STATISTICAL ANALYSIS OF THE SPREADS OF CATASTROPHE BONDS AT THE TIME OF ISSUE

BY

DIMITRIS PAPACHRISTOU

ABSTRACT

In this paper the catastrophe bond prices, as determined by the market, are analysed. The limited published work in this area has been carried out mainly by cat bond investors and is based either on intuition, or on simple linear regression on one factor or on comparisons of the prices of cat bonds with similar features. In this paper a Generalised Additive Model is fitted to the market data. The statistical significance of different factors which may affect the cat bond prices is examined and the effect of these factors on the prices is measured. A statistical framework and analysis could provide insight into the cat bond pricing and could have applications among other things in the construction of a cat bond portfolio, cat bond price indices and in understanding changes of the price of risk over time.

KEYWORDS

Catastrophe Bonds; Bond Pricing; Regression; Generalised Additive Models.

1. INTRODUCTION

The recent increase in catastrophe (cat) bond issues has also created an interest in understanding how these instruments are priced. The purpose of this paper is to examine the factors that affect cat bond prices and measure the effect of these factors on the bond prices using statistical models.

This paper does not try to estimate what the price of a cat bond should be. This is a different subject and the answer to it depends, among other things, on the requirements, the restrictions and generally the risk appetite of the investors. Several theoretical aspects of cat bond pricing are covered in Cox, S. & Pedersen, H. (1997), in Schmock, U. (1999), in Tilley, J.A. (1997) and in Wang, S. (2004). In this paper the bond prices are considered to be a given input determined by the market. Also this paper does not examine the fluctuations of the prices of the traded cat bonds. It analyses the prices at the time of the issue of the bond.

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Some of the results in this article are known to practitioners. For example the fact that bonds which cover US natural perils have required a higher return than similar bonds which cover, for example, Mediterranean earthquake is common knowledge. However, a statistical analysis confirms this belief, estimates the difference in the reward that these two different perils require, and also enables us to separate the effect on the price of the covered perils from the effect of other features of the cat bond.

Usually there is not a single best statistical model. Different models can be used, giving different results. These models could provide a better insight in the way the market prices insurance risk. It could also provide a framework for analysing and monitoring the price movements of cat bonds as well as the changes in the perception of risk over time.

Examples of alternative statistical models are those which have been published by Lane Financial. One of their most recent models is described in the joint paper by Lane, M. and Mahul, O. (2008). Their model has a different structure from the one described in this paper. One of the main differences is that in this paper we use non parametric functions to represent some of the factors affecting cat bond prices. In their paper Lane, M. and Mahul, O. do not show statistics for the residuals, but a visual inspection of the residuals in a graph may indicate that there is scope for improvement in the fit.

The model presented in the paper has been based on historical information. Therefore it should be used with care when estimating current or future prices of cat bonds. Despite the growth over the last two years the market is still small compared to that of bonds for other asset classes. The relatively limited amount of data introduces some uncertainty in our estimates.

The analysis showed that the principal factors driving the price of cat bonds are:

- *Expected loss* which also reflects to some extent the volatility of loss
- *Perils and territories covered* mainly reflecting the correlation with the investor's portfolio as well as other factors such as available capacity
- *Reinsurance cycle* reflecting loss experience, changes of perception of risk over time and availability of capital
- *Type of Trigger* mainly reflecting the amount of basis risk

2. Main features of cat bonds

The workings of cat bonds have been described in detail in other papers, for example Doherty, N.A. (1997), Tilley, J.A. (1997), Walker, S. et al. (1999) and James, G. et al. (2008). In this section only some of the main features of cat bonds are briefly mentioned. These are the features which were examined as explanatory variables in the statistical model.

A risk taker, often called the sponsor, issues a cat bond to one or more investors and the nominal amount of the bond is placed in a Special Purpose Vehicle. The investors receive regular payments, usually quarterly, called the coupon. If a certain insured event happens then the investor loses part or all of his capital and consequently part or all of his remaining coupons. The issuer of the bond receives part or all of the money in the SPV to mitigate his loss from the insured event.

Each cat bond has a term which is typically less than five years and on average a little less than three years. The term can usually be extended if there is uncertainty in the determination of the loss.

The size of the bonds has varied from a few million dollars to a few hundred million dollars. In recent years "shelf programs" have become common. Under this arrangement, only part of the full nominal amount is issued initially and later the issuer has the option to issue more capital if it is necessary. This has the advantage of savings in administration costs and ease of issuance of capital when it is needed.

Usually an independent natural hazards modelling agency carries out an analysis of the risk and provides details of the results including statistical summaries of the loss distribution. Very few cat bonds have had an annualised expected loss of more than 5%.

A cat bond may cover a variety of perils and territories such as US Hurricane, US Earthquake, European Wind, Japanese Earthquake, Mediterranean Earthquake, etc. Some cat bonds cover multiple territories and perils. In this case almost all of them have included US hurricane.

An event (an earthquake, hurricane or similar) can trigger the non payment of the coupon and or loss of capital of a cat bond. The type of trigger may be on an indemnity, modelled loss, industry index, or parametric basis or a combination of those.

INDEMNITY: The bond triggers a loss to investors if the losses to the sponsor's covered portfolio exceed a predetermined value. This works in a similar way to a reinsurance contract.

MODELLED LOSS: Under these bonds a notional portfolio of policies is used to determine the loss. The portfolio is selected in such a way to best reflect the expected portfolio of the sponsor.

PARAMETRIC INDEX: These bonds determine any losses to investors by creating an index based on the actual catastrophic natural hazard magnitude at different locations with each location carrying its own weight in the index. The weights are set at the start of the deal to best reflect the expected exposure of the portfolio of the sponsor

INDUSTRY LOSS: An Industry Loss Index determines the loss in this case. Typically this form of trigger is used for US perils and is based on the Property Claims Services (PCS) index.

The state of the market, the perception of risk and the availability of capital varies over time. The market cycle of the cat bonds seem to follow the cycle of the (re)insurance markets. However, the relation between cat bond and (re)insurance prices is not examined here.

3. Data

Cat bonds issued between January 2003 and July 2008 were examined. The premiums for the early cat bonds issued before 2003 may have been influenced by some "novelty effect".

The following table shows the number of tranches of bonds by territory/peril and type of trigger in the data.

TABLE 1

Number of cat bonds in the data by trigger and peril/territory

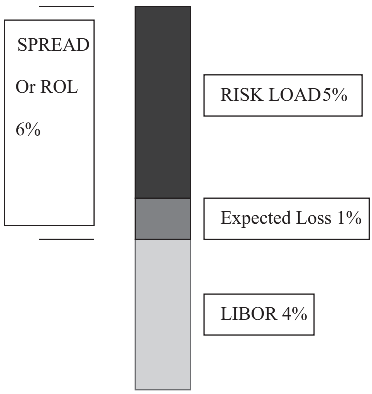
	indemnity	Industry Index Modelled Loss	parametric	Total
US Hurricane only	5	28	7	40
Multi-peril including US Hurricane	26	23	19	68
US Earthquake		16	18	34
Japanese Earthquake			10	10
European Storm, Japanese Typhoon, other	5	3	24	32
Non-Peak Territories		1	7	8
Total	36	71	85	192

Although almost all the bonds issued in the market are included in the data, there are cells in the above table which are empty. There are also correlations in the data which may make a statistical model unstable. For example most of the indemnity cat bonds cover US perils and most of the non peak territories bonds have a parametric trigger.

4. Some initial considerations for the statistical model

The price of a cat bond especially for those exposed to weather perils is influenced by the annual variation (seasonality) in the risk and by other events such as the formation of a hurricane in the Atlantic. Prices at the date of issue of a cat bond were examined which are usually influenced to a lesser extent by this seasonality of risk. There are different ways of looking at the pricing of a cat bond. One of the most common ways is to look at the expected annual loss and the coupon payments to the investors. In most cases a cat bond pays a benchmark rate usually based on LIBOR or EURIBOR and on top of that an excess return for the risks taken by the investor. It is this excess return, which is comparable with the Rate on Line (ROL) paid for a similar reinsurance transaction, and the factors affecting it that we are interested in. This excess return is usually referred to as the spread.

The excess return is higher than the estimated expected loss and the difference (spread – expected loss) rewards the investors for the risk they take. We call the quantity (spread – expected loss) the risk load.



Multiple = 6% / 1% = 6

FIGURE 1: Definitions and Numerical Example.

4.1. Choice of Dependent Variable

One of the first considerations was choosing an appropriate dependent variable. Practitioners often use the ratio of spread/expected loss which is usually called multiple. It shows how many times the premium covers the expected loss. However, ratios may behave erratically and multiples were not the preferred choice.

An alternative dependent variable is the spread. However, the analysis showed that one of the main factors affecting the price of a cat bond is the expected loss. The spread includes the expected loss and the use of a dependent variable which includes one of the independent variables is often avoided.

The final choice for the dependent variable was the risk load.

4.2. Form of the Model

There does not seem to be a clear intuitive answer as to whether the effect of the different factors affecting cat bonds will be additive or multiplicative. An additive model could potentially give negative values for the risk load which does not make sense. Actually the fitted additive model, although overall it provides a good fit to the data, it does give negative values of risk load for some types of cat bond with very low expected loss. Experiments with both types of model gave reasonably good fits to the data, but the preferred model was in the end a multiplicative one.

One thing that quickly became obvious was that the risk load depends on the annualised expected loss. Generally, the higher the annualised expected loss is, the higher the risk load. The following graph shows the risk load against the expected loss for the cat bonds we examined:

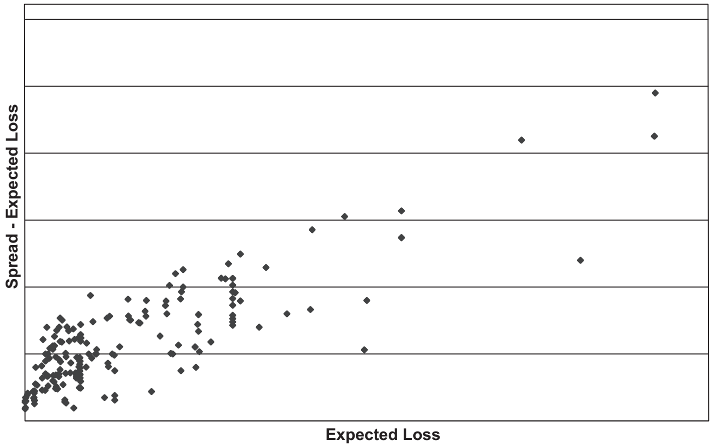


FIGURE 2: Risk Load against Expected Loss.

