28th November 2016

Bermuda Monetary Authority

Catastrophe Risk in Bermuda

BSCR Stress Testing and Modeling Practice Analysis

2015 Report

Foreword

Bermuda is predominantly an insurance-based International Financial Centre specialising in the niche of catastrophe reinsurance and is host to the third largest reinsurance market in the world.

With such a relatively high concentration of catastrophe risk, a broad understanding of the potential adverse impacts, including identification of any concentration of risks and catastrophe modeling practices in Bermuda is central to the Bermuda Monetary Authority's supervisory framework. This information is also important to Bermuda insurers and other stakeholders and markets around the globe.

Realising the significant role that Bermuda plays as a leader in the regulation of the catastrophe market, and in an effort to continue to reemphasise our commitment to high standards of transparency, the Authority has produced this report giving a high level overview of the catastrophe risk stress testing and modeling practice in Bermuda.

Overall, the results highlighted the industry's resilience to major, but improbable, catastrophe events and the sophistication, advancement and diversification of the modeling practices in Bermuda. This underscored the reputation of Bermuda insurers of being well capitalised, innovative and technically proficient.

We hope you will find the information in this report of interest. Should you have any questions, comments or suggestions to improve this report, please contact Leo Mucheriwa at lmucheriwa@bma.bm or Nikolaos Georgiopoulos at ngeorgiopoulos@bma.bm.

Craig Swan
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Acronyms

AAL	Average Annual Loss
AIR	AIR Worldwide
AMO	Atlantic Multi-decadal Oscillation
BMA	Bermuda Monetary Authority
BSCR	Bermuda Solvency Capital Requirement
BU	Business Unit
Cat	Catastrophe
Cat Return	Catastrophe Risk Return and Schedule of Risk Management
CSR	Capital and Solvency Return
EQECAT	Catastrophe Risk Management (CoreLogic)
EP	Exceedance Probability
IAIS	International Association of Insurance Supervisors
IFC	International Financial Centre
ILS	Insurance Linked Securities
ISD	Insurance Supervision Team
Mph	Miles per hour
PML	Probable Maximum Loss
RMS	Risk Management Solutions
RDS	Realistic Disaster Scenarios
The Authority	Bermuda Monetary Authority
SAC	Segregated Account Companies
SPI	Special Purpose Insurer
SST	Sea Surface Temperatures
TVaR	Tail Value at Risk

Contents

1. Executive Summary

This report has four main objectives. First, it gives a high level overview of the capacity of the sector to absorb shocks from various Cat risk events underwritten by Bermuda insurers[1]. Second, the report reviews various stress tests to assess if Bermuda insurers are adequately capitalised to withstand severe, but remote, underwriting losses from various possible Cat events that might adversely impact their balance sheets. Third, the report analyses the exceedance probability curve trends, including the level of reliance and sufficiency of the reinsurance, and pricing dynamics. Finally the report analyses the Cat modeling practices in Bermuda.

Overall, the 2015 Cat underwriting stress test results demonstrated that the Bermuda insurance market is resilient to potential adverse impacts from various Cat underwriting loss scenarios, and that insurers' reliance on reinsurance varies. The results also establish Bermuda insurers' ability to absorb these unlikely potential large losses and still have capital remaining to settle policyholder obligations.

Insurers will retain, on average, 70% gross (before reinsurance) and about 84% net (after reinsurance) of their statutory capital & surplus after the largest single Cat underwriting loss event. These results highlight the industry's overall resilience. The results also show that there was no significant impact from the standardised terrorism stress scenario carried out by insurers.

An analysis of the exceedance probability curve demonstrates that Bermuda insurers are more exposed to Atlantic hurricane than any other peril, with gross median exposures over all companies stretching from US$417.8 million for the "1-in-50" year events up to US$771.0 million for the "1-in-1,000" year events. Other perils show lower exposures, however, with significant variation between firms. The use of reinsurance[2] is widespread with the Atlantic hurricane net median exposures stretching from US$192.2 million for the "1-in-50" year events up to US$517.5 million for the "1-in-1,000" year events. Reinsurance is generally more pronounced for lower frequency return periods for all perils except Japanese typhoon**.** Pricing data seems to confirm the overall softening of the market[3].

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[1] Insurers also include reinsurers.
[2] Net results are also net of reinstatement premiums so not all of the differential may arise from reinsurance.
[3] Lower pricing could reflect less risk from differing exposures.

Average loading factors in the accumulation process have been declining steadily since 2011, reaching 7.7% in 2015 versus 16.3% in 2011. This could reflect (but not be limited to) improved modeling approaches, more robust model exposure coverage and/or greater modeling precision by insurers. Atlantic multi-decadal oscillation is taken into consideration in the near-term by fewer insurers.

AIR and RMS are the most frequently used modeling software, while they are occasionally used in tandem with EQECAT. In-house modeling[4] has increased from 34.7% of insurers in 2011 to 39.0% in 2015 while sole vendor usage has declined by an equal amount over the same time period, i.e. 66.7% in 2011 versus 61.0% in 2015. 51.6 % of insurers report that they use more than one model in their accumulation process. Insurers use their models more on a quarterly basis with 43.9% of insurers doing so, while monthly and daily usage is performed by 24.4% and 22.0% respectively.

[4] In-house model is a proprietary model built by an insurer

2. Introduction

Bermuda's insurance sector is regulated and supervised by the Authority. As part of the regulatory and supervisory measures, the Authority requires all Class 3B and Class 4 insurers to submit a Catastrophe Risk Return and Schedule of Risk Management (Cat Return), as part of their annual statutory filing, detailing the insurers' catastrophe risk management practices.

Within the Cat Return, insurers report their catastrophe exposures, their Exceedance Probability (EP) curves for various return periods, their Average Annual Loss (AALs) and Probable Maximum Loss (PMLs) as well as stress test results that the Authority designates for their own solvency assessment. The Cat Return serves as a point of reference in the prudential filings for quantification of catastrophe risk assumed in Bermuda.

The Cat Return also determines the extent of reliance on vendor models to assess catastrophe exposures and highlights the actions insurers take to mitigate model risk, including a description of procedures and analytics in place to monitor and quantify exposure to vendor models. It also serves as a tool to assist the Authority to assess the reasonableness of inputs into the catastrophe component of the regulatory capital requirement, and whether standards are being applied evenly.

The global insurance market and the Bermuda market in particular, significantly rely upon vendor models to assess catastrophe exposures. If the vendor models underestimate potential losses arising from events, the industry as a whole may have capital levels impacted to a greater extent than expected. Not only is this a strategic and risk management issue for an insurer, it also impacts its regulatory capital requirement since the Catastrophe Risk Charge is generally a significant contributor to this requirement. Therefore, a comprehensive understanding of the modeling practices in Bermuda is a central aspect to the Authority's supervisory framework.

Drawing from the information in the Cat Returns, this report gives a high level overview of the capacity of the Bermuda insurance sector to absorb shocks from various Cat risk events underwritten by Bermuda insurers, including identification of any concentration of risks and an analysis of the catastrophe modeling practices.

The report contributes to improved understanding of Bermuda as an insurance-based International Financial Centre (IFC) and a leader in the regulation of the catastrophe market.

This ultimately demonstrates the contribution of Bermuda and emphasises the commitment of the Authority to a high standard of transparency.

3. Methodology

The report was produced using aggregated and non-aggregated data from the Bermuda Capital and Solvency Return (CSR) filings of Class 3B and Class 4 insurers for the period ended 31st December 2015. Specifically, the following schedules from the CSR were used as data sources:

- Schedule V(e) – Schedule of Risk Management: Stress/Scenario Test;
- Schedule X(a) - Catastrophe Risk Return: EP Curve Total;
- Schedule X(c) - Catastrophe Risk Return: EP Curve for Regions-Perils;
- Schedule X(e) – Catastrophe Risk Return: Accumulations Overview;
- Schedule X(f) - Catastrophe Risk Return: Data Analysis; and
- Schedule X(g) - Catastrophe Risk Return: Reinsurance Disclosures

Data was aggregated only when it could be. For example we did not use aggregated EP curve data, while we used aggregated AAL data. EP curves were not aggregated since they represent upper quantiles of distributions and quantiles are not additive functions. AALs on the other hand, since they represent averages over distributions can be aggregated without logical inconsistencies.

When data could not be aggregated, an augmented box plot presenting percentiles and averages was used in order to describe the distribution of the variable within the industry. Care has been taken not to identify individual insurers to preserve the confidentiality of the CSR filings.

The report did not review or analyse the actual experience of Cat losses versus modeled projected losses. In total, the report was able to capture a high level overview of the Cat risk in Bermuda.

The report uses data from Class 3B and Class 4 insurers (legal entity level) only. The exclusion of all other classes, such as insurance groups and Special Purpose Insurers (SPIs), limits the conclusions that can be gleaned from the results of this survey. Therefore one should view the results as being reflective of a segment of the industry and not the entire exposure of the Bermuda insurance market[5] which is expected to be larger than what is

[5] Bermuda insurance market includes the Bermuda reinsurance market.

presented in this report. It should also be noted that, having excluded the Long-Term (life) insurers, the report does not consider mortality catastrophic risk.

