TERRITORIAL DIVERSIFICATION OF CATASTROPHE BONDS

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ABSTRACT

As the issuance of catastrophe bonds becomes more familiar in the risk markets, so more variety in their structure may be anticipated. One aspect of this variety is their expanding territorial coverage. With catastrophe bonds being under investment management as a distinct asset class, the addition of bonds which are geographically uncorrelated (or weakly correlated) with others, comes as a welcome source of portfolio diversification. Apart from the most acute concentrations of earthquake risk in California and Tokyo, bonds have been issued to cover aggregations of earthquake risk in less active seismic zones such as Monaco. Severe windstorms in Europe have also been covered, along with tropical cyclones in USA and Japan. Although catastrophe bonds initially focused on a single peril and territory, latterly, they have been structured with independent multiple event triggers, differing according to peril and territory. This paper reviews the territorial development of catastrophe bonds and explores the geographical horizon for new issues.

INTRODUCTION

The global financial markets are sufficiently correlated for large fluctuations in one major national market to be capable of rippling rapidly through to others. Investment managers seeking territorial diversification of asset portfolios make their decisions in the face of such coherent international market interaction. The Japanese and US stock markets may be inter-linked electronically, but there is no discernible dynamical linkage between Tokyo and Californian seismic activity. Not only are catastrophe bonds minimally correlated with other financial investments, but, viewed as an asset class, there is the virtue that the correlation between bonds covering different territories may also be minimal. The prospect exists for a portfolio of catastrophe bonds to be built which is sufficiently diversified territorially to be capable of sustaining the occurrence of a trigger event as a mild perturbation, without unduly impairing the overall performance of the fund. With such financial impetus for the territorial expansion of catastrophe bonds, the following sections are designed to catalyze interest in this development.

REVIEW OF SOME MULTI-TERRITORY CATASTROPHE BONDS

An insurer or reinsurer wishing to securitize risk exposure for multiple perils and territories might choose to issue catastrophe bonds separately for each peril and territory, or severally, or all together. Single peril/territory bonds have the manifest virtues of simplicity and transparency for rating agencies and investors, and it is not surprising that, initially, most public offerings were of this type.

However, notwithstanding the greater complexity, there are also distinct benefits to the cedent sponsor associated with the collective coverage of multiple perils and territories within a single bond issue. First, it could be a particular combination or aggregate of major losses from multiple perils and territories for which the cedent specifically requires added protection over existing reinsurance or retrocession programs. Secondly, the pooling of territories allows the transaction costs to be shared over a broader premium base; the cost of securitization may make a specific single peril/territory issue uneconomic. Thirdly, at any given time, the market capacity for a group of different bonds may be limited.

Given that the major insured hazard exposures are in USA, Japan and Europe, it is natural that these regions should have figured prominently so far in multi-territory issues. The Halyard Re transaction covers European windstorm as well as Japanese typhoon and earthquake risks. Northwest European windstorm and California earthquake are covered by Prime Capital CalQuake & Eurowind. Northwest European windstorm, California and Japanese earthquake are covered within the tri-continental Atlas Re. Some recent multi-territory issues are reviewed here:

(a) Atlas Re p.l.c.

SCOR is the leading French reinsurer, providing reinsurance to primary insurers of property, construction and other risks. SCOR is consequently exposed to losses from natural perils such as windstorms and earthquakes, any of which might cause losses in one or many reinsurance treaties, facultative contracts or lines of business. SCOR's reputation for innovation was underlined by the securitization of part of its natural catastrophe event exposure; a deal which was cited in its award as the reinsurance company of the year 2000.

Through the special purpose reinsurance company, Atlas Re p.l.c., domiciled in Ireland, SCOR has a three-year retrocessional capacity for certain insured windstorm losses in Northwest Europe, as well as earthquake losses in Japan and the continental United States. The aggregate of all loss payments from any single covered event is capped at $100 million, and the aggregate of all loss payments from all covered events is limited to $200 million. For this coverage, a single multi-peril/territory catastrophe bond is more efficient and practical than the issuance of three separate bonds for Northwest European windstorm, Japanese and US earthquakes. The $200 million transaction comprised three Classes of notes, structured in a hierarchy of tranches. In ascending order of risk: $70 million of Class A; $30 million of Class B; and $100 million of Class C. Losses are modeled for a reference portfolio, which is updated annually, with the calculation agent performing a model-based reset analysis.