At first sight the relation looks linear. However, trials with linear models showed that the fit was not very good for the lower values of expected loss, where a relatively large number of cat bonds lies.

In addition, based on observations in prices in the reinsurance market, a linear relation between the risk load and the expected loss is unlikely to hold for high values of expected loss.

Trials with linear and piece wise linear model did not give a satisfactory fit to the whole range of expected losses and in the end smoothing functions were employed to describe the relation between the risk load and the expected loss.

Smoothing functions were also considered an appropriate way to describe the relation between the risk load and the market cycle. The market cycle could be alternatively described by a factor variable probably with three levels: "soft market", "hard market" and "other". However such a classification would be somewhat arbitrary. Furthermore, during these chosen periods of "hard" or "soft" markets the prices would not remain stable. A three level variable could only describe the average risk load in the selected periods.

The selected model has the form:

$$Log(RL_i) = f_1(\log(EL_i)) + f_2(time_i) + Peril\,/\,Territory_i + Trigger_i + \varepsilon_i, \quad (4.1)$$

where RL_i is the risk load, EL_i the expected loss, the fs are smoothing functions, the Peril / Territory and Trigger are factor variables and the ε_is are i.i.d. $N(0, \sigma^2)$ random variables.

4.3. One Model or Several Sub-models

It did not seem possible to find a simple single model which would fit all the cat bonds. The main reason for this was that the market cycle seemed to be different for different territories. The volatility of the risk loads for US bonds seemed to be a little higher than that of the other territories. Therefore two models were used: one for cat bonds including US perils and another for the remaining bonds. The multi-peril, multi-territory bonds invariably covered US perils and were included in the first group.

5. Main factors driving the spreads and summary results

In this section the factors which were included in the model as well as some which were not included are discussed. Also some summary results are shown.

5.1. Expected Loss

The main driver of the risk load is the expected loss. The expected loss we examine is an "annualised" expected loss. Consider a cat bond exposed to European storm with a term of 3.5 years issued in October. Although the bond has a term of 3.5 years it is exposed to 4 winters. In this case, a direct comparison of the annual expected loss, which refers to four winters, and the coupon, payable for 3.5 years, is not valid. Modelling agencies adjust the expected loss to an annual basis so that such comparisons are meaningful.

The higher the expected loss is, the higher the risk load. However, the relationship is not linear, with a doubling of the expected loss not carrying a proportionately higher risk load. Investors require a minimum risk load as compensation for factors including the provision of capital, uncertainties inherent in the product, expenses and the relatively low liquidity of cat bonds.

Recently there have been some cat bonds for what are considered to be very remote events with very small annualised expected loss of less than 0.01%. The risk loads for these bonds have been around 1 to 2%. The high ratio of spread to the annualised expected loss may be due to a premium required for the lower liquidity of the cat bond market, for the uncertainty in the results of natural hazards models, the cost of capital, expenses, or some other reasons.

Other alternatives to the expected loss could be suggested as the main driver of the risk load. For example the probability of a first loss and the conditional (given that the event occurred) expected loss could be used. This approach was taken in Lane, M. (2000), but it was not used in his later papers. Although this is theoretically and intuitively appealing, the use of the conditional expected loss in addition to the probability of first loss had little additional predictive power and therefore it was not used in the model.

Another alternative suggestion could be the rate assigned to a cat bond by a rating agency. The rating agencies base their rating on the probability of first loss or expected loss, but also on other factors which include legal risk, credit risk and other. The expected loss seemed to have more predictive power than the rating.

The expected loss is usually estimated by a specialist company. Different companies may come up with different estimates. However, here it has been assumed that the investors rely on the analysis of the specialist company as far as the estimation of the expected loss is concerned.

Figure 3 is based on the fitted model. Although the risk load was modelled, the "multiple" against the expected loss is shown because the multiples are what practitioners usually look at. The "multiple" is the number of times that the spread covers the expected loss.

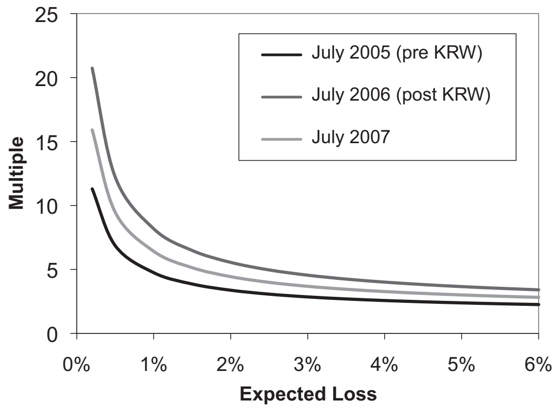


FIGURE 3: Modelled multi-peril including US hurricane multiples (the number of times spread covers expected loss) at three different dates.

5.2. Date of Issue – Market Cycle

Cat bonds issued at different points in time are subject to different market conditions. According to the model, following the 2005 hurricanes Katrina, Rita and Wilma (KRW), the risk loads for US perils increased by around 30% since their 2003 levels. (Re)insurance prices are not analysed in this paper, but it is known that they were increased significantly after KRW. Initial investigation showed that the market cycle seemed to be different for US and non US perils and therefore there were modelled separately. Generally, as it can be seen in Figure 4, the market cycle has been more pronounced for US perils than for non US perils in the last five years. It would be interesting to see how the market would react if large losses occur in non US territories.

Another factor which is likely to have affected the risk load is the timing of the changes in the natural hazard models. For example, most of the US hurricane models were revised by the middle of 2006 showing significantly higher probabilities for the same US hurricane events. The belief that the revised models have been more conservative may have been another factor that the market started levelling off after the middle of 2006 for US perils.

The fitted multiples for a given annualised expected loss of 1% are shown in Figure 4 for one US and one non US peril.

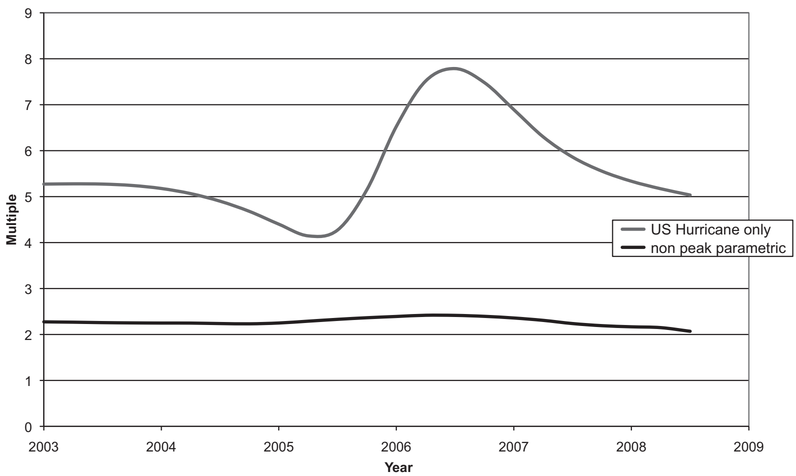


FIGURE 4: Modelled Multiples for annualised expected loss 1% over time.

5.3. Peril and Territory

After experiments with different combinations, the following groups of peril/territory were chosen:

a. Multi-peril, multi-territory including US hurricane
b. US hurricane only
c. US earthquake
d. European storm, Japanese typhoon and Japanese earthquake
e. "non- peak" territories

Levels a to c formed one sub-model and levels d to f formed another sub-model. The "non peak" level includes cat bonds covering risk such as Mexican earthquake or Mediterranean earthquake and other similar types of risk.

The differences in the risk loads for different perils/territories vary over time. Figure 5 shows estimated relative risk loads at the end of 2007 for cat bonds for different perils (with a US hurricane-only peril used as the benchmark). For example, if the risk load for a US hurricane-only cat bond was 10%, for an identical bond covering European and Japanese wind with an index as trigger, the load is estimated to be around 8.1%. Risk loads for non-peak zones have been significantly lower than those for other perils, reflecting the diversifying nature of non-peak territories in a cat bond portfolio.

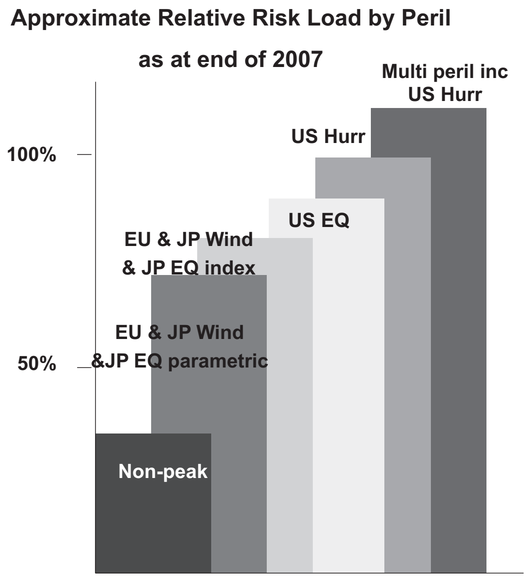


FIGURE 5: Relative risk loads by peril/territory estimated by the model.

Peril/Territory	Trigger	Relative Risk Load
Multi Peril incl. US Hurricane	index and parametric	112%
US Hurricane	index and parametric	100%
US Earthquake	index and parametric	87%
European and Japanese Wind and Japanese Earthquake	index	81%
European and Japanese Wind and Japanese Earthquake	parametric	71%
Non Peak	parametric	33%

Note that the comparisons in Figure 5 are not direct because the triggers for US and non US perils are different. This is because of the composition of the portfolio with respect to triggers and territories and the way those were modelled as explained in the next section.

5.4. Trigger

After experiments with different combinations, the following levels for the factor variable Trigger were chosen:

a. Indemnity
b. Industry Loss and Modelled Portfolio
c. Parametric and Parametric Index

For indemnity bonds the investor assumes moral hazard risk. This will influence the price demanded, though for cat bonds the additional risk load required has not been significant — it seems the reputation of the sponsor is more important in placing an indemnity cat bond. With non-indemnity products such as parametric cat bonds basis risk is retained by the cedant.

As mentioned earlier in the paper, there has been correlation between the type of trigger and peril. For example the vast majority of indemnity bonds include US hurricane. On the other hand non-peak peril bonds have usually been issued on parametric triggers. This type of correlation and the relatively small amount of data makes the model unstable and the results need to be interpreted with care.