The analysis of the accumulation process is based on responses from insurers in the 2015 and previous years' CSR filings. The accumulation process provides insights into the relationship between the modeling process of insurers and the actual management of those risks from an operational point of view.

The analysis in this report was based purely from original CSR data input. No reference was made to other supporting documents separately required as part of the CSR filing. These additional documents are also reviewed by the Authority's supervisory team at the micro level in the context of individual insurers. As such, subtle nuances provided from an insurer's full return that might otherwise impact these results are not reflected in this report.

Information Box

Class 3B companies are large commercial (re-)insurers underwriting 50% or more unrelated business and with total net premiums [from unrelated business] of US$50 million or more. Class 4 (re)insurers have a minimum capital and surplus floor of US$100 million and underwriting direct excess liability and/or property catastrophe reinsurance.

Aggregate Statistics for Classes 3B and 4, 2015. (In US$ billions)

Net Earned Premiums	34.0
Net Written Premiums	35.0
Net Income	8.8
Total Claims	17.6
Total Assets	164.7

Source: BMA

4. Catastrophe risk stress test

As part of the annual statutory CSR filing, insurers are required to carry out rigorous and comprehensive forward-looking stress tests to measure the sensitivity of their statutory capital & surplus to various significant Cat risk underwriting loss scenarios[6].

Stress testing is a fundamental element of an insurer's overall risk management framework and capital adequacy determination[7]. The main objective of underwriting stress testing is to assess the capacity of individual insurers, and the entire sector, to absorb shocks from adverse impacts and to identify any concentration of risk that may emerge. Stress testing can also be used to assess the effect of tail events beyond the measured level of confidence.

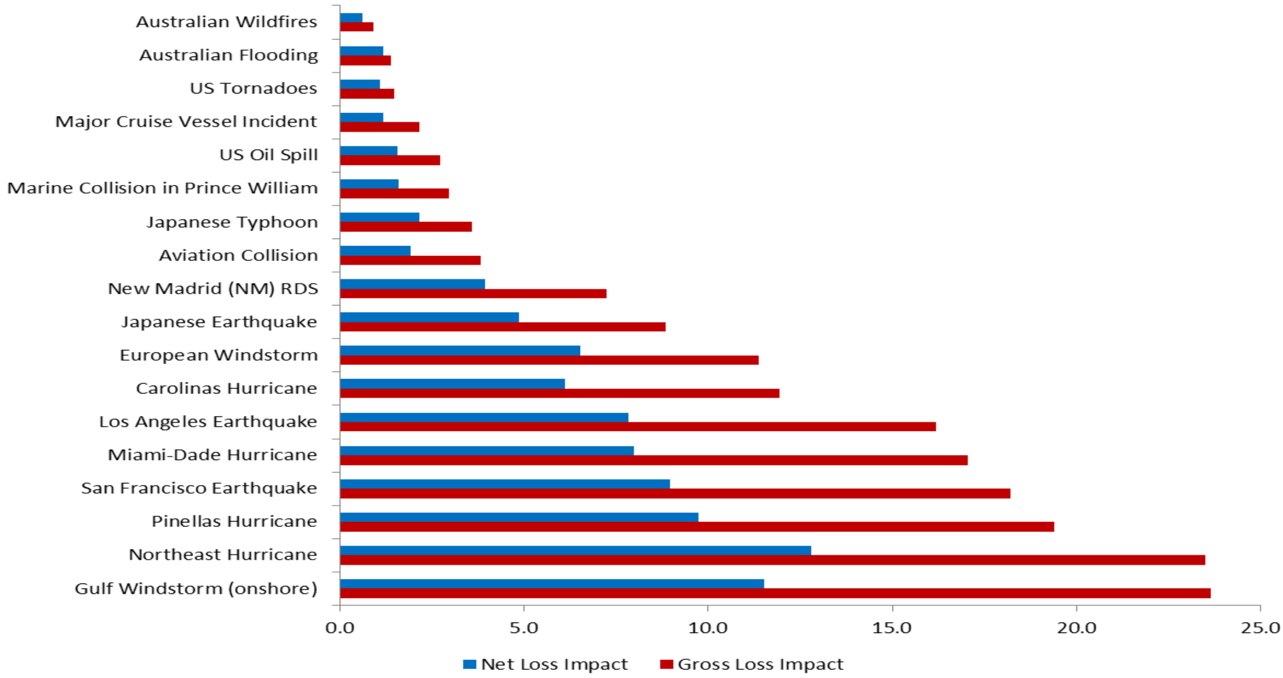
The Authority assesses Cat risk stress tests at three different levels: First, using both the Lloyd's developed Realistic Disaster Scenarios (RDS) and other scenarios designed by the Authority, each insurer is required to estimate its loss impact for 18 standardised Cat underwriting loss scenarios (see Appendix 1 for details on each underwriting loss scenario's key assumptions that insurers use as a guide to estimate their market share). Second, the insurer is required to submit to the Authority three of its own underwriting loss scenarios if the 18 standardised RDS underwriting loss scenarios provided by the Authority do not fully apply to the insurer's underwriting exposure. Finally, the insurer is required to consider and provide estimates for its worst-case underwriting loss scenario based on its own independent underlying assumptions.

In general, the 2015 Cat underwriting loss scenario results showed that not only is the Bermuda insurance market resilient to potential Cat underwriting loss impacts arising from all major perils underwritten[8], but will still hold satisfactory capital to settle policyholders' obligations. Out of the 18 standardised underwriting loss scenarios, Gulf Windstorm (onshore) had the largest potential adverse effect with an estimated gross loss impact[9] to statutory capital & surplus of 24% (and 12% net loss impact), followed by Northeast Hurricane which had the potential to deplete 23% (and 13% net loss impact) of the total

[6]Insurers are also required to conduct stress scenarios to assess their capital adequacy under an adverse financial market and a combination of an adverse financial market scenario with an adverse underwriting scenario. However, this report only discusses the underwriting loss scenarios from Cat events.
[7]IAIS
[8]The underwriting loss impact and associated assumptions reported by insurers are probabilistically expected outcomes and represent calculated estimates. Actual results may significantly differ from these estimates.
[9]Gross loss impact is before any reinsurance and/or other loss mitigation instruments.

statutory capital & surplus[10]. The gross impact from each of all the other perils was below 20% with the majority of the perils (11) having gross loss impact of less than 10% (see Appendix 2).

Figure 1. Stress Testing - Cat Loss Scenarios (In Percentage of Total Capital & Surplus)



Source: BMA staff calculations.

At the individual entity level, the results showed that Bermuda's insurance entities are resilient to their worst Cat event underwriting loss scenario.

Finally, insurers are also required to carry out a separate stress test for terrorism coverage by estimating the potential loss impact using a standardised scenario of an explosion of a two-tonne bomb. The results from the test showed that all entities would comfortably withstand their worst impact from this standardised scenario, retaining on average 87% of the statutory capital & surplus on a gross basis and 93% on a net basis.

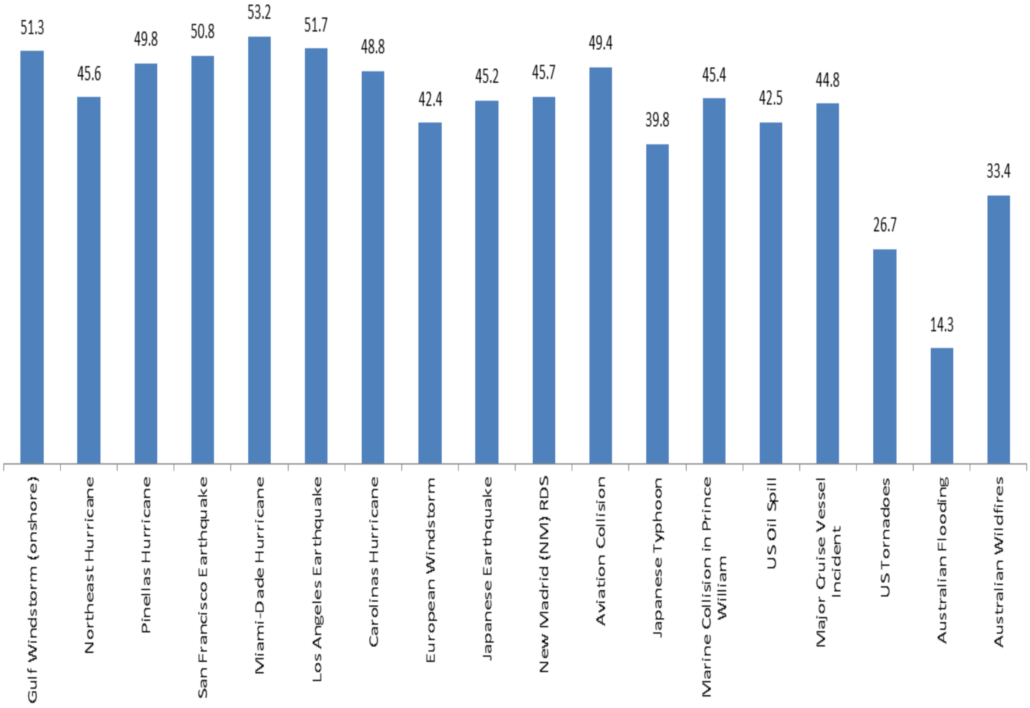
Reliance on reinsurance

The Authority also assesses the level of insurers' reliance on reinsurance and/or other loss mitigation instruments for each peril. Overall, looking at aggregate loss impact, the results

[10]Total Capital & Surplus includes only Capital & Surplus for insurers that underwrite Cat risk i.e. Capital & Surplus for insurers that do not underwrite Cat risk is not included.

showed that the level of reliance on reinsurance varies across each peril. Typically, perils which have potential for the largest losses, such as Northeast Hurricane and Gulf Windstorm, are heavily reinsured.