(b) Mediterranean Re p.l.c.

Assurances Generales de France (AGF) is one of the largest insurers in France. Whereas the French natural catastrophe reinsurance pool is quite broad in its coverage, it does not include French windstorm or Monaco earthquake risks, both of which are significant for AGF. Seeking an alternative source of reinsurance with high credit quality and 5-year capacity, AGF chose to securitize these risks through a catastrophe bond, for which the issuer is the special purpose reinsurance company Mediterranean Re p.l.c.. This is the first purely French securitization of natural catastrophe risk.

This $129 million transaction comprised about one-third Class A notes, and about two-thirds Class B notes. The lower risk Class A notes are mainly associated with Monaco earthquake risk; the Class B notes are mainly linked with French windstorm risk. The trigger events for this transaction are defined in terms of modeled windstorm loss to a notional portfolio designed to approximate AGF’s actual French exposure, and a modeled earthquake loss to a notional portfolio designed to approximate AGF’s actual Monaco portfolio. There is no change to the notional portfolios during the five year term of the transaction. Future evaluation of event loss will use earthquake magnitude and epicenter data supplied by the European Mediterranean Seismological Centre (EMSC), and windspeed data supplied by Meteo France.

The timing of this transaction is not unrelated to the occurrence of the destructive Lothar storm of 26th December 1999, which caused a massive insured loss in France. This event is associated with a modeled loss exceeding the attachment point for the Class B notes. By contrast, there is no known historical earthquake around Monaco which would have caused a loss to Mediterranean Re.

The Class A notes are expecially attractive to investors, because they are predominantly exposed to Monaco earthquake risk, which is uncorrelated with any natural peril risk so far securitized. Furthermore, compared with all other territories for which earthquake risk has been securitized (e.g. California, Japan, Central USA), Monaco, being situated within the interior of the Eurasian tectonic plate, is exposed to the lowest seismic hazard. Fig.1 shows the historical seismicity around Monaco. There have been no known regional historical earthquakes of magnitude 7 or more.

The Class B notes are also of interest for investors, because, apart from the modest Monaco component, they have only a slight correlation with Atlas Re, as a consequence of the limited French component of the reference portfolio for this latter transaction, and the more northerly track of storms impacting on Atlas Re.

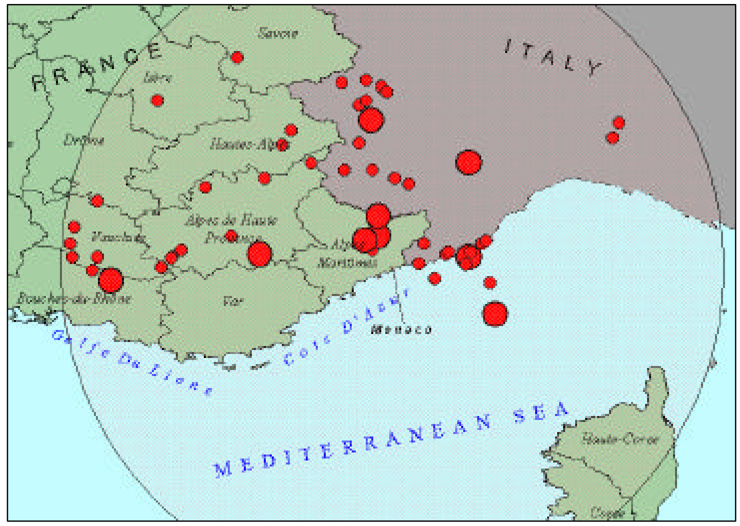

Fig.1: Historical seismicity around Monaco.
The large circles denote earthquakes of Magnitude 6;
the small circles denote earthquakes of Magnitude 5.

(c) Prime Calquake & Eurowind Ltd.

Munich Re, one of the oldest and most respected reinsurance institutions in the world, securitized $136.5 million of their exposure over three years to Californian earthquake and European windstorm through a special purpose Cayman Islands company PRIME Capital CalQuake & Eurowind Ltd.