5.4.1. *Bonds covering risks including US hurricane*

For bonds covering risks including US hurricane, the risk load for indemnity bonds compared to the other types of trigger is no more than 5-10% higher. Someone needs to bear in mind that the majority of indemnity bonds have been issued by established insurers or reinsurers who have been in the cat bond market for several years and have developed a relation with the investors. Parametric triggers seem to carry a slightly lower but not statistically significantly different risk load. This may be at least partly explained by the perception of the market that the data quality and validity of natural hazard models for US hurricane is higher than for other territories. Another relevant point is that there are several bonds covering perils including US hurricane where both the sponsor and placement agent belong to the Swiss Re group. For these bonds there seems to be a slightly higher differentiation between triggers.

5.4.2. *Bonds covering risks not including US hurricane*

For bonds not covering risks which include US hurricane the scarce data do not allow an estimation of the indemnity premium. The parametric triggers seem to have a risk load which is lower by 10-15%, although this is not statistically significant at the 5% level.

5.5. Other Features of Bonds not Included in the Model

It is interesting to comment on some other features of the cat bonds that do not appear to be statistically significant factors of the cat bonds prices.

5.5.1. *Term to Maturity*

For other bonds, like government bonds, the yield usually depends on the duration of the bond, as usually expressed by the yield curve. There are different reasons for this dependence of the yield on the term which include future expectations about interest rates, variations in demand of certain terms for matching purposes and other.

Unlike a government bond which usually pays a fixed coupon, a cat bond usually pays the current rate of LIBOR or EURIBOR until the next coupon date. The attachment point may also be reset annually so that the probability or expected loss remains the same. Both of these features of cat bonds make the dependence of the yield on the term weaker, because the interest payment and risk of a cat bond generally adjust with the market conditions, possibly with some delay.

The natural hazards model that is used to assess these probabilities is often set at the time of the issue and it does not change. Therefore, there is some sort of "model" risk, the risk that the model used may not reflect changes in the perception of the risk and updates in the parameters of the risk. Someone would expect that a longer term for a cat bond will require an additional risk load. However, the data do not support a higher spread/load, or maybe the differences in spread/load are small and not easy to detect.

The relation between risk load and term may be further complicated by the market cycle. For example, an investor who buys a bond of say 4 years term locks into favourable (or unfavourable) rate for a relatively long term. This investor may be prepared to accept the higher model risk in return for locking into what he believes to be a favourable rate. The amount of available data does not allow a detail investigation of these effects.

Figure 6 shows the residuals of the fitted model against the term of the bonds:

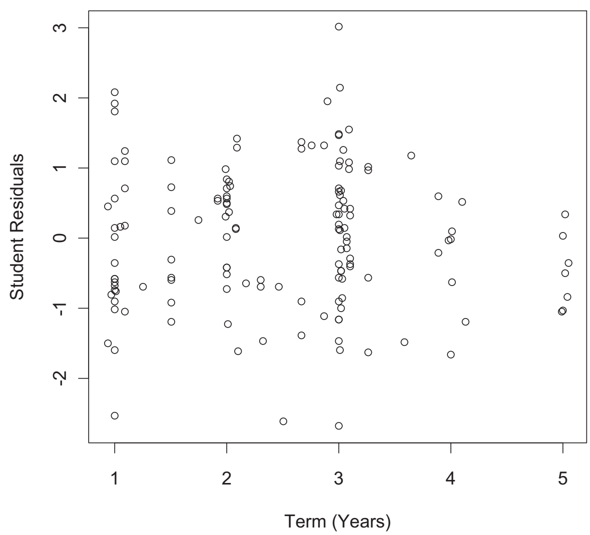


FIGURE 6: Residuals against term of the bond.

There is not any obvious trend in the residuals in Figure 6. Adding the term as an additional variable into our model does not improve the results with any statistical significance.

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5.5.2. *Size of the Transaction*

It is believed that the size of the transaction has an effect on the premium. This is something that has been observed in markets for other assets. The rationale is that a larger size of deal may require a bigger number of investors and therefore a higher reward as more investors need to be satisfied by the price. However, there is not any obvious statistically significant relation between the size of the deal and the risk load in the historical data.

5.5.3. *Time of Issue within a Calendar Year*

Some practitioners have expressed the view that the time of the issue within a calendar year may have some effect on the risk load. For example a bond covering US hurricanes issued just before the US hurricane season may have a higher risk load. This is not supported by the data and this factor is not statistically significant. This effect may be more significant in the reinsurance market.

5.5.4. *Second Event Cover*

Some preliminary work by the author in the retrocession market has shown that for the same expected loss and covered perils, a second event cover tends to demand a higher risk load than a first event cover in the retrocession market. This may reflect retrocession underwriters' views about the increased probability of a second event in the wake of an earlier major catastrophe (i.e. "clustering") and the aggregation of risk in their portfolios, but it is also probably a reflection of their lack of confidence in models to accurately assess second-event probabilities. This factor does not seem to have a significant impact on the cat bond risk loads.

6. Fitted model

6.1. Bonds Covering Risks Including US Hurricanes

The selected model which describes bonds covering risks including US hurricanes is as follows:

$$Log(RL_i) = S(\log(EL_i)) + NS(time_i) + Peril\,/\,Territory_i + Trigger_i + \varepsilon_i, \quad (6.1)$$

Where RL_i is the risk load, EL_i the expected loss, $time_i$ the date of issue of the bond, $Peril\,/\,Territory_i$ is a discrete variable with three levels:

1. multi-peril, multi-territory including US hurricane
2. US hurricane only
3. US earthquake

$Trigger_i$ is also a discrete variable with two levels:

1. indemnity
2. other

and the ε_is are i.i.d. normally distributed errors with zero mean. The function S is a smoothing spline and NS is a natural spline. A summary of the model is given by Table 2.

TABLE 2

SUMMARY OF MODEL

added term	Residual df	Residual Deviance	Difference in df	Difference in Deviance	P(>|Chi|)
Intercept	141	53.845			
s(log(EL))	137	11.137	4	42.708	0.0000%
ns(year)	132	5.931	5	5.206	0.0000%
Peril/Territory	130	4.251	2	1.680	0.0000%
Trigger	129	4.155	1	0.097	8.3000%

Table 3 shows the coefficients and their standard errors for the linear terms in the model.

TABLE 3

COEFFICIENTS AND STANDARD ERRORS OF THE LINEAR TERMS

Factor	Level	Estimate	Standard error	t-value	Pr(>|t|)
Trigger	Indemnity	0.0819	0.0437	1.8732	6.33E-02
Peril/Territory	Multi incl. US Hurricane	0.1174	0.0390	3.0111	3.13E-03
Peril/Territory	US Earthquake	–0.1392	0.0444	–3.1384	2.11E-03

Figure 7 shows the Student residuals of the model and the normal qq plots of the student residuals together with 95% confidence intervals respectively.

The partial residuals are shown in Figure 8.

In figure 8b, where the partial residuals of the variable time (year) are shown, the spline function has knots at time 2005 and 2005.5, 2006 and 2007.25. The knot at 2005.5 is not statistically significant. However, if we omit the knot at this point the "bottom" of the market occurs early in 2005 as a result of the data smoothing and the small number of points around 2005.5. It is known that the market "hardened" after the middle of 2005 following the three big North Atlantic hurricanes.

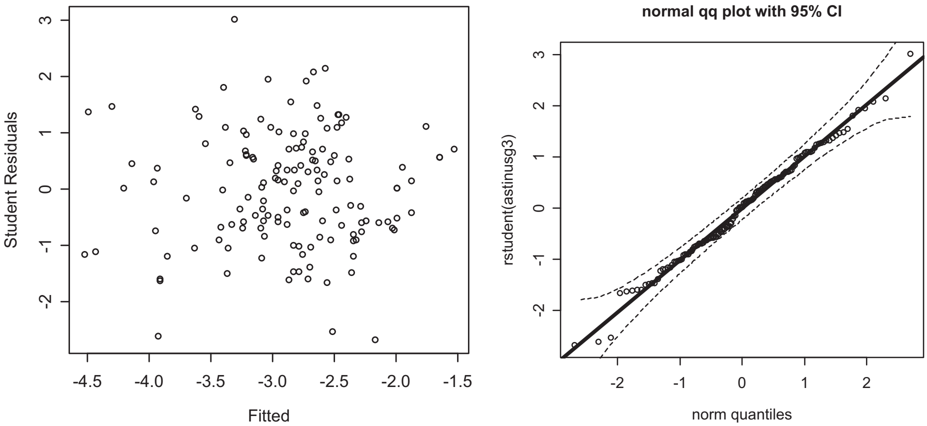
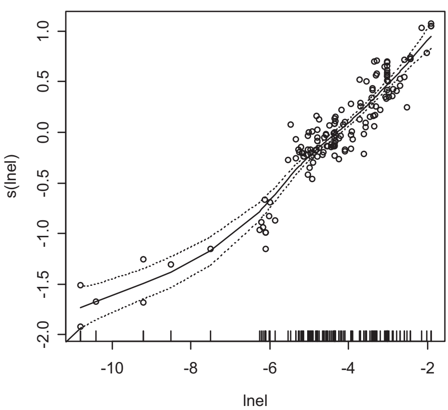
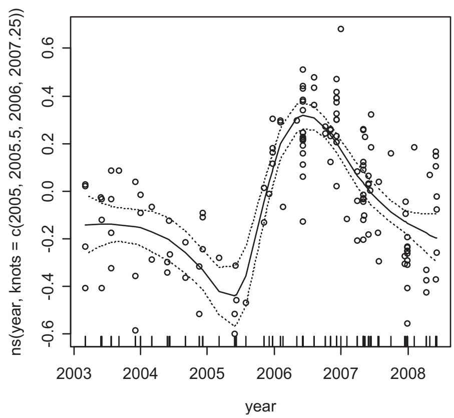


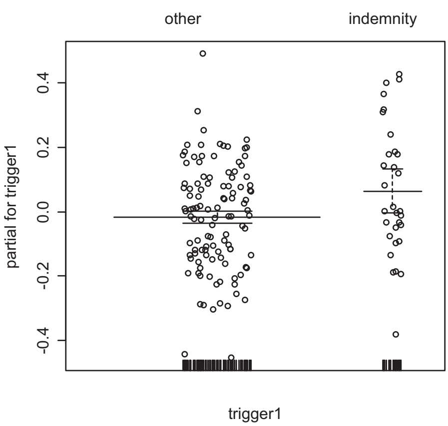
FIGURE 7: Residuals and Normal qq plot.



