its downside effects: mainly that overconfidence due to knowledge and know-how can lead to take inconsiderate risks that can't be managed. Individual and national experiences are full of examples of it. However, humans can learn how not to be blinded by their enlightenment and, instead, learn to earn power (wisdom).

### ***1.3 Managing risks***

Individuals can deal with many risks by themselves, but most will gain from the society they belong to (or more relevantly, the community they join, i.e, the society where they put their wealth, including knowledge, in common). Given that a society is formed of individuals sharing some culture, language, skills and wills, individual behaviors and preferences can't be ignored, even though decisions are taken at a collective level. Once clarity has been overcome, power can be exercised in order to manage risks.

#### ***1.3.1 Social management***

Certainly the first way of confronting risks was religion. A religion is founded on gods that were the name put on phenomena. Notice that what is still not understood today is often called supra natural, or spiritual, by opposition to phenomena that are better understood and then interpreted as "natural". Religion keeps the knowledge under the supervision of priests that know how to obtain the god's good will. Such a belief (creed, faith, whatever yields a feeling of certainty) is enough to reassure humans and make them firm enough to confront risks. Moreover, religions are organizations that have developed groups of support for victims of catastrophes in parallel with their purely religious activities. Generally, religions have been related to political power very narrowly, a chief or king being considered as crowned by a god or even considered as a god himself (Pharaoh, Cesar Augustus<sup>1</sup>). Nowadays, religions are replaced by sciences that explain risky phenomena. Scientific knowledge has no pretence to universality, but it is a base on which governments and social organizations rely in order to have political power.

Political power in turn can impose regulations and laws that help to manage and confront risks. Examples of managing risks through social regulations are many: Limitations on hunting so as not to destroy games, irrigations works and sharing rules for agriculture, property codes, interdiction of risky products and activities, market regulations, derogatory insurance...

Thus, reassured by political power, individuals or groups of them, according to hierarchies, can confront risks and undertake actions with a sense of power (with "gods on their side"). Obviously, as has been observed all over history until today, this feeling of power may lead to catastrophic decisions.

#### ***1.3.2 Individual and social preferences and behaviors in front of risks***

Social organizations are necessary to manage risk but individuals are the ones that can and/or want to take risks. Some will take more than others, depending on several factors: Psychological, social, economical... Most individuals will enter into some ways of sharing risks or comparing their valuation of risks. Trades of commodities obtained by taking risks

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<sup>1</sup> Augustus comes from augurus, the priest that says what the gods want.

(hunting, fishing, planting etc.) give a social value to these risks. Moreover, once a monetary system is developed, financial contracts can be traded and give a direct value to the risks they represent. For instance, borrowing and lending, because it was made under strict rules and religious oath, was possible without default risk. Hence such contracts define a rate of return characterizing the price of time: non-usurer rate. This is a direct measure of a part of risk: Time. Another essential part of risk is Uncertainty. And indeed, in order to have some direct valuation of risks (including Time and Uncertainty), it has been necessary to develop the concept of “risk” itself.

### ***1.3.3. Risk: image of a reef***

Religion, as we saw, has had its good sides in order to reassure humans in front of risks, it has had its dark sides too:

- Forbidding to research knowledge and understanding of phenomena has kept priests in a powerful social position, but left humanity in a poor state of understanding.
- Because faith yields certainty, it has been hard for religious power to recognize that there were some uncertainties that could be understood without questioning faith in gods. Indeed, the word “uncertain” only appeared for the first time in the 15<sup>th</sup> century, when science was starting to exist independently of religion in Europe (but it took three more centuries to achieve this).

The concept of risk has freed entrepreneurship. In fact, this concept has been the founding stone of modern industrial development, even though it took nearly a thousand years to complete the social transformation at stake.

The problem was that financial contracts could not be underwritten at a rate exceeding the non-usurer rate. The reason was that a usurer rate was considered as a bet on the gods (and in the 12<sup>th</sup> century in Europe and the Mediterranean area, one God: YHWH, the Lord, or Allah). A bet with God was considered as a blasphemy (i.e. implying death sentence under any political-religious system). But the non-usurer rate concerns what we call nowadays “riskless assets”, it is not adapted to finance a risky adventure, such as sea transportation of very valuable cargos. Indeed, in order to finance such an enterprise, one needs to recognize somehow that the cargo may be lost and the borrower unable to reimburse the lender. This is what the concept of risk, i.e. the “image of a reef” (*rhizikon*) in the contract, was designed to characterize. The fact that a certain amount of present money is transformed into an uncertain list of possible money amounts, is what risk is all about. Such a risky contract must have a rate of return that is above the non-usurer rate (the price of time): this is fixed by the risk premium (if it is paid ex-ante) or, more generally, the price of risk.

As from then (12<sup>th</sup> century), finance could deal with uncertainty without violating religious rules, and it did develop as a means for individuals as well as groups of them to confront risks (expressed by contracts in monetary terms).