This is a pure event trigger catastrophe bond, with discrete loss payments of 20%, 80% and 100% of principal being made, contingent not on any modeled loss, but on seismological and meteorological observations. Specifically, these loss payments depend on the occurrence of earthquakes of particular magnitudes in certain clearly defined area boxes in northern and southern California, and are contingent on the occurrence of Northwest European windstorms of specific sizes, as gauged by a windstorm index constructed out of recorded windspeeds in European CRESTA zones. The agency responsible for reporting earthquake data is the US National Earthquake Information Center (NEIC); and the agencies responsible for reporting windspeed data are Meteo France, Deutscher Wetterdienst, Germany; KNMI, Holland; Royal Institute of Meteorology, Belgium; and the Meteorological Office, UK.

LOSS CORRELATION

An astute investment analyst who performs Sharpe ratio calculations for a portfolio of catastrophe bonds will appreciate that the mean excess return divided by the standard deviation of return is improved the less correlated the constituent bonds are. Zero correlations are fine; but if some returns are negatively correlated, so much the better. With some individual bonds spanning continents in their geographical coverage, evaluating these correlations is not the simple task it might otherwise be. As funds of risk-linked securities develop in size and diversity, fund managers will benefit from advice on the correlations between the returns on different bonds.

For two catastrophe bonds sharing at least one territory in common, e.g. Japan, the estimation of the correlation is a task which requires some detailed scenario risk analysis. This is comparatively straightforward for parametric bonds, where the trigger event set is clearly specified, so that the overlapping set of loss-triggering events can be unambiguously constructed. For bonds with modeled loss triggers, correlation can be estimated, but with less precision and more effort. This can be achieved by simulating event scenarios in the common territory, then ranking and calibrating the losses for the ensemble of scenarios according to the loss curves published in the respective offering circulars.

Where no territory is shared by two bonds, the question of correlation may be readily dismissed as trivial, as in the case of Japanese and Californian earthquake: - or it may require substantial scientific knowledge to answer. Consider earthquake occurrence for example. Within a tectonic domain, it is possible for one large earthquake to trigger another, through a process of static and dynamic stress transfer. However, such interaction over a large distance is very weak as the separation distance between the causative faults reaches a thousand kilometres or more. Consequently, the correlation between well-separated major earthquakes is very small, although not necessarily zero. Thus, in a seismic risk analysis, earthquakes in Taiwan and Japan would be taken as essentially independent, as would earthquakes in California and Central USA.

The critical dynamical state of the Earth’s crust is reflected in the triggering of earthquakes by minor perturbations. In principle, just as a straw may break the proverbial camel’s back, it is possible for a low pressure atmospheric system, such as a tropical cyclone, to trigger an earthquake. The 1923 Kanto, Japan, earthquake was preceded by the passage of such an atmospheric depression, as was a destructive earthquake in 1867 in the Virgin Islands. Intriguing though these cases may be, dynamical triggering is a highly variable random process, and for practical risk analysis purposes, the overall correlation between windstorm and earthquake risk in the same territory may be effectively ignored.

It is universally appreciated that UK windstorm risk is correlated with French windstorm risk, because both UK and France may be struck by the same European windstorm originating from an Atlantic depression. The correlation between windstorms generated in different ocean basins, (e.g. Japanese typhoon and Atlantic hurricane), is dynamically more complex because of the teleconnection of climate on a global scale, such as manifest in the El Nino/Southern Oscillation. Although there are some causal linkage factors, their influence is imbedded in the stochastic noise contributed by other fluctuating regional factors affecting windstorm occurrence.

EPISTEMIC UNCERTAINTY

Correlation is of course only one factor which an investor will be considering in deciding on a new offering. Where a new catastrophe bond issue covers a territory to which an investor has little or no exposure, the spread offered may seem particularly attractive. However, the advantages of low correlation have to be weighed against other factors. Unfamiliarity with the hazard in the new territory; ignorance of the national seismological or meteorological institutions; lack of a benchmark comparison with previous offerings; concern over the robustness of the risk analysis; these can all present obstacles to a potential investor.