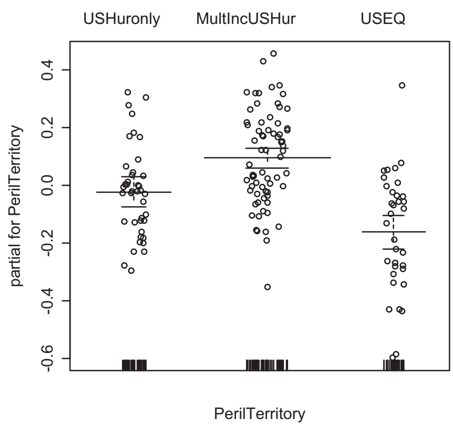
(a) Log(EL)



(b) Time(Year)



(c) Trigger



(d) Peril/Territory

FIGURE 8: Partial Residuals.

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Figure 9 shows the logarithm of the estimated and actual risk loads. Each black dot represents the estimated risk load for each of the cat bonds. The grey dots show the actual risk loads. The dark lines are the 95% confidence intervals for the estimates. The light grey lines are the 2.5% and 97.5% points of the distribution of the risk loads. The estimated risk loads have been sorted in ascending order so that the graph can be visualised more easily.

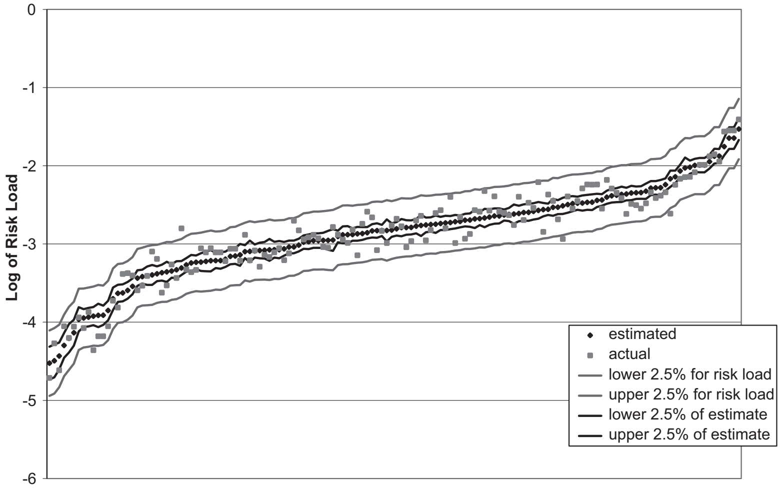

FIGURE 9: Actual and fitted risk loads on a logarithmic scale.

Figure 10 shows the estimated and actual risk loads. The estimates for the risk loads are the medians of the distribution.

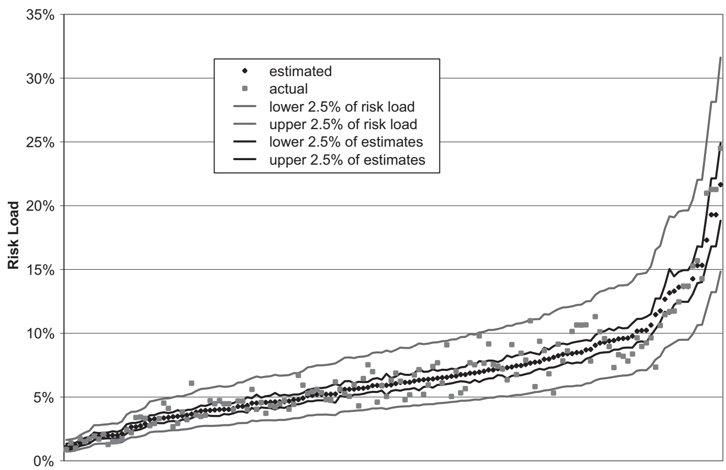

FIGURE 10: Actual and Fitted Risk Loads.

It can be seen from the previous graphs that there is significant residual volatility.

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6.2. Non US Risks

The selected model for non US risks is as follows:

$$Log(RL_i) = S(\log(EL_i)) + lo(time_i) + Peril/Territory_i + Trigger_i + \varepsilon_i, \quad (6.2)$$

where RL_i is the risk load, EL_i the expected loss, $time_i$ the date of issue of the bond, $Peril/Territory_i$ is a discrete variable with two levels:

1. European Storm, Japanese Typhoon and Japanese Earthquake
2. "non- peak" Territories,

$Trigger_i$ is also a discrete variable with two levels:

1. Industry Loss and Modelled Portfolio
2. Parametric and Parametric Index,

and ε_i are i.i.d. normally distributed errors with zero mean.
The function S is a smoothing spline and lo is a locally fitted polynomial.
A summary of the model is given by Table 4.

TABLE 4

SUMMARY OF MODEL

added term	Residual df	Residual Deviance	Difference in df	Difference in Deviance	P(>|Chi|)
Intercept	49	11.1143			
s(log(EL))	45	6.2776	4	4.837	0.0000%
lo(year)	42	5.3399	3	0.938	0.0001%
Trigger	41	5.2233	1	0.117	5.0100%
Peril/Territory	40	1.2033	1	4.020	0.0000%

The term "Trigger" is not statistically significant at 5% if we change the order of adding the terms. A locally fitted polynomial in "time" does not necessarily give a better fit than some type of spline function, but it gives a fit which is more consistent with our knowledge of the market cycle.

Table 5 shows the coefficients and their standard errors of the linear terms in the model.

TABLE 5

COEFFICIENTS AND STANDARD ERRORS OF THE LINEAR TERMS

Factor	Level	Estimate	Standard error	t-value	Pr(>|t|)
Trigger	Parametric	–0.1271	0.0690	–1.8437	7.2721%
Peril/Territory	Non Peak	–0.9054	0.0697	–12.9956	0.0000%

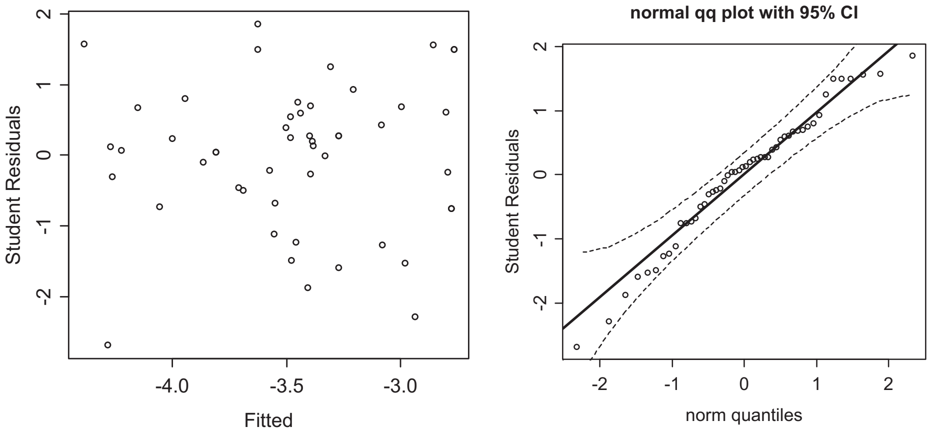
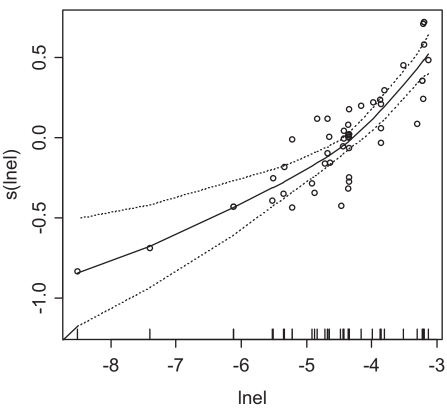
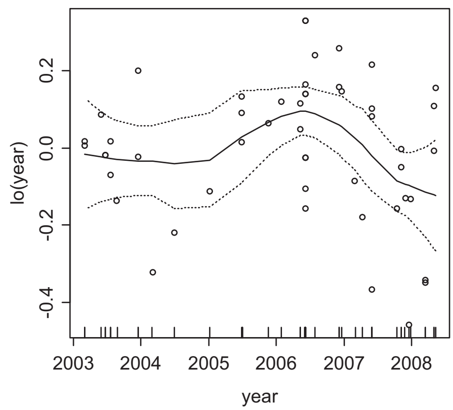


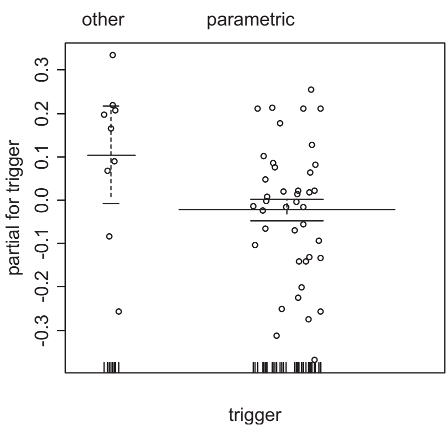
FIGURE 11. Residuals and Normality Test.



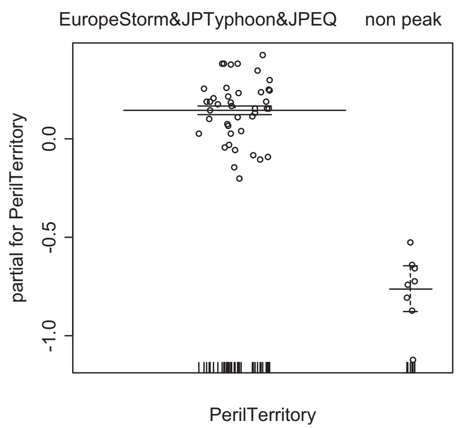
(a) Log(EL)



(b) Time(Year)



(c) Trigger



(d) Peril/Territory

FIGURE 12: Partial Residuals.

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Figure 11 shows the Student residuals of the model and the normal qq plots of the student residuals together with 99% confidence intervals respectively.

The normality assumption is weak at the left tail.

The partial residuals are shown in the Figure 12.

Figure 13 shows the logarithm of the estimated and actual risk loads. Each black dot represents the estimated risk load for each of the cat bonds. The grey dots show the actual risk loads. The dark lines are the 95% confidence intervals for the estimates. The light grey lines are the 2.5% and 97.5% points of the distribution of the risk loads. The estimated risk loads have been sorted in ascending order so that the graph can be visualised more easily.