Finance developed financial risky contracts, added to classical riskless ones, in order to help individuals or groups of them to take risks. The contract transfers some of the risk, expressed in monetary terms, from the entrepreneur to a financial institution. Moreover, individuals could easily write contracts between themselves to share and pool some risks: Securities, or society shares. When all these contracts became familiar enough, they could be traded between partners and later on organized markets. Financial markets yield a collective price of risk<sup>2</sup>.

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<sup>2</sup> See Briys and de Varenne (2001) for an interesting history of risks and its modern developments.

When probability theory was developed by Pascal and Huygens in the 17<sup>th</sup> century, and statistics were invented a century later, a particular kind of risk could be defined and dealt with: risks with weighted outcomes<sup>3</sup>. Furthermore, among such risks some have an interesting property: they are independent. Independence, even though it may be related to some independence between the causes of the risks, is a probabilistic property: two risks are independent, if the joint probability of their outcomes is the product (hence lower) of each outcome's probability. Such very particular risks are the ones that have made possible to develop a specialization of finance: Insurance.

Insurance is a strange institution: it buys risks with only negative outcomes (something that no one would do in general), and it has however a riskless portfolio of these risks! As a result the insurance company can manage its portfolio at a riskless rate. This comes from two properties of insurance contracts: mutualization (pooling) of the risks (i.e. one is not insured against his own risk but against his share of the pooled risks), and the law of large numbers (if the number of pooled independent risks becomes great enough, the pooled risk converges towards its certain mean value). The last result is however an approximate one and insurance companies have to re-insure themselves and/or hedge their positions with risky financial assets.

#### ***1.4. The society of risk***

The feeling of power can be an enemy, it may lead to forget that not everything can be controlled, that human capacities are decreasing with age, that we shall die. Examples at the individual level are many but it is true also at the collective level. Nations, for instance, have abused of their power through colonial expansion. Concerning risks, the danger is to think it can be controlled even when scientific knowledge is insufficient, for instance. Then death, at the individual level, deadly damages and destructions at the collective level have to be faced. Consciousness of this deadly enemy, and responsible behavior to confront it is what we've seen arise in the industrial world during the 20<sup>th</sup> century: what Giddens (1990) called the society of risk.

We'll address this topic from another point of view in next section.

## **2. Confronting catastrophe (seismic among others) risk : The three P principles**

Jurisprudence distinguishes three types of risky situations: Individual responsibility (Prudence), collective risk management (Prevention) and, lately, a collective approach to new risks (Precaution) (Ewald, 1996).

### ***2.1 Prudence***

Individuals in Lambesc 1909 had no idea that they lived on a hazardous site. Therefore, they couldn't be held responsible to have been careless about anti-seismic construction standards that were already available.

Could we say the same thing today? Assume your little boy spends the night at a friend of yours in Lambesc and gets injured because the building fell on him during an earthquake. Could you sue your friend for not having made his house seism-proofed? Would it be the same if instead of Lambesc your friend lived in San Francisco or Tokyo?

I'll leave the question open for discussion. Just note that your friend would have at least an insurance (derogatory) covering his civil responsibility attached to the one on his

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<sup>3</sup> Unfortunately, such particular risky situations have become known as the sole "risks" during the 19<sup>th</sup> century, and all the others called uncertain situations (Knight, 1921).

house's damages. You may still want to punch his nose because your son is wounded, but at least the cost of curing him and some monetary compensations will be taken in charge. In case of an earthquake, the insurance company will be hedged by a national fund (CatNat in this case in France) in order to face a catastrophe risk that it cannot insure according to usual professional standards.

## ***2.2 Prevention***

The same argument is valid about preventive actions: In 1909, there were no serious findings leading to expect an earthquake such as the one that stroke Lambesc. It is not the same nowadays because it did strike, and because we know more about tectonics. Prevention doesn't mean in this case that there are ways to prevent or soften the effects of a new earthquake, nor that devices could be put up to confront it. It means that the experience is recorded, that information about it and on new knowledge are made available and, eventually, that some recommendations, if not obligations, are given to the public about seismic proofness and prudent attitudes.

At least as far as public building and facilities are concerned, prevention means that everything should be done so as to make them safer, as is done in towns like SF or Tokyo where the risk is scientifically well known. Recent ill-built schools in China have led to indict officials for not having done the proper preventive actions before the last earthquake that devastated the country.

However, prevention devices are costly and the question is: are they worth the cost, given such a tiny probability that an earthquake prevails?

## ***2.3 Precaution***

Actually, talking about "tiny probability" is misleading: We just don't know what the probability is. Even though we know a lot of things about earthquakes, we are still in a situation of "scientific uncertainty" about when and with what magnitude an earthquake may hit Lambesc. Furthermore, the statistics we have do not satisfy the conditions to estimate a probability from the sample<sup>4</sup>.