Fortunately for investors, these additional factors weigh heavily not just on their minds, but also concentrate the minds of the rating agencies which review and stress test the risk analyses. The level of rigor demanded by rating agencies for risk analyses is generally no less than that required by national regulatory agencies for safety-critical industrial installations.

The intrinsic element of randomness, or aleatory uncertainty, associated with the occurrence of natural hazards forms the probabilistic core of a risk analysis. Because of only partial observational data about these hazards, there is an additional uncertainty attributable to lack of knowledge, i.e. epistemic uncertainty, which has to be recognized. Catastrophe bonds cover extreme events. Inevitably, historical precedents are comparatively rare, and there is uncertainty in parametrizing any statistical model of event recurrence. Appropriately, actuaries refer to this as parameter uncertainty. This uncertainty is epistemic rather than aleatory, since it is reducible through the acquisition of additional event data obtained through earthquake monitoring.

A simple illustration of this component of uncertainty is the estimation of the frequency of occurrence of earthquakes above a given magnitude in a seismic area zone. Assuming that events occur as Poisson arrivals, which is valid for many intraplate regions, the likelihood function for the zonal activity rate takes the form of a Gamma distribution. For a 200 kilometer radius circle around Monaco, the maximum likelihood value for the number of events of magnitude 5.0 or more is 0.18 events per year. The upper percentiles of the associated Gamma distribution are tabulated as follows:

Percentile	55%	65%	75%	80%	85%	90%	95%	98%	99%
Frequency	0.189	0.197	0.207	0.212	0.219	0.227	0.241	0.256	0.267

The Class A notes of Mediterranean Re are predominantly exposed to Monaco earthquake. Uncertainty in the expected loss figure is largely associated with volatility in estimating the frequency of earthquakes around Monaco. But even if this figure were increased by a half, in accord with a very conservative upper 99th percentile activity rate value, the spread offered is still many times as large.

BIAS AUDIT

Within the framework of an equilibrium pricing model, it may be argued that parameter uncertainty should have little or no effect on the pricing of catastrophe bonds, provided the treatment of parameter uncertainty is unbiased. But investor suspicions over bias in risk analysis may be raised as a possible reason why spreads are as high as they have been. To help dispel such doubts, a modeler's perspective on bias is presented here.

The challenge of tackling the question of bias is one that can be met through conducting a bias audit. In engineering probabilistic risk analysis, bias audits are undertaken to check on model distortion. (This risk technology has been especially important in its critical application to the safety of radioactive waste disposal.) A bias audit explores ways in which a model, through its varies stages of construction, may yield probabilities which are ultimately biased. Random data errors may be positive or negative, but modeling errors need not be zero-centred. The conduct of a bias audit is, in itself, a useful exercise which can assist in eradicating the effects of bias from a model.

There are two types of bias: witting (of which the risk analyst is aware); and unwitting (of which the risk analyst is not aware). A professional risk analyst will aim to construct a scientifically sound and reliable model, free from bias. Cognizant of the extensive stress testing conducted by rating agencies, a risk analyst will be especially mindful to avoid any procedure or parametrization which may be construed by rating agencies as unconservative or biased against an investor.

A risk analyst may have to go to some lengths to avoid the pitfall of bias against an investor. Simplicity in modeling may be convenient, but it cannot be used as an excuse for the introduction of unconservative bias. In the Monaco risk analysis for Mediterranean Re, for example, the simple assumption that the spatial distribution of regional seismicity was uniform around Monaco might have been advocated on the grounds of compatibility with traditional seismic hazard methodology. But, such an assumption, however economical, would have been unconservative, since a number of significant historical earthquakes have been epicentred comparatively near to Monaco (see Fig.1). The null postulate of uniformity was thus rejected at the outset in favor of the more sophisticated statistical procedure of kernel smoothing the earthquake epicenter data. Sensitivity analysis was conducted to demonstrate the unconservative nature of the results stemming from the uniform seismicity assumption.