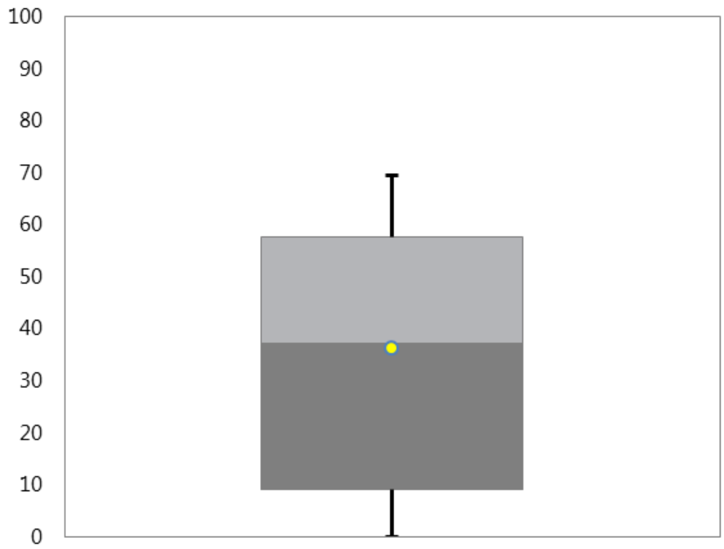
Figure 2. Percentage of Gross Loss Impact Ceded (In percent)



Source: BMA staff calculations.

While the percentage of the aggregate loss impact ceded seems to imply a significant market wide reliance on reinsurance (figure 2 above), on average insurers ceded only 36% of their loss impact (figure 3).

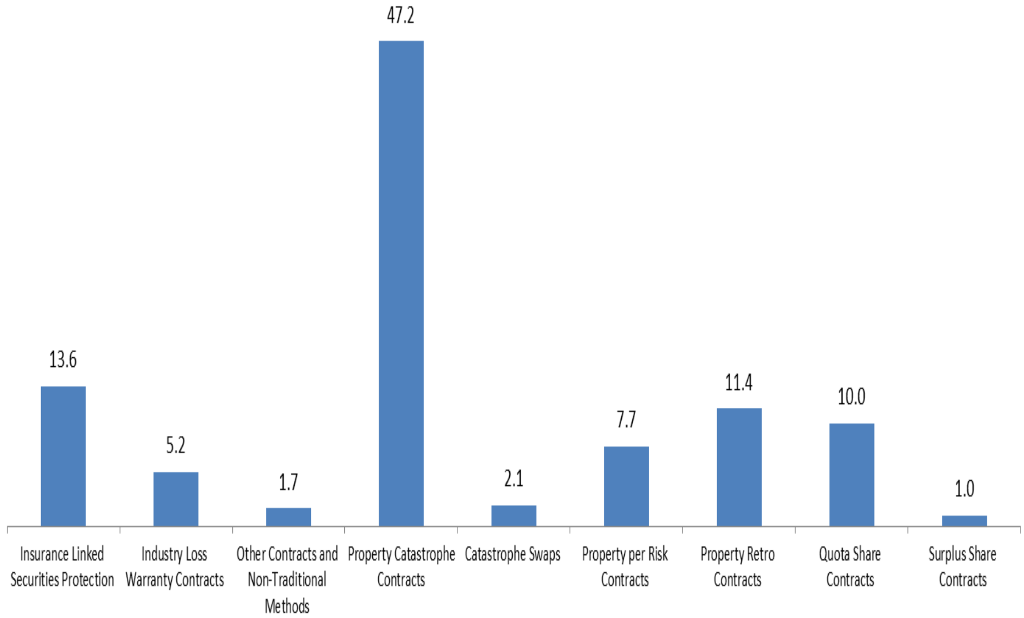
Figure 3. Percentage of Loss Impact Ceded



Source: BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

The results also showed that Bermuda insurers use a variety of reinsurance methods to cede some of their Cat exposure. While the majority of the exposure is ceded using the traditional property catastrophe contracts, there also is a sizeable use of other reinsurance arrangements such as quota share contracts, Insurance Linked Securities (ILS) protection and industry loss warranties contracts.

Figure 4. Reinsurance Strategy (Aggregate Occurrence Limit)

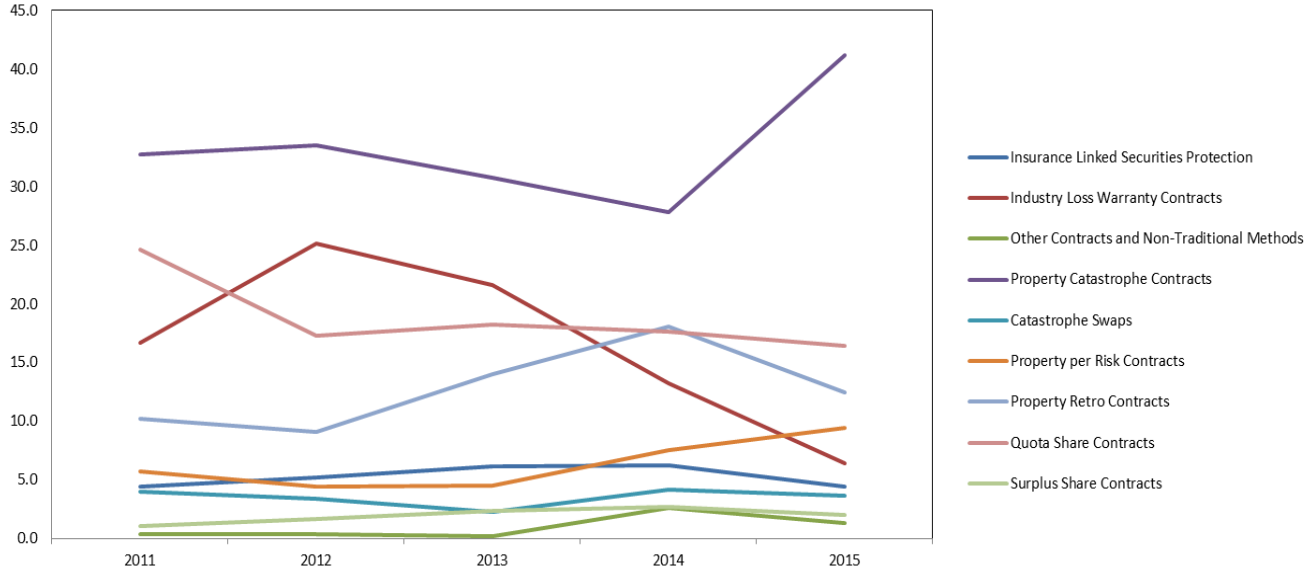


Source: BMA staff calculations.

A review of the reinsurance arrangements for the last five years noted a significate drop in the use of industry loss warranty contracts i.e. from 25% in 2012 to 6% in 2015. The use of property catastrophe contracts gradually dropped between 2012 and 2014; however, there was steep increase in 2014 i.e. from 28% to 41% in 2015. The use of other reinsurance arrangements has relatively stayed the same over the past five years.