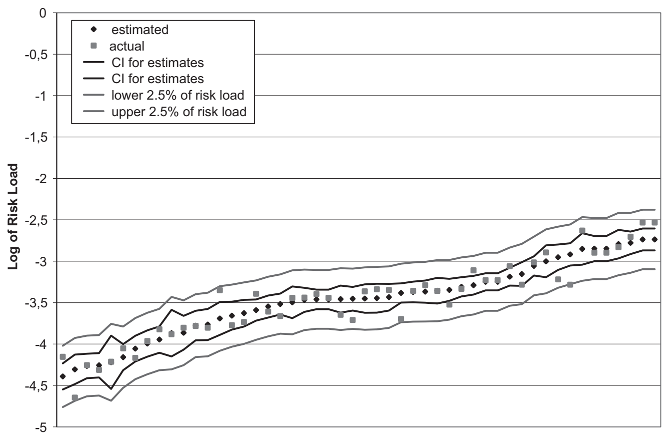

FIGURE 13: Actual and Fitted Risk Loads on a logarithmic scale.

Figure 14 shows the estimated and actual risk loads. The estimates for the risk loads are the medians of the distribution.

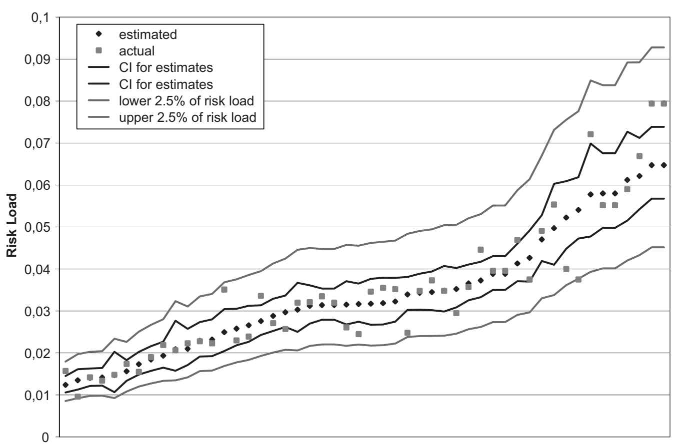

FIGURE 14: Actual and fitted risk loads.

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European storm, Japanese Typhoon and Japanese Earthquake have been grouped all in one level of the Peril/Territory factor. Japanese Earthquake may have a lower risk load than the others in its group, but this is not significant at the 5% level. If the Peril/Territory was split into three levels:

1. European Storm and Japanese Typhoon
2. Japanese Earthquake and
3. "non peak" Territories,

then the estimates and their standard errors for the linear terms would have been

TABLE 6

COEFFICIENTS AND STANDARD ERRORS OF THE LINEAR TERMS

Factor	Level	Estimate	Standard error	t-value	Pr(>|t|)
Trigger	Parametric	0.1007	0.0693	–1.4529	15.4345%
Peril/Territory	Japanese EQ	–0.0999	0.0641	–1.5589	12.7174%
Peril/Territory	Non Peak	–0.9247	0.0700	–13.2083	0.0000%

The parameters for Japanese Earthquake and for the parametric trigger are not statistically significant at the 5% or 10% level.

7. Conclusions and suggestions for future work

The market of the insurance linked bonds and the volume of trading in these securities have been relative small. As the volumes increase it will be helpful to have a framework to analyse the market. In this paper an attempt was made to provide one possible framework for analysing the factors that affected the cat bond prices at issue in the last few years and show a way of quantifying the effect of these factors. The main driver of the risk load of a cat bond has been the expected loss. Peril/Territory, market cycle and to a lesser extent the type of trigger have been important factors affecting the cat bonds price.

A statistical framework is a good way to go about analysing the cat bond market. The statistical analysis will lead to a better understanding of the market and a more informed environment for the trading of cat bonds. However, the relative small amount of available data places some limitations on what the statistical analysis can currently achieve. As the amount of data accumulates more accurate estimates and firmer conclusions could be drawn. In addition, work in the following areas could be carried out.

7.1. Comparisons Between the Prices of Cat Bonds and Reinsurance and Retrocession

This is an area that everybody involved in the risk transferring market is interested in. Although there are similarities between risk transfer mechanisms, there are also differences in the risk transfer products and the markets they operate. A statistical analysis of the prices and for measuring the value of some specific features of the risk transfer products will be useful for practitioners. Some initial analysis was presented in Dallison, Papachristou and Potter (2008), but the results were approximate. The difficult areas were the accuracy of expected loss estimates and the treatment of expenses. Despite the progress and effort in estimating the distribution of losses to reinsurance/retrocession programmes in recent years, the quality of data, especially for retrocession, is not always ideal and parts of the portfolio can only be modelled approximately. This is in contrast to the portfolios covered by a cat bond where even for indemnity triggers the data quality is generally of good standard and the portfolios often very specific. Some of the expenses of issuing a cat bond such as legal fees, modelling agency fees, etc., are explicit and are not included in the spread. On the other hand reinsurance/retrocession premiums make implicit allowance for the company expenses.

7.2. Factors Affecting the Prices of Cat Bonds in the Secondary Market

In this paper only prices at the time of issue were considered. Cat bonds are traded and an interesting area of research would be the analysis of the prices in the secondary market. The prices of a bond are affected by the seasonality of some natural perils. Adjustments need to be made for these temporal variations in the risk before the prices are analysed. The relatively infrequent trading of cat bonds may place some limitations to such a statistical analysis.

7.3. Comparison of Market Prices to Actuarial Pricing Methods

The relatively detailed information provided in a cat bond circular on the statistical analysis of the risk enable us to examine the true market prices and compare them with standard actuarial premium methods, such as the standard deviation, Kreps' method as described in Kreps, R. (1999), Esscher, and other premium principles. The parameters of these methods could be estimated and they may be different for different perils/territories and they will certainly vary over time. Some initial research by the author showed that the standard actuarial premium methods do not seem to agree with the market prices over the whole range of expected losses. However, these methods appear to come more in line with the market prices when approximate allowance is made for parameter uncertainty. Maybe underwriters and investors, although not necessarily familiar with the mathematics of parameter uncertainty, they do intuitively take it into account. An interesting initial analysis in this area using

Wang's transforms can be found in Wang, S.S. (2004). The comparison of the market prices to actuarial methods and risk measures is a big topic on its own which may require several papers. As the amount of cat bond data increases this kind of investigations may become more fruitful.

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The statistical analysis has been performed using the statistical package R. I would also like to thank all those excellent statisticians who have contributed in creating such great and versatile free software.

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DIMITRIS PAPACHRISTOU
Financial Services Authority
25 The North Colonade
Canary Wharf
London E14 5HS
Tel: +44 20 7066 0488
E-mail: dimitris.papachristou@fsa.gov.uk