Scientific uncertainty is one of the fundamental elements of the Precautionary Principle, a recent (end of the 80's) principle that has been introduced into jurisprudence and at different levels in laws and regulations to address some of the "new risks", i.e. risks that can't be handled by conventional means.

Scientific uncertainty is characterized by controversies at the scientific level. Controversies can be about the phenomenon (this is not the case for earthquakes but it is about climate change, for instance, and climate change may have some – controversial – influence on earthquakes), or they can be about the damage's importance, or its date, and most of the time about assigning a probability of occurrence.

Precaution is furthermore addressed to risks that may involve very high damages. This is the case of earthquakes and other natural catastrophes. Precaution is concerned with risks that may occur in an undetermined future, even though actions must be taken at present. And, last but not least, Precaution concerns risks that are faced collectively, and very often at a supra national level (where there is not always a regulating organization that can impose regulations). For, instance this is the case for new endemics and earthquakes.

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<sup>4</sup> Conditions are spelled by the theory of statistical inference. Notably, exchangeability of the data: the order in which they are recorded should be irrelevant. This is not satisfied by earthquakes linked to tectonics.



Notice however, that Prevention as well as Precaution are included at the individual Prudence level, but they must be enforced at the collective level first, at least as far as information and regulations are concerned.

Precaution, even more than Prevention, opens the problem of figuring out the costs reasonably (socially) acceptable to spend now in order to be able to manage possible controversial damages in the future.

Economics and Management have developed tools to calculate damages that are not priced by markets, this is still work in progress but some results have already been used by jurisprudence, notably in the US for the Alaska catastrophic oil nuisance of the Amoco Cadix' wreck. Other work in progress concerns the adapted discount factors to use in order to compare future benefits (resp. losses) and precautionary actions costs.

Because cash flows (and not a given lump sum at a predetermined term) are concerned, financial technology is called for and adapted to value managing methods.

### **3 Managing risk instruments**

Managing risks (in financial terms) belongs to the *savoir faire* of Finance and of Insurance. But, as important, solidarity in confronting risks relies on national and mutual funds under the supervision of regulators and collective decision makers. Furthermore, Finance and Insurance that have been separated as two specialties since Insurance was created in the 18<sup>th</sup> century, have merged again at the very time when the Precautionary Principle emerged in collective consciousness, and for the same reasons. There are risks that conventional managing instruments and organizations are not adapted to manage. Re-insurance companies, which always made the link between finance and insurance, have developed a kit of innovative instruments that are helpful and may be adapted outside their sphere of influence. These tools involve collective as well as individual organizations, a tricky mixture that has still to be enforced, and/or invented to serve the purpose of managing new risks.

#### ***3.1 Risks and Finance***

After having dealt with lending and borrowing at fixed terms from the beginning of history (in what is now Iraq and part of Iran), finance invented the notion of risk, i.e. contracts including possible losses. The first contracts were pretty complex; they were designed in an adaptive and personal way between the financier and the entrepreneur. Similar transactions are still common at the Lloyd's of London, a special institution in which "names" underwrite contracts involving their personal liability. Insurance companies may write similar contracts in some circumstances (e.g. under requirement of a government for a national project such as nuclear technology or rocket launchings). However, over time, contracts have been simplified, standardized and, in some cases, made impersonal so that they could be traded to newcomers on competitive markets.

For instance, company shares, which correspond to parts of the investment in a risky industry, are not anymore nominal and can be traded freely on organized as well as on "over the counter" (OTC) markets. Moreover, contracts have been analyzed and divided into particular parts that concentrate on a special aspect of the risk. For instance, securities are a share of the gains, not of losses; Futures are contracts fixing the future price of an exchange at a given date; Options are contracts that offer the possibility, but not the obligation, to buy or to sell another contract at a fixed price and at a fixed term. Options are more flexible tools than futures and forwards contracts that do not leave open the future choice of buying or selling. Portfolios of such contracts make it possible to

replicate some particular cash flows adapted to hedge a given risk. The engineering of finance has been developed at the end of the last century, thanks to mathematical models helping to value these contracts ... when the assumptions of the underlying model are satisfied! For instance, the securitization of insurance portfolio is a way to spread the risk, or sell it to investors that are interested by their high returns. Obviously, high returns correspond to high risk-premiums and hence to very risky assets.

Most of these instruments have been designed to manage market risks, however the same techniques have been employed recently to design instruments adapted to other risks, such as climate-linked risks, and some other catastrophe risks.