Figure 5. Reinsurance Strategy trends - Average Occurrence Limit 2011-2015

(In percent)



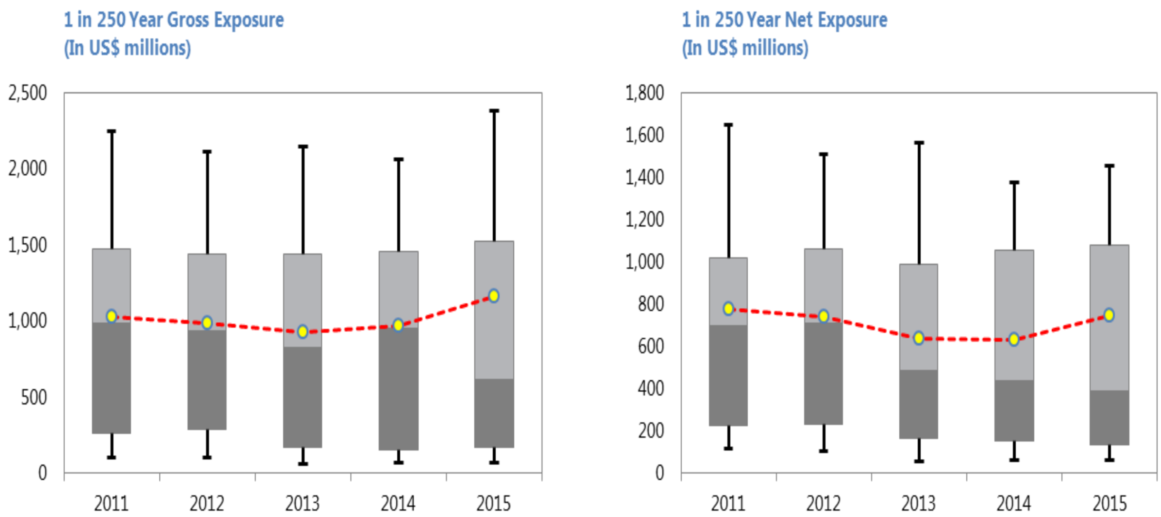
Source: BMA staff calculations.

*Average Occurrence Limit is the average percent of each reinsurance strategy per insurer aggregated together.

5. Exceedance Probability Curves

Historical trends of the gross and net Probable Maximum Loss (PML) for aggregate exposures for the past five years were evaluated for “1-in-250” year events. The following panel presents the distribution of the PML for the aforementioned return period.

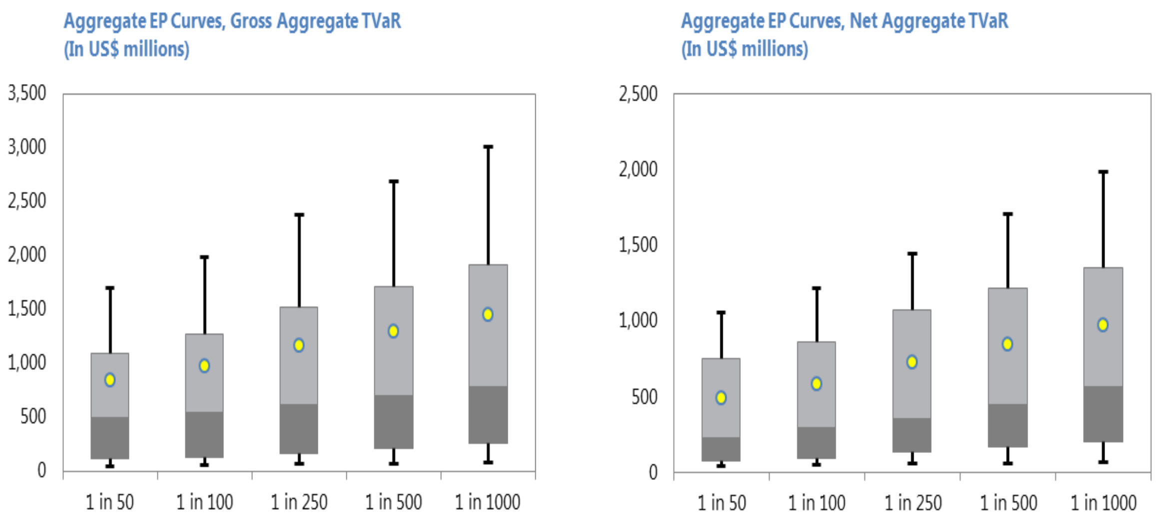
Panel 1. Gross and Net 1-in-250 PML



Source: BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

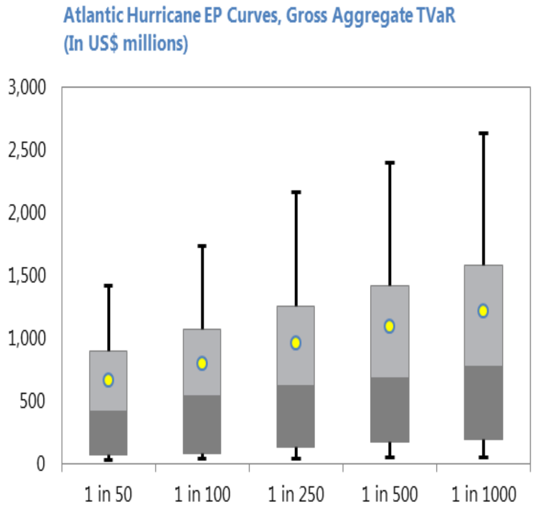
The insurers have increased their average gross exposure since 2011 by 13.3% or 3.32% per year. Inflation has run to an average of 1.8% during 2011-2015. The real average growth in exposure for the “1-in-250” year events is approximately 1.5%. For the same return period the average net exposure dropped by 4.2%, indicating more widespread use of reinsurance.

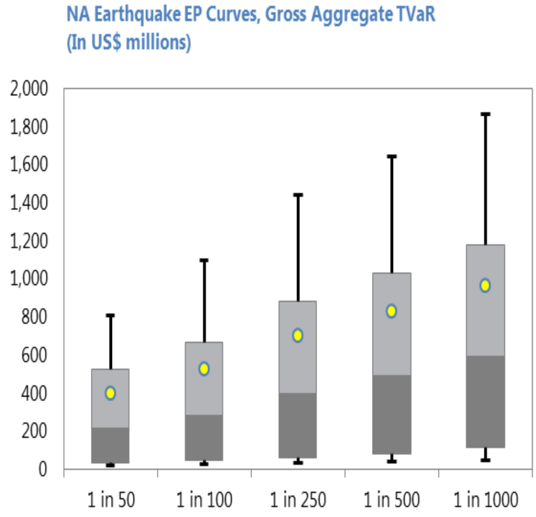
Panel 2. Gross and Net EP Curves, Year 2015

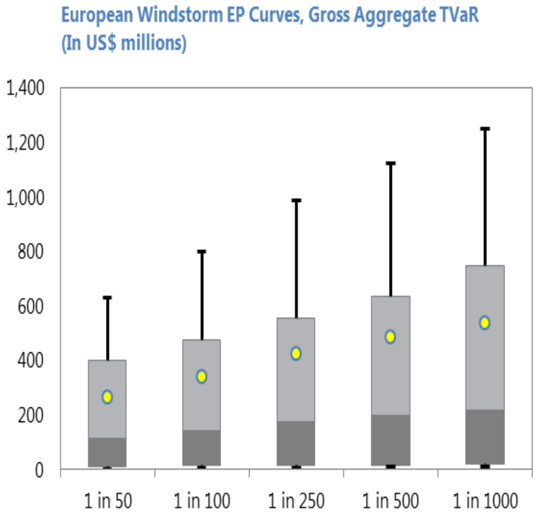


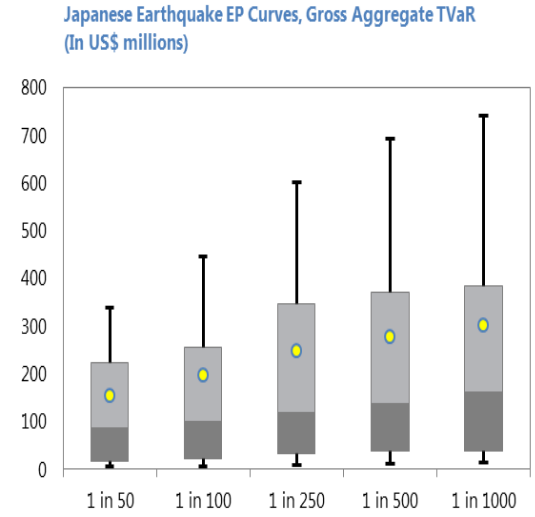
Source: BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

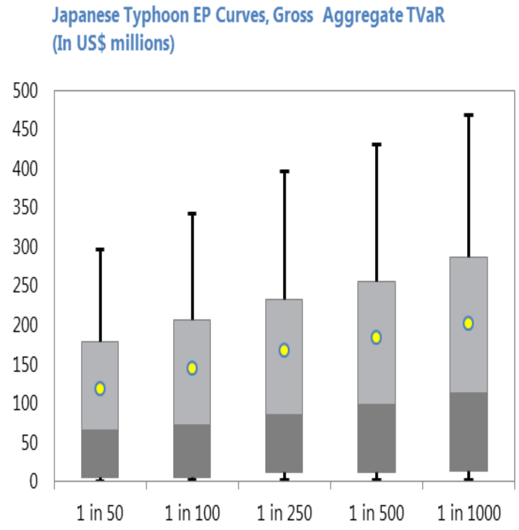
Panel 3. Gross EP Curves for Various Perils