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APPENDIX

List of Bonds Considered in the Study

Sponsor	Issue	Program	Class	Perils	Inception	Trigger	Risk Capital	MIS	S&P	Fitch
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	A-03-1	US HU	17 March 2003	Parametric Index	$6,500	Ba3	BB+	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	B-03-1	EU Wind	17 March 2003	Parametric Index	$8,000	Ba3	BB+	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	C-03-1	US EQ	17 March 2003	Parametric Index	$6,500	Ba3	BB+	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	D-03-1	US EQ	17 March 2003	Parametric	$5,500	Baa3	BBB-	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	E-03-1	JP EQ	17 March 2003	Parametric Index	$8,000	Ba3	BB+	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	F-03-1	US/EU Wind, US/JP EQ	17 March 2003	Parametric Index	$8,140	Ba3	BB+	
USAA	Residential Reinsurance 2003 Limited	Residential Reinsurance 2003 Limited		US HU, EQ	30 May 2003	Indemnity	$160,000	Ba2	BB+	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	B-03-2	EU Wind	17 June 2003	Parametric Index	$12,250	Ba3	BB+	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	C-03-2	US EQ	17 June 2003	Parametric Index	$7,250	Ba3	BB+	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	D-03-2	US EQ	17 June 2003	Parametric	$2,600	Baa3	BBB-	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	A-03-2	US HU	17 June 2003	Parametric Index	$9,750	Ba3	BB+	
Zenkyoren	Phoenix Quake Ltd.	Phoenix Quake Ltd.		JP EQ	25 June 2003	Parametric Index	$192,500	Baa3	BBB+	
Zenkyoren	Phoenix Quake Wind II Ltd.	Phoenix Quake Wind II Ltd.		JP TY, EQ	25 June 2003	Parametric Index	$85,000	Ba1	BBB-	
Zenkyoren	Phoenix Quake Wind Ltd.	Phoenix Quake Wind Ltd.		JP TY, EQ	25 June 2003	Parametric Index	$192,500	Baa3	BBB+	
Swiss Re	Arbor Ltd.	Arbor II Ltd.	Series 1	US/EU Wind, CA/JP EQ	24 July 2003	Parametric Index	$26,500	A1	A+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 1	US/EU Wind, CA/JP EQ	24 July 2003	Parametric Index	$95,000		B	
Swiss Re	Arbor Ltd.	Palm Capital Ltd.	Series 1	US HU	24 July 2003	Parametric Index	$22,350	Ba3	BB+	
Swiss Re	Arbor Ltd.	Oak Capital Ltd.	Series 1	EU Wind	24 July 2003	Parametric Index	$23,600	Ba3	BB+	
Swiss Re	Arbor Ltd.	Sequoia Capital Ltd.	Series 1	US EQ	24 July 2003	Parametric Index	$22,500	Ba3	BB+	
Swiss Re	Arbor Ltd.	Sakura Capital Ltd.	Series 1	JP EQ	24 July 2003	Parametric Index	$14,700	Ba3	BB+	
TREIP	Formosa Re Ltd	Formosa Re Ltd.		Taiwan EQ	25 August 2003	Indemnity	$100,000		NR	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 2	US/EU Wind, CA/JP EQ	15 September 2003	Parametric Index	$60,000		B	
Swiss Re	Arbor Ltd.	Palm Capital Ltd.	Series 2	US HU	15 December 2003	Parametric Index	$19,000	Ba3	BB+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 3	US/EU Wind, CA/JP EQ	15 December 2003	Parametric Index	$8,850		B	
Swiss Re	Pioneer 2002 Ltd.	Pioneer 2002 Ltd.	D-03-3	US EQ	15 December 2003	Parametric	$51,000	Baa3	BBB-	
EDF	Pylon Ltd.	Pylon Ltd.	Class A	EU Wind	18 December 2003	Parametric Index	€ 70,000	A2	BBB+	
EDF	Pylon Ltd.	Pylon Ltd.	Class B	EU Wind	18 December 2003	Parametric Index	€ 120,000	Ba1	BB+	
CEA	Redwood Capital III, Ltd.	Redwood Capital III, Ltd.		US EQ	31 December 2003	Industry Index	$150,000	Ba1	BB+	
CEA	Redwood Capital IV, Ltd.	Redwood Capital IV, Ltd.		US EQ	31 December 2003	Industry Index	$200,000	Baa3	BBB-	
Swiss Re	Arbor Ltd.	Oak Capital Ltd.	Series 2	EU Wind	15 March 2004	Parametric Index	$24,000	Ba3	BB+	
Swiss Re	Arbor Ltd.	Sequoia Capital Ltd.	Series 2	US EQ	15 March 2004	Parametric Index	$11,500	Ba3	BB+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 4	US/EU Wind, CA/JP EQ	15 March 2004	Parametric Index	$21,000		B	
USAA	Residential Reinsurance 2004 Limited	Residential Reinsurance 2004 Limited	Class A	US HU, EQ	21 May 2004	Indemnity	$127,500		BB	
USAA	Residential Reinsurance 2004 Limited	Residential Reinsurance 2004 Limited	Class B	US HU, EQ	21 May 2004	Indemnity	$100,000		B	
Converium	Helix 04 Limited	Helix 04 Limited		US/EU Wind, US/JP EQ	10 June 2004	Modeled Loss	$100,000		BB+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 5	US/EU Wind, CA/JP EQ	15 June 2004	Parametric Index	$18,000		B	
Swiss Re	Gi Capital Ltd.	Gi Capital Ltd.		JP EQ	30 June 2004	Parametric Index	$125,000		BB+	
Swiss Re	Arbor Ltd.	Oak Capital Ltd.	Series 3	EU Wind	15 September 2004	Parametric Index	$10,500	Ba3	BB+	
Swiss Re	Arbor Ltd.	Sequoia Capital Ltd.	Series 3	US EQ	15 September 2004	Parametric Index	$11,000	Ba3	BB+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 6	US/EU Wind, CA/JP EQ	28 September 2004	Parametric Index	$31,800		B	
Hartford Fire Ins	Foundation Re Ltd.	Foundation Re Ltd. Series 2004-I	Class A	US HU	17 November 2004	Industry Index	$180,000		BB+	
Hartford Fire Ins	Foundation Re Ltd.	Foundation Re Ltd. Series 2004-I	Class B	US HU, EQ	17 November 2004	Industry Index	$67,500		BBB+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 7	US/EU Wind, CA/JP EQ	15 December 2004	Parametric Index	$15,000		B	
CEA	Redwood Capital V, Ltd.	Redwood Capital V, Ltd.		US EQ	31 December 2004	Industry Index	$150,000	Ba2	BB+	
CEA	Redwood Capital VI, Ltd.	Redwood Capital VI, Ltd.		US EQ	31 December 2004	Industry Index	$150,000	Ba2	BB+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 8	US/EU Wind, CA/JP EQ	15 March 2005	Parametric Index	$20,000		B	
USAA	Residential Reinsurance 2005 Limited	Residential Reinsurance 2005 Limited	Class A	US HU, EQ	31 May 2005	Indemnity	$91,000		BB	
USAA	Residential Reinsurance 2005 Limited	Residential Reinsurance 2005 Limited	Class B	US HU, EQ	31 May 2005	Indemnity	$85,000		B	
Factory Mutual Insurance Company	Cascadia Limited	Cascadia Limited		US EQ	07 June 2005	Parametric	$300,000		BB+	BB
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 9	US/EU Wind, CA/JP EQ	15 June 2005	Parametric Index	$25,000		B	
Zurich	KAMP Re 2005 Ltd.	KAMP Re 2005 Ltd.		US HU, EQ	28 July 2005	Indemnity	$190,000		BB+	
PXRE	Atlantic & Western Re Limited	Atlantic & Western Re Limited	Class A	US/EU Wind	08 November 2005	Modeled Loss	$100,000		BB+	BB
PXRE	Atlantic & Western Re Limited	Atlantic & Western Re Limited	Class B	US/EU Wind, US HU	08 November 2005	Modeled Loss	$200,000		B+	B
Munich Re	Aiolos Ltd.	Aiolos Ltd.		EU Wind	15 November 2005	Parametric Index	€ 110,000		BB+	
Swiss Re	Arbor Ltd.	Arbor I Ltd.	Series 10	US/EU Wind, CA/JP EQ	15 December 2005	Parametric Index	$18,000		B	
PXRE	Atlantic & Western Re II Limited	Atlantic & Western Re II Limited	Class A	US/EU Wind, US EQ	21 December 2005	Modeled Loss	$125,000		BB+	
PXRE	Atlantic & Western Re II Limited	Atlantic & Western Re II Limited	Class B	US/EU Wind, US EQ	21 December 2005	Modeled Loss	$125,000		BB+	
Montpelier Re	Champlain Limited	Champlain Limited	Class A	US/JP EQ	22 December 2005	Modeled Loss	$75,000		B	B-
Montpelier Re	Champlain Limited	Champlain Limited	Class B	US HU, EQ	22 December 2005	Modeled Loss	$15,000		B+	B-

Sponsor	Issue	Program	Class	Perils	Inception	Trigger	Risk Capital	MIS	S&P	Fitch
Swiss Re	Australis Ltd.	Australis Ltd. Series 1		AU CY, EQ	26 January 2006	Parametric Index	$100,000		BB	
CEA	Redwood Capital VII, Ltd.	Redwood Capital VII, Ltd.		US EQ	09 February 2006	Industry Index	$160,000		BB+	
CEA	Redwood Capital VIII, Ltd.	Redwood Capital VIII, Ltd.		US EQ	09 February 2006	Industry Index	$65,000		BB+	
Hartford Fire Ins	Foundation Re Ltd.	Foundation Re Ltd. Series 2006-I	Class D	US HU, EQ	17 February 2006	Industry Index	$105,000		BB	
FONDEN	CAT-Mex Ltd.	CAT-Mex Ltd.	Class A	Mexico EQ	11 May 2006	Parametric	$150,000		BB+	
FONDEN	CAT-Mex Ltd.	CAT-Mex Ltd.	Class B	Mexico EQ	11 May 2006	Parametric	$10,000		BB+	
ACE INA	Calabash Re Ltd.	Calabash Re Ltd. Series 2006-I	Class A-1	US HU	24 May 2006	Industry Index	$100,000		BB	
USAA	Residential Reinsurance 2006 Limited	Residential Reinsurance 2006 Limited	Class A	US HU, EQ	31 May 2006	Indemnity	$47,500		B	
USAA	Residential Reinsurance 2006 Limited	Residential Reinsurance 2006 Limited	Class C	US HU, EQ	31 May 2006	Indemnity	$75,000		BB+	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	D-II	US HU	06 June 2006	Industry Index	$10,250		B	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	E-II	US HU	06 June 2006	Industry Index	$35,000		NR	
Swiss Re	Successor Ltd.	Successor Japan Quake Ltd.	C-II	JP EQ	06 June 2006	Modeled Loss	$3,000		B	
Swiss Re	Successor Ltd.	Successor Euro Wind Ltd.	A-II	EU Wind	06 June 2006	Parametric Index	$3,000		BB	
Swiss Re	Successor Ltd.	Successor Euro Wind Ltd.	C-II	EU Wind	06 June 2006	Parametric Index	$3,000		B	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	B-I	US HU	06 June 2006	Industry Index	$14,000		BB-	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	C-I	US HU	06 June 2006	Industry Index	$7,250		B	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	D-I	US HU	06 June 2006	Industry Index	$34,250		B	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	E-I	US HU	06 June 2006	Industry Index	$5,000		NR	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	F-I	US HU	06 June 2006	Industry Index	$54,000		B	
Swiss Re	Successor Ltd.	Successor Hurricane Modeled Ltd.	B-I	US HU	06 June 2006	Modeled Loss	$42,250		BB-	
Swiss Re	Successor Ltd.	Successor Cal Quake Parametric Ltd.	A-I	US EQ	06 June 2006	Parametric Index	$47,500		BB	
Swiss Re	Successor Ltd.	Successor Japan Quake Ltd.	A-I	JP EQ	06 June 2006	Modeled Loss	$103,470		BB	
Swiss Re	Successor Ltd.	Successor Japan Quake Ltd.	B-I	JP EQ	06 June 2006	Modeled Loss	$26,250		BB-	
Swiss Re	Successor Ltd.	Successor Japan Quake Ltd.	C-I	JP EQ	06 June 2006	Modeled Loss	$70,750		B	
Swiss Re	Successor Ltd.	Successor Euro Wind Ltd.	A-I	EU Wind	06 June 2006	Parametric Index	$97,130		BB	
Swiss Re	Successor Ltd.	Successor Euro Wind Ltd.	B-I	EU Wind	06 June 2006	Parametric Index	$18,500		BB-	
Swiss Re	Successor Ltd.	Successor Euro Wind Ltd.	C-I	EU Wind	06 June 2006	Parametric Index	$110,750		B	
Swiss Re	Successor Ltd.	Successor II Ltd.	A-I	US/EU Wind, US/JP EQ	06 June 2006	Multiple	$73,200		B	
Swiss Re	Successor Ltd.	Successor II Ltd.	E-I	US/EU Wind, US/JP EQ	06 June 2006	Multiple	$154,250		NR	
Swiss Re	Successor Ltd.	Successor III Ltd.	A-I	US/EU Wind, JP EQ	06 June 2006	Multiple	$7,200		NR	
Swiss Re	Successor Ltd.	Successor IV Ltd.	A-I	US/EU Wind, US/JP EQ	06 June 2006	Multiple	$30,000		B	
Munich Re	Carillon Ltd.	Carillon Ltd. Series 1	Class A2	US HU	19 June 2006	Industry Index	$23,500		B+	
Munich Re	Carillon Ltd.	Carillon Ltd. Series 1	Class B	US HU	19 June 2006	Industry Index	$10,000		B	
Munich Re	Carillon Ltd.	Carillon Ltd. Series 1	Class A1	US HU	19 June 2006	Industry Index	$51,000		B+	
Liberty Mutual Ins Co	Mystic Re Ltd.	Mystic Re Ltd. Series 2006-1	Class A	US HU	21 June 2006	Industry Index	$200,000		BB+	
Balboa Insurance Group	VASCO Re 2006 Ltd.	VASCO Re 2006 Ltd.		US HU	21 June 2006	Indemnity	$50,000		BB+	
Dominion Resources	Drewcat Capital Ltd.	Drewcat Capital Ltd.	Class A	US HU	30 June 2006	Parametric Index	$50,000		NR	
Hannover Re	Eurus Ltd.	Eurus Ltd.		EU Wind	28 July 2006	Parametric Index	$150,000		BB	
Tokio Marine & Nichido Fire	Fhu-Jin Ltd.	Fhu-Jin Ltd. Series 1	Class B	JP TY	03 August 2006	Parametric Index	$200,000		BB+	
Endurance Specialty Insurance Company	Shackleton Re Limited	Shackleton Re Limited	Class A	US EQ	03 August 2006	Industry Index	$125,000	Bz3	BB	
Endurance Specialty Insurance Company	Shackleton Re Limited	Shackleton Re Limited	Class B	US HU	03 August 2006	Industry Index	$60,000	Ba3	BB	
Endurance Specialty Insurance Company	Shackleton Re Limited	Shackleton Re Limited	Class C	US HU, EQ	03 August 2006	Industry Index	$50,000	Ba2	BB+	
Swiss Re	Successor Ltd.	Successor Hurricane Industry Ltd.	E-III	US HU	04 August 2006	Industry Index	$50,000		NR	
Factory Mutual Insurance Company	Cascadia II Limited	Cascadia II Limited		US EQ	25 August 2006	Parametric	$300,000		BB+	BB+
Catlin Insurance Company Ltd.	Bay Haven Limited	Bay Haven Limited	Class A	US/EU/JP Wind, US/JP EQ	17 November 2006	Multiple	$133,500		AA	
Catlin Insurance Company Ltd.	Bay Haven Limited	Bay Haven Limited	Class B	US/EU/JP Wind, US/JP EQ	17 November 2006	Multiple	$66,750		BBB-	
Hartford Fire Ins	Foundation Re II Ltd.	Foundation Re II Ltd.	Class G	US (HU, EQ, ST)	17 November 2006	Industry Index	$67,500		B	
Hartford Fire Ins	Foundation Re II Ltd.	Foundation Re II Ltd.	Class A	US HU	17 November 2006	Industry Index	$180,000		BB+	
Liberty Mutual Ins Co	Mystic Re Ltd.	Mystic Re Ltd. Series 2006-2	Class A	US HU	30 November 2006	Industry Index	$200,000		BB+	
Liberty Mutual Ins Co	Mystic Re Ltd.	Mystic Re Ltd. Series 2006-1	Class B	US HU	30 November 2006	Industry Index	$125,000		BB	
Swiss Re	Successor Ltd.	Successor I Ltd.	B-I	NA/EU W, CA/JP Q	08 December 2006	Multiple	$4,000		NR	
Swiss Re	Successor Ltd.	Succ Hurricane Industry Ltd.	E-IV	US HU	08 December 2006	Industry Index	$4,000		NR	
Swiss Re	Successor Ltd.	Successor I Ltd.	B-II	NA/EU W, CA/JP Q	08 December 2006	Multiple	$24,500		NR	
Swiss Re	Successor Ltd.	Succ Hurricane Industry Ltd.	E-V	US HU	08 December 2006	Industry Index	$26,000		NR	
Swiss Re	Successor Ltd.	Succ Hurricane Industry Ltd.	A-III	EU Wind	08 December 2006	Parametric Index	$118,000	Ba3	BB	
Swiss Re	Successor Ltd.	Succ Euro Wind Ltd.	C-III	EU Wind	08 December 2006	Parametric Index	$15,000	B3	B	
Zurich Re	Lakeside Re Ltd.	Lakeside Re Ltd.		US EQ	20 December 2006	Multiple	$190,000		BB+	