### ***3.2 Probabilities and Insurance***

Risks in Finance have not, in general, a known or uncontroversial, probability of occurrence. Indeed, risky contracts were invented 200 years before the notion of uncertainty allowed to separate religious faith from scientific knowledge, and then enable to develop probability calculus for chance games that became the mathematical foundation for statistics that was developed four centuries later. As from then, using statistics, frequency and average age of death, for instance, have been calculated and made possible to propose contracts based on the length of one's life: life insurance. In fact, in spite of its name, life insurance is not a typical insurance contract: both sides face risks that have positive as well as negative outcomes. Conversely, what is very special about insurance contracts is that they are contracts with only gains on one side and only losses on the other side. The know how of insurers consists in learning the type of risks (risk profiles), the probabilities (figured out thanks to statistical frequencies) and check independence of their client's risks in order for their risk portfolio to satisfy the two principles of insurance mentioned above in 1.3.3.

This doesn't necessarily excludes catastrophe risk if an insurance company can spread the risks between regions exposed independently to catastrophes. However, the problem of valuating probabilities of occurrence and average means can be deterring.

When there is no non-controversial nor sufficiently reliable probabilities, none of the techniques of insurance apply: the premium can't be fixed, the terms may be variable, the contracts themselves are not obvious to write if the list of possible outcomes is not commonly admitted. In fact, catastrophe risks belong to the type of risks dealt with in Finance, and not to the engineering of Insurance. However, there has always been a link between those two industries: Re-insurance.

*Probability calculus is founded on chance games, cards, dices (alea), etc., in which every outcome is given (or has) the same "chance" or "probability" or "evidence" of coming out. It has been extended in a mathematical theory, and (is nowadays a part of measure theory) to all kind of set of outcomes, together with "events" (i.e. subsets of outcomes) that are measured by a probability: and additive function of events to the interval (0, 1). This defines a probabilized set of states.*

*Based on probability theory, statistics (series) of observations have been considered as the outcomes of something similar to a chance game, i.e. a probabilized set of states. A mathematical theory of statistics has been developed, it justifies estimations of probability parameters (means, variance, etc.) and allows to test some assumptions (independence, for instance). Statistics yields frequencies, i.e. numbers between 0 and 1. These frequencies can define a probability. For instance, in chance games, frequencies justify that probability calculus is right. However, in most cases statistics are used for the outcomes of phenomena that have nothing in common with a chance game and for which probability calculus couldn't be used. This is the case of any scientific law of the type:  $y = f(x)$  where the "cause"  $x$ , explains through a function,  $f$ , the effect  $y$ . In fact, observation doesn't satisfy the proposed law, so one assumes the differences between the theoretical value  $f(x_i)$  and the observed value  $y_i$  is random. Then, assuming for instance that the  $y_i$ 's are measured by a given probability law (Gauss-Laplace in general), the parameters*

*of the law are estimated. For instance the mean value (that is called mathematical expectation and is not necessarily what people expect!).*

*$y = f(x) + \varepsilon$  where  $\varepsilon$  is a random variable, is the expression of what is called “scientific certainty”. Conversely, if theories disagree on the function  $f$ , if controversies arise about the probability distribution or its estimation, then we are in a situation of scientific uncertainty.*

### ***3.3 Re-insurance and managing instruments***

Because the Law of Large Numbers only yields an approximation, an insurance portfolio is not riskless. There are other reasons: risk profiles are difficult to determine and subject to information asymmetries such as moral hazard (i.e. the fact that once insured an individual can take more risks than before (s)he was), independence is hard to check, etc. Besides, due to competition, insurance companies have had a tendency to accept insuring risks that weren't “insurable”, at least given their knowledge.

So, insurance companies have to manage some risks and they turn to a super organization: Re-insurance. The first idea is to insure insurance companies: mutualizing (pooling) their risks, diversifying away their specialties, making the pooled risk portfolios independent so that the principle of insurance can be used. This is not sufficient, though, so Re-insurance developed ways to manage the part of risk insurance companies wanted to hedge, by issuing financial contracts and dealing on financial markets to diversify these risks away. Furthermore, and that's the part that concerns us here, they developed some particular contracts in order to address the problems of typically non-insurable risks.

Besides private re-insurance companies, let us mention the important role played by the States, and/or other public organizations, to re-insure insurance companies (as well as other finance activities, e.g. banks) in case a specific systemic risk or a catastrophe occurs (insurer of the last resort). States can use their wealth, extracted from the people's taxes, to hedge in last resort risks that insurance companies are unable to face in case some particular hazard strikes and would make them default. We'll see later in section 4, how these organizations may be involved on a more efficient manner to deal with seismic and other catastrophe risks, when the know how developed by Re-insurance companies is not sufficient or may be improved by interactions.

As an example, we shall refer to Swiss Re, the world biggest Re-insurance company, and it's pioneering efforts to built contracts to hedge seismic risks in section 4.

### ***3.4 More organizations and innovative instruments***

Insurance, even sustained by reinsurance, cannot offer a solution to all risks of damage problems. Indeed, solidarity at a more general level than simple mutualization is necessary for most catastrophe risks and for new risks.