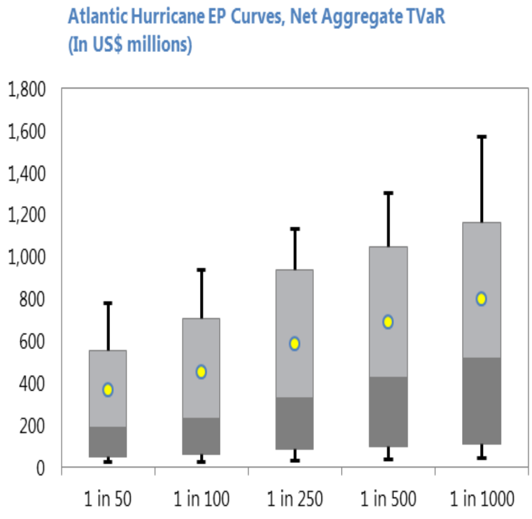
Source: BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

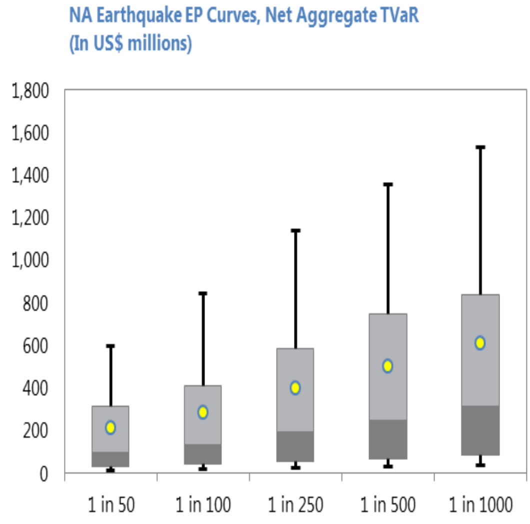
Referring to panels 2 and 3 we observe, as expected, the return period average and median exposures are increasing in the rarity of the event. The majority of gross exposure is tied to Atlantic hurricane while the smallest amount relates to insured losses for Japanese typhoon, this information validating that the Bermuda market primarily insures US-based risks.

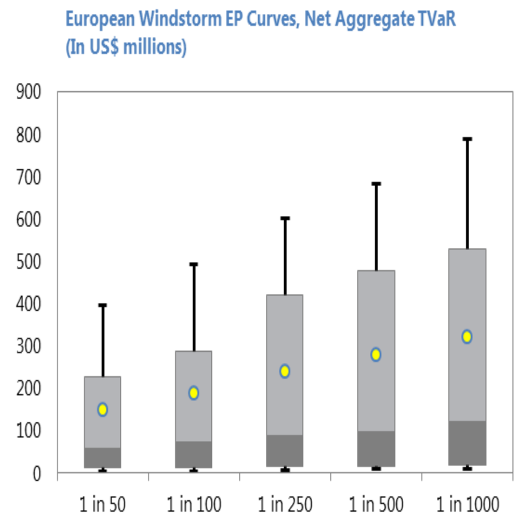
In terms of gross median exposures, Atlantic hurricane varies between US$417.8 for “1-in-50” year events up to approximately US$771.0 million for “1-in-1,000” year events. Gross median losses vary from US$211.0 million for “1-in-50” year events up to close US$591.0 million for “1-in-1,000” year events for NA earthquake. For other perils the gross median EP loss varies between US$67.0 million and US$217.0 million for all return periods.

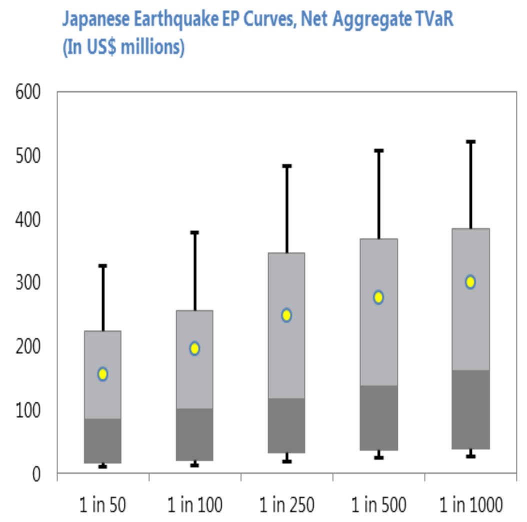
Some companies are more exposed than others with their gross EP curves stretching to US$1.5 billion for “1-in-50” year events for Atlantic hurricane up to US$2.5 billion for “1-in-1,000” year events. Other perils show similar variations in gross exposures. European windstorm can reach gross exposures up to US$1.2 billion for “1-in-1,000” year events while Japanese earthquake and typhoon can stretch up to US$740.8 million and US$468.2 million respectively. Another salient characteristic of the sample is that the average exposure is higher than the median, indicating a skewed distribution of exposures among Bermuda insurers.

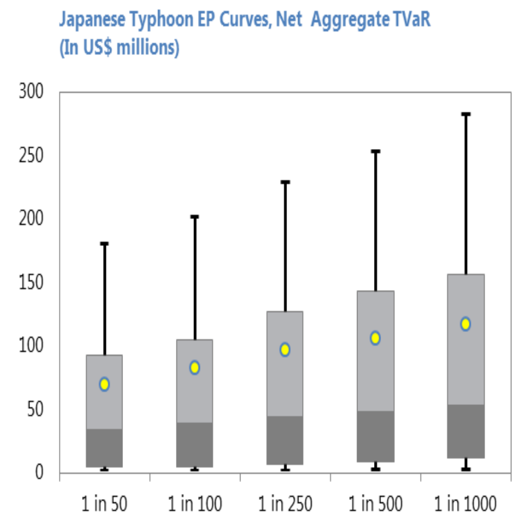
Panel 4. Net EP Curves for Various Perils









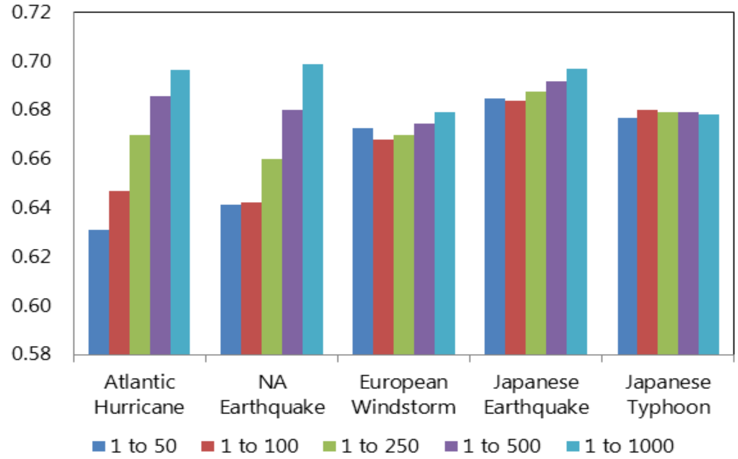


Source: BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

A similar picture is apparent for net losses where Atlantic hurricane and NA earthquake are the largest perils in terms of exposures for all return periods. The net median exposures stretch from US$192.2 million for ”1-in-50” year events up to US$517.5 million for “1-in-1,000” year events. Average net exposure for Atlantic hurricane varies between US$363.8 million for to “1-in-50” year events up to US$795.8 million for “1-in-1,000” year return periods.

The average ratio of net to gross exposure is between 0.63 and 0.7 for all return periods for Atlantic hurricane, 0.64 to 0.7 for NA earthquake, around 0.67 times for European windstorm, 0.7 for Japanese earthquake and close to 0.68 for Japanese typhoon. These averages pertain to all return periods and exhibit stability on average. There are a few firms who do not cede their Cat exposure for all return periods but the exposures are small in probabilistic terms. We studied the average ratios of gross to net exposures on the EP curves for all perils and return periods.

Figure 6. Average Net to Gross EP Exposure per Peril and Return Period (Aggregate EP Curves)



Source: BMA staff calculations.

For Atlantic hurricane the ratios are increasing as the return period increases, but the probabilistic frequency is decreasing. Rarity is defined according to the return period, with "1-in-50" years return period being the more frequent and the "1-in-1,000" years return period being the least frequent.