Sponsor	Issue	Program	Class	Perils	Inception	Trigger	Risk Capital	MIS	S&P	Fitch
SCOR	Atlas Reinsurance III p.l.c.	Atlas Reinsurance III p.l.c.		JP EQ, EU Wind	21 December 2006	Modeled Loss	€ 120,000		BB+	
CEA	Redwood Capital IX, Ltd.	Redwood Capital IX, Ltd. Series 1	Class A	US EQ	29 December 2006	Parametric Index	$125,000	Ba2	BB+	
CEA	Redwood Capital IX, Ltd.	Redwood Capital IX, Ltd. Series 1	Class B	US EQ	29 December 2006	Parametric Index	$125,000	Ba2	BB+	
CEA	Redwood Capital IX, Ltd.	Redwood Capital IX, Ltd. Series 1	Class C	US EQ	29 December 2006	Parametric Index	$18,000	Baa3	BBB-	
CEA	Redwood Capital IX, Ltd.	Redwood Capital IX, Ltd. Series 1	Class D	US EQ	29 December 2006	Parametric Index	$20,000	Ba3	BB	
CEA	Redwood Capital IX, Ltd.	Redwood Capital IX, Ltd. Series 1	Class E	US EQ	29 December 2006	Parametric Index	$12,000	B3	B	
ACE INA	Calabash Re II Ltd.	Calabash Re II Ltd. Series 2006-I	Class A-1	US HU	08 January 2007	Modeled Loss	$100,000		BB	
ACE INA	Calabash Re II Ltd.	Calabash Re II Ltd. Series 2006-I	Class D-1	US EQ	08 January 2007	Modeled Loss	$50,000		B+	
ACE INA	Calabash Re II Ltd.	Calabash Re II Ltd. Series 2006-I	Class E-1	US HU, EQ	08 January 2007	Modeled Loss	$100,000		BB	
Hannover Re	Kepler Re Ltd.	Kepler Re Ltd.		US/EU/JP/Australia/New Zealand/Canada (Wind,EQ)	01 March 2007	Indemnity	$200,000	Ba2		
Swiss Re	Australis Ltd	Australis Ltd Series 2		AU CY, EQ	14 March 2007	Parametric Index	$50,000		BB	
Allianz SE	Blue Wings Ltd.	Blue Wings Ltd. Series 1	Class A	US EQ, UK Flood	03 April 2007	Multiple	$150,000		BB+	
Aspen Insurance Limited	Ajax Re Limited	Ajax Re Limited Series 1	Class A	US EQ	13 April 2007	Industry Index	$100,000		BB	
Chubb Group	East Lane Re Ltd.	East Lane Re Ltd. Series 2007-I	Class A	US HU	30 April 2007	Indemnity	$135,000		BB+	
Chubb Group	East Lane Re Ltd.	East Lane Re Ltd. Series 2007-I	Class B	US HU	30 April 2007	Indemnity	$115,000		BB+	
Munich Re	Carillon Ltd.	Carillon Ltd. Series 2	Class E	US HU	08 May 2007	Industry Index	$150,000		B	
Travelers Indemnity Co	Longpoint Re Ltd.	Longpoint Re Ltd. Series 2007-I	Class A	US HU	08 May 2007	Industry Index	$500,000		BB+	
Swiss Re	Successor Ltd.	Successor II Ltd.	Class A-2	NA/EU W, CA/JP Q	10 May 2007	Multiple	$100,000		B	
Mitusui Sumitomo Insurance Co	AKIBARE Ltd.	AKIBARE Ltd. Series 1	Class A	JP TY	14 May 2007	Parametric Index	$90,000		BB+	
Mitusui Sumitomo Insurance Co	AKIBARE Ltd.	AKIBARE Ltd. Series 1	Class B	JP TY	14 May 2007	Parametric Index	$30,000		BB+	
Nephila	Gamut Reinsurance Limited	Gamut Reinsurance Limited	Class A	US/EU/JP W, US/JP Q	29 May 2007	Indemnity	$60,000	Aa3	A-	
Nephila	Gamut Reinsurance Limited	Gamut Reinsurance Limited	Class B	US/EU/JP W, US/JP Q	29 May 2007	Indemnity	$120,000	Baa3	BBB-	
Nephila	Gamut Reinsurance Limited	Gamut Reinsurance Limited	Class C	US/EU/JP W, US/JP Q	29 May 2007	Indemnity	$60,000	Ba3	BB-	
Swiss Re	MedQuake Ltd.	MedQuake Ltd.	Class A	EU EQ	31 May 2007	Parametric Index	$50,000		BB-	
Swiss Re	MedQuake Ltd.	MedQuake Ltd.	Class B	EU EQ	31 May 2007	Parametric Index	$50,000		B	
Liberty Mutual Ins Co	Mystic Re II Ltd.	Mystic Re II Ltd. Series 2007-1		US HU	31 May 2007	Industry Index	$150,000		B+	
USAA	Residential Reinsurance 2007 Limited	Residential Reinsurance 2007 Limited, Series 2007-I	Class 1	US HU, EQ	31 May 2007	Indemnity	$145,000		BB	
USAA	Residential Reinsurance 2007 Limited	Residential Reinsurance 2007 Limited, Series 2007-I	Class 2	US HU, EQ	31 May 2007	Indemnity	$125,000		B	
USAA	Residential Reinsurance 2007 Limited	Residential Reinsurance 2007 Limited, Series 2007-I	Class 3	US HU, EQ	31 May 2007	Indemnity	$75,000		B	
USAA	Residential Reinsurance 2007 Limited	Residential Reinsurance 2007 Limited, Series 2007-I	Class 4	US HU, EQ	31 May 2007	Indemnity	$155,000		BB+	
USAA	Residential Reinsurance 2007 Limited	Residential Reinsurance 2007 Limited, Series 2007-I	Class 5	US HU, EQ	31 May 2007	Indemnity	$100,000		BB+	
Glacier Reinsurance AG	Nelson Re Ltd.	Nelson Re Ltd. Series 2007-I	Class A	US/EU W, US Q	11 June 2007	Multiple	$75,000		B	
Allstate Insurance Co	Willow Re Ltd.	Willow Re Ltd. Series 2007-1	Class B	US HU	14 June 2007	Industry Index	$250,000		BB+	
Swiss Re	Spinnaker Capital Ltd.	Spinnaker Capital Ltd. Series 1		US HU	15 June 2007	Industry Index	$200,000	B1		
CIG Reinsurance Ltd, New Castle Reinsurance Company Ltd.	Emerson Reinsurance Ltd.	Emerson Reinsurance Ltd.	Class D	NA/EU/UK/JP/AU/NZ All Natural Perils	20 June 2007	Indemnity	$45,000	Ba3		
CIG Reinsurance Ltd, New Castle Reinsurance Company Ltd.	Emerson Reinsurance Ltd.	Emerson Reinsurance Ltd.	Class A	NA/EU/UK/JP/AU/NZ All Natural Perils	20 June 2007	Indemnity	$185,000	A2		
CIG Reinsurance Ltd, New Castle Reinsurance Company Ltd.	Emerson Reinsurance Ltd.	Emerson Reinsurance Ltd.	Class B	NA/EU/UK/JP/AU/NZ All Natural Perils	20 June 2007	Indemnity	$140,000	Baa3		
CIG Reinsurance Ltd, New Castle Reinsurance Company Ltd.	Emerson Reinsurance Ltd.	Emerson Reinsurance Ltd.	Class C	NA/EU/UK/JP/AU/NZ All Natural Perils	20 June 2007	Indemnity	$130,000	Ba2		
Brit Insurance Limited	Fremantle Limited	Fremantle Limited Series 2007-I	Class A	US/EU/JP W, US/JP Q	21 June 2007	Multiple	$60,000	Aa1		AAA
Brit Insurance Limited	Fremantle Limited	Fremantle Limited Series 2007-I	Class B	US/EU/JP W, US/JP Q	21 June 2007	Multiple	$60,000	A3		BBB+
Brit Insurance Limited	Fremantle Limited	Fremantle Limited Series 2007-I	Class C	US/EU/JP W, US/JP Q	21 June 2007	Multiple	$80,000	Ba2		BB-
Swiss Re	Spinnaker Capital Ltd.	Spinnaker Capital Ltd. Series 2		US HU	22 June 2007	Industry Index	$130,200	Ba2		
Swiss Re/Kyoei Fire and Marine Insurance Company	Fusion 2007 Ltd.	Fusion 2007 Ltd.	Class A	JP TY, Mexico EQ	25 June 2007	Parametric Index	$30,000		B	
Swiss Re/Kyoei Fire and Marine Insurance Company	Fusion 2007 Ltd.	Fusion 2007 Ltd.	Class B	JP TY, Mexico EQ	25 June 2007	Parametric Index	$80,000		B	
Swiss Re/Kyoei Fire and Marine Insurance Company	Fusion 2007 Ltd.	Fusion 2007 Ltd.	Class C	Mexico EQ	25 June 2007	Parametric Index	$30,000		BB+	
State Farm Mutual Automobile Insurance Company	Merna Reinsurance Ltd.	Merna Reinsurance Ltd.	Class A	US/Canada (Wind, EQ, ST, WS, WF)	05 July 2007	Indemnity	$256,000	Aa2		AAA
State Farm Mutual Automobile Insurance Company	Merna Reinsurance Ltd.	Merna Reinsurance Ltd.	Class B	US/Canada (Wind, EQ, ST, WS, WF)	05 July 2007	Indemnity	$647,600	A2		AA+
State Farm Mutual Automobile Insurance Company	Merna Reinsurance Ltd.	Merna Reinsurance Ltd.	Class C	US/Canada (Wind, EQ, ST, WS, WF)	05 July 2007	Indemnity	$155,000	Baa2		A-
State Farm Mutual Automobile Insurance Company	Merna Reinsurance Ltd.	Merna Reinsurance Ltd.	Class A	US/Canada (Wind, EQ, ST, WS, WF)	05 July 2007	Indemnity	$94,000	Aa2		AAA
State Farm Mutual Automobile Insurance Company	Merna Reinsurance Ltd.	Merna Reinsurance Ltd.	Class B	US/Canada (Wind, EQ, ST, WS, WF)	05 July 2007	Indemnity	$19,000	A2		AA+
State Farm Mutual Automobile Insurance Company	Merna Reinsurance Ltd.	Merna Reinsurance Ltd.	Class C	US/Canada (Wind, EQ, ST, WS, WF)	05 July 2007	Indemnity	$9,000	Baa2		A-
Arrow Capital Reinsurance Company, Limited	Javelin Re Ltd.	Javelin Re Ltd.	Class A	Worldwide All Perils	18 July 2007	Indemnity	$94,500		A-	
Arrow Capital Reinsurance Company, Limited	Javelin Re Ltd.	Javelin Re Ltd.	Class B	Worldwide All Perils	18 July 2007	Indemnity	$30,750		BBB-	
Swiss Re	Spinnaker Capital Ltd.	Spinnaker Capital Ltd. Series 3		US HU	20 July 2007	Industry Index	$50,000		NR	
Japan Railway East	MIDORI Ltd.	MIDORI Ltd.	Class A	JP EQ	15 October 2007	Parametric	$260,000		BB+	
Allianz SE	Blue Fin Ltd.	Blue Fin Ltd. Series 1	Class A	EU Wind	07 November 2007	Parametric Index	€ 155,000		BB+	
Allianz SE	Blue Fin Ltd.	Blue Fin Ltd. Series 1	Class B	EU Wind	07 November 2007	Parametric Index	$65,000		BB+	
Catlin	Newton Re Limited	Newton Re Limited; Series 2007-1	Class A	US EQ	17 November 2007	Industry Index	$87,500		BB+	
Catlin	Newton Re Limited	Newton Re Limited; Series 2007-1	Class B	US HU	17 November 2007	Industry Index	$137,500		BB+	
SCOR	Atlas Reinsurance IV Limited	Atlas Reinsurance IV Limited	Class A	EU Wind, JP EQ	29 November 2007	Modeled Loss	€ 160,000		B	
Swiss Re	GlobeCat Ltd.	GlobeCat Ltd. Series LAQ	Class A-1	Latin America EQ	21 December 2007	Modeled Loss	$25,000	Ba3e		
Swiss Re	GlobeCat Ltd.	GlobeCat Ltd. Series USW	Class A-1	US HU	21 December 2007	Industry Index	$40,000	B3e		
Swiss Re	GlobeCat Ltd.	GlobeCat Ltd. Series CAQ	Class A-1	US EQ	21 December 2007	Industry Index	$20,000	B1e		