Under close scrutiny from the rating agencies, a risk analyst will endeavor, to the best of his or her knowledge, to avoid bias against an investor. But what of the possibility of unwitting bias against an investor; bias that escapes the notice of both the risk analyst and the reviewing rating agencies? A bias auditor has a remit to address this question. Assuming that any unwitting errors in risk analysis may be positive or negative, and therefore unlikely to be systematically biased, the introduction of unwitting bias would usually be associated with some measure of technical ignorance, or information deficiency. How can this come about? There is an inherent gross asymmetry about the use of information, in that the attention of modelers is naturally focused on what is known rather than unknown. Such attention may be deceptive. A map of active tectonic structures would not normally be accompanied with geographical information on mapping completeness. Care has to be taken not to presume that the only active tectonic structures are those marked on the map. Ideally, such hazard maps should be overlaid with a layer of information on epistemic or knowledge-based uncertainty. In the absence of this layer, it was inevitable that there should have been surprise over the hidden location of the 1994 Northridge earthquake. Asymmetry in the use of information can also lead to bias if insufficient weight is attached to the prospect of new engineering discoveries. The vulnerability of steel-framed buildings in southern California had been under-estimated prior to the 1994 Northridge earthquake because the weld-failure mechanism in steel-framed buildings surprised earthquake engineers.

Diligent risk analysts will be watchful for possible sources of unconservative bias in models. These include: under-estimation of event frequencies due to omissions from historical event catalogs; ignorance of unmapped hazard sources (the most notorious example of which was the blind thrust which caused the 1994 Northridge earthquake); mis-location of events away from concentrations of risk exposure; under-estimation of the sizes of events; neglect of correlations between events; and the assumption of long-term stationarity of a low hazard environment.

Probabilistic assignments in a model are as objectively data-driven as possible, but some may involve recourse to expert judgement. The rating agencies carefully scrutinize risk analyses for subjective judgements which may be biased against investors, and prudent risk analysts bear this in mind in constructing their models. One formal graphical procedure by which potential bias may be tracked systematically is to construct a logic-tree of plausible modeling alternatives. The branches of a logic-tree are exhaustive of possible model choices, and are assigned probabilistic weights, (summing to unity) which reflect their perceived relative likelihood. Changes in these weights affect the results of a risk analysis, so bias in the perception of relative likelihood can propagate through to biasing the results.

Considerable effort is required to construct multi-tiered logic-trees, because of the large number of alternatives that need to be analyzed. Implementation is most feasible for event trigger catastrophe bonds, where overall event frequencies can be enumerated economically by multiplying and summing branch weights. In contrast with modeled loss bonds, the computational time and expense of executing portfolio risk analyses for all the different branches are avoided. A compact logic-tree was constructed for the seismic hazard sources around Tokyo, as part of the Parametric Re risk analysis. Explicit disclosure of the logic underlying the treatment of uncertainty provides investors with additional quantitative information upon which to form their own views on the conservatism of a risk analysis.

Beyond the realm of earthquake fault rupture, logic-tree methods are gradually finding application to the estimation of the risk of explosive volcanic eruption. This systematic approach allows probabilities to be constructed which are more robust than those estimated simply from historical precedent, or by comparison with similar volcanoes elsewhere. Risk analyses based on logic-trees may be rigorous enough for volcano risk to be securitized, provided the financial justification exists. This would expand the territorial base of securitization, which is considered next.

ADDITIONAL TERRITORIES FOR SECURITIZATION

Currently, the catastrophe bond market is comparatively small in terms of the number of active institutional investors. Looking ahead to a future when there are many more participants in the catastrophe bond market, and spreads on catastrophe bonds are much narrower than they are at present, it may become financially viable for bonds to be issued to cover natural hazards in many different territories. Can one envisage an exotic bond including cover for a rare tropical cyclone striking Tahiti, such as has happened in some El Nino years?

With the pursuit of the Global Seismic Hazard Assessment Project (GSHAP) during the 1990's international decade for natural disaster reduction, almost all territories in the world have now been subject to some level of seismic hazard investigation, and basic seismological research has been carried out for most countries. But the robustness of a seismic risk analysis will vary from one territory to another, according to the quality of these investigations, and the complexity of the seismic sources.