Concerning catastrophe risks, most States have set up an organization of funds and some regulations in order to provide first aid, medical care and some monetary compensation to victims. Historically, as we have seen, that was the first type of organizations set up to help confronting risks. However, with the development of the insurance and the finance industries, a better understanding of the way to manage risks has developed. For instance, the problem known in insurance as “moral hazard”<sup>5</sup> is typically at the source of mismanaged preventions and of abuses in the distribution of the social funds. Another knowledge obviously developed by insurance companies is their ability to valuate possible damages and, as far as data are

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<sup>5</sup> Moral hazard is the risk that someone wouldn't have taken but could take when insured, thus changing his risk profile.

available, their occurrence frequencies. This ability is difficult to achieve without bias by a public agency, submitted to lobbies and other political and social pressures. Furthermore, experts are costly and are not easily rewarded by a public fund in proportion with the money they would help to save. The two previous (extreme) know how developed by insurance companies have led public organizations to cooperate with them, in most developed countries. For example, in case an event occurs, public experts have to decide that it is a catastrophe. Then insurance companies compensate the insured according to their damage estimation, but the public fund compensates in turn insurance companies for compensations above the non-catastrophic damages. Other ways of dealing with catastrophic events are similar: cooperation between public agencies and private insurance companies helps both parties to manage this type of risks.

In front of the increase of damages due to catastrophes, such a cooperation is felt as necessary by both parties. A bigger role is attributed to private insurance, for instance by subsidized incentives, derogatory insurance, prevention means and regulations that make insurable, risks that were not, etc. Conversely, private insurance companies and other financial institutions are sustained by public funds in case of difficulties they face, assuming they respected fundamental precautionary rules.

New risks open another type of problem. Typically they cannot be insured because the phenomenon is not known and probabilities are controversial. Furthermore, damages may occur at unknown and very remote future dates, and often are of unknown magnitude. This is why the precautionary principle emerged and is, little by little, integrated in national and international regulations. At this level, cooperation between judiciary and political public decision makers, on the one side, insurance and other financial institutions, on the other side, is welcome. Private sectors can't work without adapted regulations, besides, financial markets for new contracts have to be regulated so as to satisfy the assumptions of the theory that yield them their optimality properties. On the one hand, the public sector is less productive than the private sector, with regards to innovative instruments and developed valuation methods. On the other hand, academic research, mainly supported by the public sector, is more able than private research institutions to develop new theories and technologies<sup>6</sup>. The best example is given by the option pricing theory developed by academic research and then applied to open options markets in Chicago in 1973. Private investments need to be able to value real investments: Academic research developed a theory that was then applied by the private sector. Reciprocally, instruments based on this theory can now be used to value new risks that are similar, in essence, to real investments in innovative productions. Valuation is indeed a first step for developing managing organizations and define socially acceptable preventive and precautionary investments costs.

The public sector has also some ability that the private sector misses, for instance calling for experts of all fields to study a problem. It uses this ability to develop propositions to the private sector and organize some ways to cooperate. On the other hand, it is up to the private sector to decide whether it is willing and able to propose solutions that may alleviate the costs on the public sector. Clearly this cooperation was necessary for Swiss-Re to propose new managing instruments: Seismic catastrophe bonds, to manage a particular catastrophe risk that, although not essentially new, has all the characteristics of what the precautionary principle is about. The same approach could be developed for new endemics, tsunamis and volcano's eruptions among other "new risks".

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<sup>6</sup> Insurance and financial institutions are aware of the necessity to develop research in these fields and they finance academic research through grants and chairs for students and professors.

## **4 Risk management perspectives: Turning the enemies into allies**

The main teaching of Castaneda's writing (at least for me), is that enemies can be turned into allies.

### ***4.1 Fears is stressing but stress enhances intelligence and leads to clarity.***

Confronting risks, ruse and learning, science and control of some phenomenon are ways to deal with risks that ignorance would make just paralyzing. Thus fear can become an ally to confront risks. It's because people are afraid that they will agree to cooperate, accept some regulation rules, contract insurance and other hedging contracts and save: all that may reassure them enough to take risks.

### ***4.2 Clarity can black out and lead to overconfidence, but it may develop power with reasonable confidence.***

The danger of clarity is enhanced when the public sector uses its knowledge to reassure individuals. For instance, there is a tendency to launch slogans of the type: "low speed (on the roads) = security". Obviously, driving a car cannot be secure, even when it's stopped! Because people think they are secure when they drive slowly, they are not anymore stressed by fear that used to make them careful, they drive more carelessly and then become dangerous.

The role of the public sector is to give information, including the limits of the knowledge. Scientific certainty and statistical evidence are not "certain", they always include some variability and what is true at the collective level, may not be true anymore at the individual level. For instance, it is not true that eating *foie gras* is provoking heart disease, but it is not true either that French people are immune of this danger. For one thing such "evidence" are based on statistical results that depend on the sample, and consequences of eating *foie gras* depend on the general diet and on personal characteristics.