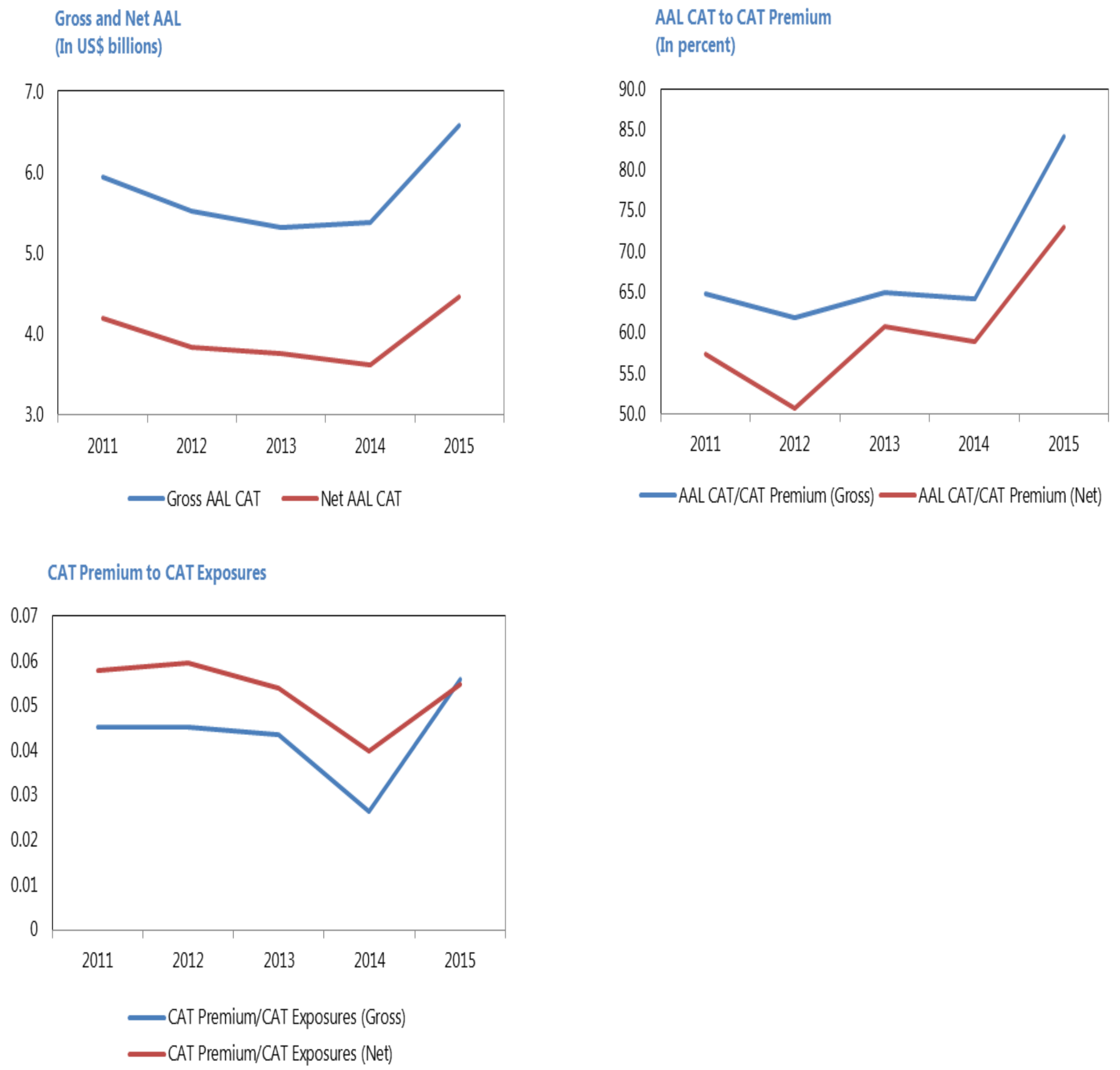
The observations indicate that less reinsurance is being purchased for more rare events ("1-in-1,000"), compared to less rare events ("1-in-50"). This is true for all perils except Japanese typhoon where rarer events appear to admit more reinsurance. The average of all net to gross ratios does not exceed 0.7, while there are insurers in the sample who exhibit ratios 0.16 net to gross exposure for Atlantic hurricane in particular indicating heavy use of reinsurance[11].

[11] Gross EP Curves are gross of reinstatement premiums whereas net EP Curves are net of reinstatement premiums so level of reinsurance may not be exact.

6. Pricing Dynamics

The following panel describes the pricing dynamics, across time, of the catastrophe market based on aggregated data.

Panel 5. Average Annual Loss, Risk & Pricing Ratios[12]



Source: BMA staff calculations. Note: The ratios are calculated only for modelled exposures and modelled premium.

The gross Average Annual Loss (AAL) has increased between 2014 and 2015 and has reached US$6.6 billion. Likewise the net AAL has reached US$4.5 billion. This development indicates that insurers are exposed to more Cat risk than the previous year on an expected basis.

Plots of the risk and the pricing dynamics were drawn to show the ratios of the Cat AAL to Cat premium for both gross and net exposures in panel 5. The AAL largely represents the

[12] We use only modeled exposures and premium.

modeled estimation of the expected Cat losses, and the gross premium this values up to includes provisions for profit and expenses. The relationship between the two ratios provides an indication of the amount of expenses; profit and other loadings charged to insured entities. We observe that on average this ratio has been steadily increasing since 2011.

Higher AALs have been compensated, on average, with fewer premiums and the ratio has increased from 64.8% to 84.1% for gross exposures, while for net exposures the ratio has increased from 57.3% to 72.9%. Between 2014 and 2015 there has been a rather steep increase in this ratio primarily due to the steep increase of the AALs in 2015. This statistic could be reflective of the softening in the reinsurance market and especially for Cat exposures.

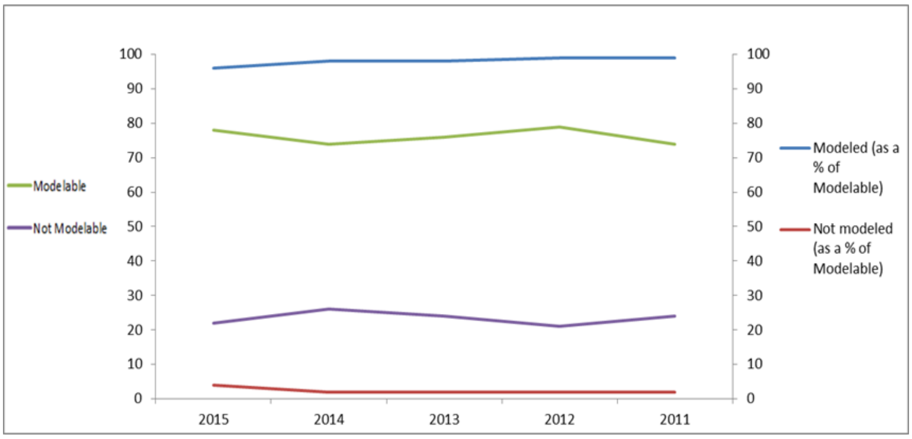
We also plot the ratio of Cat premium to Cat exposures which can be seen in panel 5. This ratio increased between 2014 and 2015, while previously the ratio was decreasing. The ratio dropped due to substantially lower reported aggregate exposure for 2015 compared to 2014. However this reporting does not necessarily imply an increasing AAL. A possible explanation for this development is that insurers are taking more skewed, to the right tail of distribution, risks with relatively low probabilities of loss occurrence.

7. PMLs and Accumulation Process

The accumulation process is an important component of the modeling process as it is an integral part of risk management. The Authority collects on an annual basis, as part of the CSR filing, information about the accumulation process from the prudential filings of companies.

The 2015 CSR filing showed that 74% of the Cat risk exposure underwritten in Bermuda is modelable and that 98% of the modelable risk was modeled. The percentage of modelable exposure slightly dropped in 2015; however the modeled exposure (as a percentage of modelable) has gradually increased during the last five years[13].[14].

Figure 7. Modelable and Modeled Exposure (In percent)



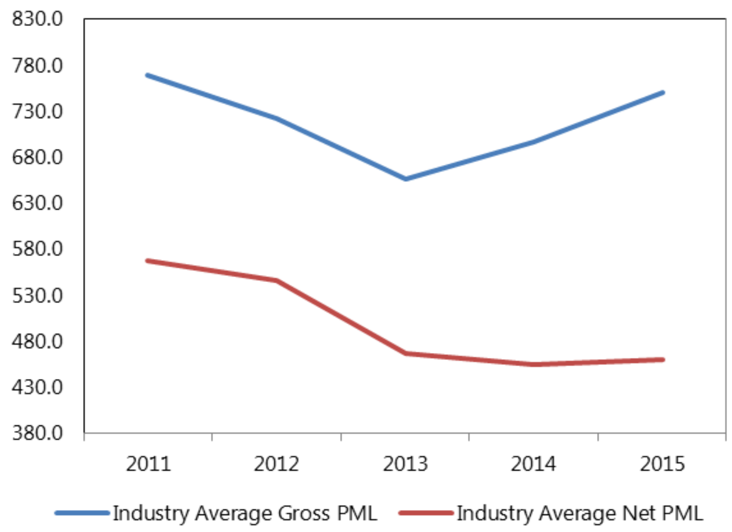
Source: BMA staff calculations.

One of the most important outputs of the accumulation process is the Probable Maximum Loss (PML). The PML is defined as the 99.0 TVaR. All PMLs refer to aggregate exposures and not to per-occurrence exposure.