Sponsor	Issue	Program	Class	Perils	Inception	Trigger	Risk Capital	MIS	S&P	Fitch
Groupama SA	Green Valley Ltd.	Green Valley Ltd. Series 1	Class A	EU Wind	27 December 2007	Parametric Index	€ 200,000	BB+		
Swiss Re	Successor Ltd.	Succ Hurr Industry Ltd.	C-VI	US HU	28 December 2007	Industry Index	$30,000	B2	B	
Swiss Re	Successor Ltd.	Succ Hurr Industry Ltd.	D-VI	US HU	28 December 2007	Industry Index	$30,000		B	
Swiss Re	Successor Ltd.	Successor II Ltd.; Series 3	C-III	US/EU Wind, US/JP EQ	28 December 2007	Multiple	$50,000			
Swiss Re	Successor Ltd.	Successor II Ltd.; Series 3	E-III	US/EU Wind, US/JP EQ	28 December 2007	Multiple	$50,000			
CEA	Redwood Capital X Ltd.	Redwood Capital X Ltd. Series 1	Class A	US EQ	31 December 2007	Parametric Index	$25,000	Baa3		
CEA	Redwood Capital X Ltd.	Redwood Capital X Ltd. Series 1	Class B	US EQ	31 December 2007	Parametric Index	$227,700	Ba2		
CEA	Redwood Capital X Ltd.	Redwood Capital X Ltd. Series 1	Class C	US EQ	31 December 2007	Parametric Index	$50,200	Ba3		
CEA	Redwood Capital X Ltd.	Redwood Capital X Ltd. Series 2	Class D	US EQ	31 December 2007	Industry Index	$130,500	Ba3		
CEA	Redwood Capital X Ltd.	Redwood Capital X Ltd. Series 2	Class E	US EQ	31 December 2007	Industry Index	$45,200	B2		
CEA	Redwood Capital X Ltd.	Redwood Capital X Ltd. Series 2	Class F	US EQ	31 December 2007	Industry Index	$20,000	NR		
Catlin	Newton Re 2008-1 A			US/EU/JP Wind, US/JP EQ	21 February 2008	Indemnity	$150,000		BB	
Munich Re	Queen Street A			EU Wind	14 March 2008	Parametric Index	€ 70,000		BB+	
Munich Re	Queen Street B			EU Wind	14 March 2008	Parametric Index	€ 100,000		B	
Chubb Group	East Lane Re II A			Northeast US All Natural Perils	31 March 2008	Indemnity	$75,000		BB	
Chubb Group	East Lane Re II B			Northeast US All Natural Perils	31 March 2008	Indemnity	$70,000		BB	
Chubb Group	East Lane Re II C			US/Canada All Natural Perils	31 March 2008	Indemnity	$55,000		B-	
Zenkyoren	Muteki			JP EQ	14 May 2008	Parametric Index	$300,000	Ba2		
Homewise	Mangrove Re Ltd	Mangrove Re Ltd. Series 2008-1	Class A	US HU	30 May 2008	Indemnity	$150,000	Ba2		
Homewise	Mangrove Re Ltd	Mangrove Re Ltd. Series 2008-1	Class B	US HU	30 May 2008	Indemnity	$60,000	B1		
Glacier Reinsurance AG	Nelson Re G			US HU, EQ	30 May 2008	Indemnity	$67,500	B3		
Glacier Reinsurance AG	Nelson Re H			EU Wind	30 May 2008	Indemnity	$45,000	B3		
Glacier Reinsurance AG	Nelson Re I			EU Wind	30 May 2008	Indemnity	$67,500	B1		
USAA	Res Re 2008 1			US HU, EQ	30 May 2008	Indemnity	$125,000		BB	
USAA	Res Re 2008 2			US HU, EQ	30 May 2008	Indemnity	$125,000		B	
USAA	Res Re 2008 4			US (HU, EQ, ST, WS, WF)	30 May 2008	Indemnity	$100,000		BB+	
Flagstone	Valais Re A			US/EU/JP Wind, US/JP EQ	30 May 2008	Indemnity	$64,000	Ba2		
Flagstone	Valais Re C			US/EU/JP Wind, US/JP EQ	30 May 2008	Indemnity	$40,000	B3		
Allstate Insurance Co	Willow Re D			US HU	17 June 2008	Industry Index	$250,000		BB+	