A well-researched historical earthquake catalog, and sustained regional seismic monitoring, are two key elements an analyst seeks. Geological and geophysical field studies are also very important; a seismic risk analysis may become fragile if the hazard is dominated by one or two individual faults, the activity of which is only vaguely known because of a lack of sufficient seismotectonic work. On the other hand, where the risk posed by an individual fault is thoroughly investigated, the risk analysis may be sufficiently robust as to sustain the issuance of a fault-specific catastrophe bond. The Middle America Trench offshore Mexico is an example. A recurrence of the great magnitude 8.1 earthquake of September 1985 is one of the few realistic scenarios which might result now in serious damage in Mexico City.

There is close coupling between the economic status of a region, and the technical level of hazard monitoring and investigation. Most local studies of seismic hazard are motivated, if not instigated, by commercial civil engineering development; residential and industrial buildings, bridges, roads, dams, utilities, etc.. Such engineering projects are common in all areas of economic development. In Bangladesh, for example, detailed analysis of the seismic environment was conducted in the course of the seismic design of the bridge across the River Jamuna, a major artery of the national economy. Where there is a financial rationale for the securitization of risk, there will usually be the tools and data available for a sound seismic risk analysis.

Many of the territories most prone to natural catastrophes, (and therefore potentially in great need of risk transfer), are, like Bangladesh, in the third-world where the cost of risk transfer would barely be affordable. Whereas northern Europe, North America and Japan have been at the forefront of securitization activity, and other prosperous countries, such as in Australasia, southern Europe and the Middle East, may be expected to follow, the financial case for the inclusion of third-world risks within catastrophe bond issues is less clear. Insurers and reinsurers with global portfolios, which may include exposure in a number of third-world countries, might wish to transfer risk via a world-wide catastrophe bond. Already catastrophe models exist for small remote countries such as Malawi and Mauritius. For major multi-national corporations which have moved much of their production to the third-world, a catastrophe bond might supplement insurance cover for their global natural hazard exposure, perhaps notably in respect of business interruption.

Mitigation of the risk posed by common natural hazards should be a priority for all civic and municipal authorities, wherever in the world. But for extreme events, with a return period in excess of a hundred years or so, the cost of loss prevention measures may be very expensive for the very occasional, and possibly limited, practical benefit. Should such a rare event occur, delay in raising funds for relief would inevitably exacerbate both the human and economic losses. The administrative mess that can result from lack of prior financial provision is highlighted by the Mozambique floods of 1999. The lives of survivors hanging in trees were jeopardised through the unseemly haggling within the British government over the cost of helicopter transport.

Should yields some day approach actuarial levels, the issuance of catastrophe bonds covering groups of vulnerable town and cities would provide authorities with finance for urgent disaster relief, obviating the need for public appeals to the charity of benevolent individuals and the goodwill of foreign governments. Neglecting the good fortune of any negative correlation with a major securitized risk, the affordability of this finance would most likely still require some subsidy. It would be a humanitarian and social benefit to all nations if a way could be found to diversify extreme third-world risks, possibly through western governments offering tax incentives to charitable private investors in less hazard-prone and more prosperous areas.

TERRITORIAL COMBINATIONS

In designing the peril/territory coverage of a new catastrophe bond, thought will be given to its appeal to an investment fund manager. The quest for optimality dictates that, in respect of loss correlation, the prospective new issue should be essentially orthogonal to existing holdings within a catastrophe bond portfolio. Ideally, no hazard event impacting on the new issue would have much impact on the existing portfolio, and vice versa. Part of the appeal of Mediterranean Re is its near-orthogonality against existing bonds: Monaco earthquake has no overlap at all; and French windstorm has comparatively little overlap with Northwest European windstorm, since the events which strike France hardest tend to be too southerly to be destructive on a broader Northwest European scale.

If the market evolved to facilitate the entry of other new territories onto the global securitization stage, this success at avoiding overlap might be more easily replicated. As with Mediterranean Re for Monaco or Concentric Re earlier for Tokyo Disneyland, one possibility is for trigger events to become more localized around individual centers of value. Where there are dense local strong-motion recording networks, as there are in Los Angeles (Tri-Net) and Tokyo (K-Net), triggers may be locally tailored to sets of ground shaking measurements, rather than being based on magnitude and epicenter. As the market becomes more congested with issues covering USA, Japan and Northwest Europe, innovative ways of packaging these main exposures will continue to be sought.