Only full available information can yield a potential power to decide what attitude to take in front of risks, whether at the individual or at the collective level: taking adapted health insurance, imposing general prevention rules, developing managing instruments that take into account the limits of knowledge (a financial hedging contract is different from an insurance contract).

### ***4.3 Power can lead to abuses, but abuses strike back and clarify the limits of power.***

The ultimate limit of power is that human life is limited, so that death has to be integrated into the use of power. But death of one is not the end of life, that's why collective choice is important: take into account that some lives will be lost so that life, in general, is not menaced.

Examples of power abuses are easy to find. For instance, recall the power of nuclear bureaucracy and misleading information. Nuclear plants include some seismic proofed construction. But not all plants are done in the same way and not all seismic magnitude can be integrated. As a consequence possible catastrophe should be integrated into the management, for instance insurance and re-insurance contracts, at least to be able to manage compensations in case a disaster occurs.

Other examples are that of industrial countries dumping their risky products over underdeveloped ones, exporting polluting products in countries with less regulations and

expose people to unacceptable pollutions, exhausting natural resources, ruining soils by industrial and non adapted agricultural methods, etc. Obviously some international organizations and regulations help to alleviate these abuses, but the result has often been terrible death tolls before anything has been done to limit powers.

Again, financial responsibility is an easy way to impose limits to these abuses: If one exposes a people to some risks, one has to be able to compensate, at least, possible catastrophic outcomes. This has a cost, the cost in turn regulates greed. National and international regulations impose limits to such costs and may develop markets to share them in an efficient ways (e.g. pollution rights).

***4.4 Death can't be defeated, obviously, but knowing it and fighting its fatal outcome helps to develop courage, intelligence and new means to exercise power.***

Fatality can be turned around into an active say: "Help yourself and Heavens will help you" is an answer in the realm of religious certainty.

In the scientific certainty societies (industrial societies until the end of the 20<sup>th</sup> century), prevention has been developed, as well as social security and private insurance contracts to confront and manage some risks collectively.

Precaution is a new concept that renews the individual and social perception of risk in its general sense: something certain (present) is transformed into a list of possible outcomes in an unknown future.

It emphasizes the necessary interaction between collective choices and private ones in order to address, confront and manage risks.

Because decisions have to be taken now for consequences that will occur in the future, at least two components of the future have to be taken into account: Time and Uncertainty at each date. When probabilities of outcomes are known, future can be mathematically described as a stochastic process. When probabilities are not known, stochastic calculus can be used ... but with precaution! Furthermore, relevant stochastic processes are not the same at a collective level (statistics on a population sample) and at the individual level (I'm not interested in the mean life time, but in my own when I make decisions that concern myself). For instance, if I were 30, I would consider to invest in seismic proofed construction if I built a house in Lambesc. But at 60 and given my health, such an investment would not be justified, unless I take into account my heirs. Then another problem arises: how do I figure out the future generations' preferences? Specially for generations that are not yet born, whose preferences will depend on the then available knowledge and on societal changes.

These problems have to be solved to make collective choice according to the precautionary principle. One of them is to choose the right interest rates measuring the cost of time<sup>7</sup>. The second one is to measure uncertainty. Without reliable probabilities, a way to respond is again to turn to finance and measure uncertainty by its "social" measure: the price of risk. But, in order to do this, we need financial instruments designed to fit the risks at stake, which are sufficiently understood and accepted to be traded on organized markets. An answer to this is the development of cat-bonds, specialized to particular catastrophes linked to climate, weather, and seisms. More could be developed for floods, tsunamis, volcano eruptions and the like, as well as for industrial risks that may be catastrophic (e.g. nuclear and chemical plants).

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<sup>7</sup> See Heal and Chichilnisky (1998) for instance.

## **5 An example of financial innovation to manage risks: the Swiss-Re seismic cat-bonds.**

Swis-Re has been able to develop specific instruments to help governments and local agencies to manage seismic risks. This is the result of a wide cooperation between the public and the private sector. The first example concerns risks in Mexico, and the second one a more general seismic risk for Mediterranean countries (but not France!).

### ***5.1 Public and private cooperation***

Catastrophes such as earthquakes can't be confronted at the individual level. However, individual behaviors do count, that's where Prudence is called for. But Prudence can be imposed by collective rules, public information, and encouraged by subsidies and/or compensations. Up to a certain point, prudent behaviors may induce banks to lend money for building, for example, even though the house may be destroyed by a seism. More typically, even though earthquakes belong to the category of non-insurable risks, insurance contracts can be designed, taking into account prudent attitudes guaranteed by public and insurance companies experts, once some collective preventive devices have been set up.

Prevention is adapted to situations of scientific certainty, so all efforts are made to get hazards and the damage's probability distribution under some acceptable level if possible. If all this is sufficiently reliable, then insurance contracts can be offered to individuals at justified risk premiums.