[13]**Modelable exposure** refers to the exposure that can be simulated through a vendor catastrophe model; **Non-Modelable exposure** refers exposure that cannot be simulated through a vendor catastrophe model or where there are no catastrophe models that assess the risk of the region-peril under consideration; **Modeled exposure** refers to risks that the insurer was able to model.

[14]Reasons for non-modeled risk may include; data limitations that prevent the exposure from being run through a vendor catastrophe model. This may be due to the resolution (or frequency) of the data or the completeness of the data, which for other reasons is not sufficient to produce credible modeling results; Model deficient, where there may be some modelable exposures but the vast majority of exposures are not modelable; and or there are no catastrophe models that assess the peril under consideration.

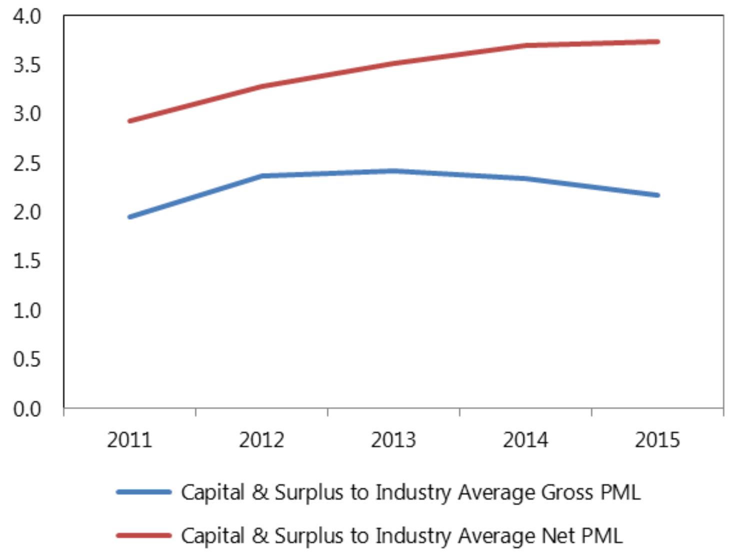
Figure 8. Gross and Net Average Industry PML (In US$ millions)



Source: BMA staff calculations.

We observe on average that the gross PMLs have increased in 2015 while the net PML has shown a steady decrease due to more pronounced use of reinsurance. We also plot the ratio of capital and surplus to average gross and net PML respectively.

Figure 9. Capital and Surplus to Gross and Net Industry PML (In percent)



Source: BMA staff calculations.

The average capital and surplus to gross PML dropped in 2015 due to an increase of the average PML, while on a net basis the ratio has increased.

In terms of aggregating exposures, Bermuda insurers use factor loadings[15] as conservative buffers in their accumulation process for prudent risk modeling where required. The following table shows the average loading factor during the past years.

Table 1. Average Loading Factor (In percent of respondents)

2011	2012	2013	2014	2015
16.3	9.2	7.5	6.6	7.7

Source: BMA

We observe diminishing loading factors in the filed data. The decline in the average loading factor does not necessarily imply less conservative modelling. Loadings compensate for model error and as models become more conservative due to additional knowledge about risks, a lower-valued loading is deemed appropriate.

Insurers responded as to whether the loadings are analytically determined or estimated. The following table shows the responses of insurers.

Table 2. Estimation Method of Loadings (In percent of respondents)

	2011	2012	2013	2014	2015
Analytically Determined	36.7	52.9	61.1	50.0	40.0
Estimated	63.3	47.1	38.9	50.0	60.0

Source: BMA

As part of their modelling process for North Atlantic hurricane exposures, Bermuda insurers use specialised modeling methodologies. One of them is the Atlantic Multi-decadal Oscillation (AMO). AMO refers to the alteration of Sea Surface Temperatures (SST) in the Northern Atlantic from cool to warm phases. These phases last for several years. Since the mid-1990s, a warm phase has existed. A correlation has been observed between warm SSTs and more frequent severe hurricanes and other destructive weather phenomena. Bermuda insurers responded as to whether they consider loadings for this risk factor on near-term or long-term views.

Table 3. AMO Factor Consideration (In percent of respondents)

	2011	2012	2013	2014	2015
Near-term frequency	97.1	85.0	76.2	66.7	64.7
Long-term frequency	2.9	15.0	23.8	33.3	35.3

Source: BMA

[15] Factor loadings are add-ons on the risk modeling process to proxy for conservatism in the assumptions that are used in the models.

Bermuda insurers use vendor as well in-house models to model their exposures to catastrophic risk. The following table illustrates the licensing of models which Bermuda insurers' use.

Table 4. Vendor Models Licensing (In percent of respondents)

	2011	2012	2013	2014	2015
AIR only	2.9	8.3	10.3	15.0	7.7
EQECAT only	0.0	0.0	0.0	0.0	0.0
RMS only	11.4	11.1	15.4	10.0	17.9
AIR and RMS	48.6	44.4	46.2	60.0	66.7
AIR and EQECAT	0.0	0.0	0.0	0.0	0.0
EQECAT and RMS	2.9	0.0	0.0	0.0	0.0
AIR, EQECAT and RMS	34.3	36.1	28.2	15.0	7.7

Source: BMA

The table shows that a majority of insurers are using a combination of AIR and RMS models at an increasing pace, while model usage of all three combined has been steadily decreasing. Most insurers appear to base their modeling and pricing not on a single model but through a combined view of multiple models.

The table below shows the actual usage (beyond the licensing) of vendor models.

Table 5. Vendor Models Usage (In percent of respondents)

	2011	2012	2013	2014	2015
AIR only	6.1	8.8	11.4	16.7	9.1
EQECAT only	0.0	0.0	0.0	0.0	0.0
RMS only	33.3	26.5	28.6	30.6	39.4
AIR and RMS	36.4	44.1	45.7	38.9	45.5
AIR and EQECAT	0.0	0.0	0.0	0.0	0.0
EQECAT and RMS	3.0	2.9	0.0	0.0	0.0
AIR, EQECAT and RMS	21.2	17.6	14.3	13.9	6.1

Source: BMA

With respect to actual usage, the share of RMS-only modeling is increasing while there is also a prevalence of using both AIR and RMS. EQECAT seems to have a declining share both in usage and licensing in the accumulation process. Vendor models are not the only models in use by insurers; in-house model development plays a significant role. The next table shows the percentage of insurers who have developed internal models to complement their Cat risk management process.

Table 6. Vendor vs. In-House Models Usage (In percent of respondents)

	2011	2012	2013	2014	2015
Both In-House and Vendor	34.3	38.9	43.6	42.5	39.0
Vendor Only	65.7	61.1	56.4	57.5	61.0

Source: BMA

We observe a relative stability across time in the usage of stochastic models built in-house versus vendor models. Almost 60% of insurers use only vendor models versus 40% of insurers who use both vendor and in-house developed models.

Table 7. Number of Model Usage (In percent of respondents)

	2011	2012	2013	2014	2015
One catastrophe model is used in the accumulations	42.9	44.4	51.3	50.0	48.7
Two catastrophe models are used in the accumulations	37.1	38.9	30.8	35.0	38.5
Three catastrophe models are used in the accumulations	5.7	2.8	5.1	5.0	5.1
More than three catastrophe models are used in the accumulations	14.3	13.9	12.8	10.0	7.7

Source: BMA

We observe that most insurers will use up to two models in the accumulation process. The above responses also include in-house models and may not necessarily reconcile with the numbers of table 2. The frequency of the accumulation process is an important component of the monitoring and management of risks.

Table 8. Frequency of Accumulation (In percent of respondents)

	2011	2012	2013	2014	2015
Ad-hoc	0.0	0.0	0.0	0.0	0.0
Annual	0.0	0.0	0.0	0.0	0.0
Semi-annual	5.7	5.6	2.6	2.5	0.0
Quarterly	34.3	38.9	38.5	35.0	43.9
Monthly	20.0	22.2	20.5	25.0	24.4
Weekly	5.7	2.8	5.1	5.0	2.4
Daily	20.0	13.9	20.5	20.0	22.0
Real time	14.3	16.7	12.8	12.5	7.3

Source: BMA

Most insurers perform monthly and quarterly accumulations while there are several insurers who perform accumulations on a daily basis or in real time. The accumulation process for most insurers has been consistent over the years except in the cases of real time and weekly accumulations which have considerably dropped as a share of accumulation frequency. Moreover, insurers responded as to whether there are differences in the frequency of accumulations for different business unit (BUs) as it can be shown in the following table:

Table 9. Differences in Modeling Frequency (In percent of respondents)

	2011	2012	2013	2014	2015
Different Frequencies for Different BUs	25.7	28.6	35.1	32.5	36.6
The Same Frequency for all Bus	74.3	71.4	64.9	67.5	63.4

Source: BMA

Insurers appear to be giving greater consideration to their approach to modelling frequency by business unit increasing from 25.7% of insurers who used different frequencies by business unit in 2011 to 36.6% in 2015.

Finally we explored relationships between the proportion of natural catastrophe exposed business written and properties of the accumulation process. This is labelled below as "high", "medium" or "low" buckets. The next tables present the distribution of used and licensed models per bucket.