However, because risks can't be reduced enough, it is still necessary that some public funds (e.g. Cat-Nat fund in France) warrant damages that are above the ones expected after preventive measures and regulations have been enforced. The problem is then to guarantee, or insure, or cover financially, this fund in case a catastrophe puts it in default.

This is because we are in situations of scientific uncertainty, even though not in a situation of complete ignorance. The measurement of uncertain losses is left to the dealers of financial instruments, through the prices they set, in a way that satisfies both the demand (public funds, and banks and insurance companies linked to them) and the supply: financial investors looking for high return rates, disconnected from financial markets volatility.

### ***5.2 Mexican Parametric Earthquake Catastrophe Bond***

In Mexico, the negotiations initiated between some States and the Federal Government on the one side and banks and insurance companies on the other side. The purpose was to obtain loans, and insurance for these loans that would make them manageable by both parties. First of all, physical hazards were to be studied with the precision that was needed for the financial side to consider the kind of contracts and adapted premiums. Once the physical data were sufficiently reliable for insurance and banks, the organization of some pooling or regional risks (in order to lower premiums) and some public funds system had to be developed. The public funds had to deal with insurance companies and be hedged by some financial instruments: notably specific cat-bonds.

A cat-bond is a bond (in this case a portfolio of government bonds), but including a default possibility that is linked to the occurrence of a given catastrophe. The problem is to define an index that will measure this catastrophe and be related to the default it may induce. Several indexes can be used. In case of a bond from a private company, the index is generally a market index for shares (S&P 500, for example). In case of a government bond, it depends on the rate attributed to the State, for instance, lately, several European countries have been rated B instead of A. For the case of a cat-bond, the index must be related to the catastrophic losses

that may induce the default of the public fund. In the case of cat-bond on seism risk for Mexico, the default has been related directly to the seism magnitude on the Richter scale. In fact, only one trigger point has been chosen: magnitude 8.0. But depending on the epicenter place relative to damages, the defaults have been measured according to expected losses.

<b>Magnitude</b>	<b>7.0</b>	<b>7.5</b>	<b>8.0</b>
<b>% bond loss inner zone</b>	40	100	-
<b>% bond loss outer zone</b>	20	60	100

Hence, the returns of the bonds, according to their ratings that go from BB to B- can be fixed so as to represent the price of risks. For instance if the issuer has a portfolio of riskless government bonds at 5% interest rate, plus a public fund risky bond, the total interest rate can be, say:  $5+4 = 9\%$  where 4% is the risk premium paid by the public fund. Such working out the design of the bond has been done through cooperation between public fund managers, the central Bank of Mexico, local banks, insurance companies and Swis-Re for the re-insurance and financial engineering technology.

#### **Hedging catastrophe risks (from Kast and Lapied, 2006)**

Catastrophe-bonds, or cat-bonds for short, are the most famous among the hedging instruments. As we shall see, they have some features in common with bonds, justifying their appellation, but these assets can be contingent on three types of random variables: Whether a damage index (insured casualties), or indexes that are specific to particular insurance companies, or/and a parameter index based on (statistically measured) catastrophe characteristics. The choice between such indexes as a reference to define a cat-bond, requires to take two risks into account: Moral hazard, due to insured agents and/or insurance societies behaviours on the one hand. And, on the other hand, basis risks, due to the imperfect correlation between the insured risks and the insurance claims. Securities defined on an insurer's specific risk have no basis risk but make the investors to face likely moral hazards. Conversely, securities founded on industrial damage indexes, sometimes completely, eliminate moral hazards, but the hedger is running basis risks.

Cat-bonds are issued whether to address specific risks, or for well delimited geographical zones, for a fixed time horizon in both cases.

Cat-bonds are called this way because, indeed, they are bonds: i.e. tradable debts based on market exchange index such as the Euribor or the Libor, which is calculated in the London market in US \$ or in UK £ or other currencies. Expiration dates are often between 3 and 10 years and these securities are contingent on conditions: If no catastrophes occurs, or more exactly if no damage claims are above the determined in advance level, investors perceive the due payments integrally. The returns on investments are above the Treasury Bonds ones (riskless), often by more than 300 points. On the contrary, if the claims exceed the fixed level, then coupons and/or the principals are reduced so as to reimburse the concerned insurance companies.

Because of regulation and tax concerns, a specific offshore structure called a "Special Purpose Vehicule" (SPV) proceeds to the bonds' emission. The SPV offers a reinsurance contract to the insurance companies seeking for one, at a cost. The total costs' amount is invested into Treasury Bills at a riskless rate, for a part, and into a short term securities' portfolio, for the remaining part. The riskless rate investments are meant to warrant the pledge on the investors, the short term high risky rate portfolio aims at hedging potential reinsured damage claims.

Catastrophe risks can also be hedged by so called "derivatives". The futures market is open on the CBOT since 1992. From 1995 on, claims are based on a group of indexes given by an official organism: The Property Claims Services (PCS). There are nine of such index-based insured damage claims, which are estimated from enquiries among insurance societies and other available information sources. Such indexes are revised day by day, they are relevant to determined geographical zones and for fixed expiration dates (trimesters or years). One index concerns the US territory as a whole and five indexes are specialised in States that are running particular risks (California, Florida and Texas, notably).

Call options on catastrophe exist, as well, they are called cat-options: In exchange of a subscription that is paid in advance (premium), options give the right, but not the obligation, to buy the PCS index at a fixed in advance price (exercise price) at a fixed expiration date. Only call options are traded on the CBOT.



Cat-spreads can be found. A spread is a combination of buying a call for a given exercise price and selling another one for a different exercise price, both calls with the same expiration date. Buying a cat-spread is a way to hedge an insurer's portfolio of claims, as an alternative to buying traditional insurance with deductible or stop-loss insurance contracts.

Comparisons between the different types of instruments can be based on: transaction costs, market liquidity and moral hazards.

- Cat-options can be traded at little cost (bid-ask spreads). Conversely, cat-bonds incur important transaction costs due to the organisational complexity and to the analysis of the underlying risk.
- Markets for cat-options are bound to be easily cleared because of the participants' anonymity and if claims have a standardised form. Up to now however, the cat-bond market is not very active and trades can take time to be cleared due to a lack of agreements on some standard forms for contingencies.
- The main advantage of cat-bonds over cat-options is that the basis risk that an investor is facing is much lower.

Seen from the insurer's point of view, the basis risk value is a fundamental argument in favour of bonds. On the other side of the market, investors are mainly interested by claims contingent on catastrophes because they offer an alternative to traditional securities for diversifying their portfolios. Researches have shown that the returns of securities contingent on catastrophes have zero, or close to zero, correlation with other major traditional assets such that stocks and bonds. Estimates of the assets' returns correlations in the US are given in the following tableau.

	<b>Cat-bonds</b>	<b>S&amp;P 500</b>	<b>Treasury Bills</b>
<b>Cat-bonds</b>	-	-	-
<b>S&amp;P 5000</b>	- 0.13	-	-
<b>Treasury Bills</b>	- 0.07	0.40	-

Cat-bonds (*Source*: Froot, Murphy, Stern and Usher (1995): "The emerging asset class: Insurance risk", Special report from Guy Carpenter and Company, Inc.

This new class of securities attractiveness can also be measured by the Sharpe ratio between excess return with respect to the riskless rate and the risk's standard error.

### **5.3 Swiss-Re cat-bonds for Mediterranean seisms**

On June 1<sup>st</sup> 2007, Swiss-Re obtained US\$ 100 Million protection against earthquake risk in Turkey, Greece, Israel, Portugal and Cyprus.

The problem has been solved on a very similar basis than the one of Mexico, however it was complicated by the references to different countries, regulations and hazards. The special sponsor vehicle to issue the cat-bonds, is MedQuake Ltd. The real issuer is Swiss-Re with a retrocession agreement between the two companies. MedQuake issued notes that cover severe earthquake risk (measured by a parametric trigger) in the countries at stake, from May 2007 to May 2010. There were two classes of issues, with different ratings (depending on two different risky parts in the portfolio of the issuer) for the same redemption date (June 2010).

<b>Class</b>	<b>Rating</b>	<b>Size in M US\$</b>	<b>Coupon (spread in basis points to LIBOR 3month rate)</b>
<b>A</b>	BB-	50	355
<b>B</b>	B	50	510

## **Conclusion**

Is it wise to conclude on such an open subject? There is considerable work in progress in the economic and financial fields. They address several problems. The first and most difficult one

is to value damages that are not marketed, i.e. with no direct market price. The way to do with environmental damages for instance, is to inquire among a relevant sample of concerned individuals about their willingness to pay (resp. their willingness to accept) for prevention or precaution devices (resp. for compensations). This incurs large costs for inquiries and for econometrical treatment of data. It necessitates also a lot of theoretical interdisciplinary work to get rid of many bias that weaken the results' reliability.

Once damages are valued in money, a risk is described as a financial asset. It is not straightforward to value such a financial contract before it can be defined as a marketable asset. For instance, the techniques of finance are not helpful to value a cat-bond if it is based on a parametric trigger. However, as examples above have shown, this can be overlooked due to experience of both the financial institution (Swiss-Re in these cases) and the investors themselves.

The valuations obtained are a good indicator for public managers to derive an overall value to the risks at stakes and obtain a basis to calculate and justify their investments in organizations, funds, and prevention or precautionary devices. Such costs are what can be integrated in a generalized cost-benefit analysis, which yields an indicator, and a criterion, which is not to be confused with a decision criteria, given the political, social and scientific uncertainty aspects.

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