Table 10. Catastrophe Buckets and Model Use (In percent)

Catastrophe Bucket	3 Models	2 Models	1 Model
High	20.0	40.0	40.0
Medium	20.0	40.0	40.0
Low	0.0	47.6	52.4

Source: BMA

Table 11. Catastrophe Buckets and Model License (In percent)

Catastrophe Bucket	3 Models	2 Models	1 Model
High	14.3	57.1	28.6
Medium	20.0	60.0	20.0
Low	4.0	72.0	24.0

Source: BMA

The licensing of two models is the most prevalent among all buckets. Only 4.0% of insurers that write a low proportion of natural catastrophe exposed business license three models and it seems that they do not use all three in the accumulation process. The picture is consistent for all other buckets in terms of model licensing and usage. One to two model accumulations remains the prevalent practice.

We also check whether the buckets are correlated to the frequency of accumulations and whether insurers use proprietary models or not. Moreover, we checked whether different buckets have different accumulation frequencies in different various BUs. The following tables summarise the results.

Table 12. Catastrophe Buckets and Differences in Modeling Frequency (In percent)

Catastrophe Bucket	Quarterly	Monthly	Weekly	Daily	Real Time
High	14.3	0.0	14.3	14.3	57.1
Medium	40.0	40.0	0.0	20.0	0.0
Low	33.3	22.2	0.0	11.1	33.3

Source: BMA

Table 13. Catastrophe Buckets and Frequencies in Different BUs (In percent)

Catastrophe Bucket	Different Frequency	Same Frequency
High	28.6	71.4
Medium	60.0	40.0
Low	33.3	66.7

Source: BMA

Table 14. Catastrophe Buckets and In-house Modelling (In percent)

Catastrophe Bucket	In-house Model	No In-house Model
High	28.6	71.4
Medium	20.0	80.0
Low	22.2	77.8

Source: BMA

We observe that insurers who write a higher proportion of natural catastrophe exposed business perform more real time accumulations compared to those insurers who write a lower proportion of natural catastrophe exposed business. Insurers that write a high proportion of natural catastrophe exposed business also tend to use more in-house modelling relative to the others buckets.

In terms of frequency of accumulations between different buckets, insurers that write a high proportion of natural catastrophe exposed business tend to use the same frequency at 71.4% of respondents. The same pattern is evident for those insurers who write a lower proportion of natural catastrophe exposed business.

Table 15. Average Loadings (In percent)

Catastrophe Bucket	Average Loading
High	5.4
Medium	5.1
Low	3.2

Source: BMA

We observe that the higher the proportion of natural catastrophe exposed business, the higher the loading factor at a spread of about two percentage points from low to high.

Appendix 1 – Underwriting Loss Scenarios guideline

1. Northeast Hurricane

The insurer/group should assume a US$78.0 billion industry property loss including consideration of demand surge and storm surge from a northeast hurricane making landfall in New York State. The hurricane also generates significant loss in the States of New Jersey, Connecticut, Massachusetts, Rhode Island and Pennsylvania.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Both main and small ports that fall within the footprint of the event
b. Both main international and small airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property US$47.5 billion
b. Commercial property US$30.5 billion
c. Auto US$1.7 billion
d. Marine US$0.7 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

2. Carolinas Hurricane

The insurer/group should assume a US$36.0 billion industry property loss including consideration of demand surge and storm surge from a hurricane making landfall in South Carolina.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Main and small ports that fall within the footprint of the event
b. Main international and small airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property US$24.0 billion

b. Commercial property US$12.0 billion

c. Auto US$0.5 billion

d. Marine US$0.3 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

3. Miami-Dade Hurricane

The insurer/group should assume a US$125.0 billion industry property loss including consideration of demand surge and storm surge from a Florida hurricane making landfall in Miami-Dade County.

The insurer/group should assume the following components of the loss:

a. Residential property US$63.0 billion

b. Commercial property US$62.0 billion

c. Auto US$2.2 billion

d. Marine US$1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

4. Pinellas Hurricane

The insurer/group should assume a US$125.0 billion industry property loss including consideration of demand surge and storm surge from a Florida hurricane making landfall in Pinellas County.

The insurer/group should assume the following components of the loss:

a. Residential property US$88.0 billion

b. Commercial property US$37.0 billion

c. Auto US$2.0 billion

d. Marine US$1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

5. Gulf Windstorm (onshore)

The insurer/group should assume a US$107 billion industry property loss including consideration of demand surge and storm surge from a Gulf of Mexico hurricane making landfall.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Main and small ports that fall within the footprint of the event
b. Main international and small airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property US$65.0 billion
b. Commercial property US$42.0 billion
c. Auto US$1.0 billion
d. Marine US$1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

6. Los Angeles Earthquake

The insurer/group should assume a US$78.0 billion industry property (shake and fire following) loss including consideration of demand surge.

The insurer/group should assume the following components of the loss:

a. Residential property US$36.0 billion
b. Commercial property US$42.0 billion
c. Workers Compensation US$5.5 billion
d. Marine US$2.2 billion

e. Personal Accident US$1.0 billion

f. Auto US$1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event. For Personal Accident and Workers Compensation losses, the insurer/group should assume that there will be 2,000 deaths and 20,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

7. San Francisco Earthquake

The insurer/group should assume a US$78.0 billion industry property (shake and fire following) loss including consideration of demand surge.

The insurer/group should assume the following components of the loss:

a. Residential property US$39.0 billion

b. Commercial property US$39.0 billion

c. Workers Compensation US$5.5 billion

d. Marine US$2.2 billion

e. Personal Accident US$1.0 billion

f. Auto US$1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event. For Personal Accident and Workers Compensation losses, the insurer/group should assume that there will be 2,000 deaths and 20,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

8. New Madrid Earthquake

The insurer/group should assume a US$47.0 billion industry property (shake and fire following) loss including consideration of demand surge.

The insurer/group should assume the following components of the loss:

a. Residential property US$32.5 billion
b. Commercial property US$14.5 billion
c. Workers Compensation US$2.5 billion
d. Marine US$1.5 billion
e. Personal Accident US$0.5 billion
f. Auto US$0.5 billion

The insurer/group should consider all other lines of business that would be affected by the event. For Personal Accident and Workers Compensation losses, the insurer/group should assume that there will be 1,000 deaths and 10,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover.

For business interruption, the insurer/group should assume that the overland transport systems are severely damaged and business impacted, leading to significant business interruption exposure for a period of 30 days. This is restricted to the inner zone of maximum earthquake intensities.

9. European Windstorm

This event is based upon a low pressure track originating in the North Atlantic basin resulting in an intense windstorm with maximum/peak gust wind speeds in excess of 20 metres per second (45 mph or 39 knots). The strongest winds occur to the south of the storm track, resulting in a broad swath of damage across southern England, northern France, Belgium, Netherlands, Germany and Denmark. The insurer/group should assume a €23 billion industry property loss.

The insurer/group should assume the following components of the loss:

a. Residential property €15.5 billion
b. Commercial property €6.00 billion
c. Agricultural €1.5 billion
d. Auto €0.7 billion
e. Marine €0.4 billion

The insurer/group should consider all other lines of business that would be affected by the event. The loss amount should be reported in Bermuda equivalent as noted under the general instructions above.

10. Japanese Typhoon

This event is based on the Isewan (‘Vera’) typhoon event of 1959. The insurer/group should assume a ¥1.5 trillion industry property loss.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Main and small ports that fall within the footprint of the event
b. Main international and domestic airports as well as small airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property ¥650.0 billion
b. Commercial property ¥850.0 billion
c. Marine ¥50 billion

The insurer/group should consider all other lines of business that would be affected by the event. The loss amount should be reported in Bermuda equivalent as noted under the general instructions above.

11. Japanese Earthquake

This event is based on the Great Kanto earthquake of 1923. The insurer/group should assume a ¥5 trillion insured industry property loss from this event.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Main ports as well as smaller ports that fall within the footprint of the event
b. Main international and domestic airports as well as smaller airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property ¥1.5 trillion
b. Commercial property ¥3.5 trillion
c. Marine ¥150.0 billion
d. Personal Accident ¥50.0 billion

The insurer/group should consider all other lines of business that would be affected by the event. The loss amount should be reported in Bermuda equivalent as noted under the general instructions above.

For Personal Accident losses, the insurer/group should assume that there will be 2,000 deaths and 20,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover. Liability exposures should also be considered.

For business interruption, the insurer/group should assume that the overland transport systems are severely damaged and business impacted, leading to significant business interruption exposure for a period of 60 days. This is restricted to the inner zone of maximum earthquake intensities.

12. Aviation Collision

The insurer/group should assume a collision between two aircrafts over a major city, anywhere in the world, using the insurer's or group's two largest airline exposures.

The insurer / group should assume a total industry loss of up to US$4.0 billion, comprising up to US$2 billion per airline and any balance up to US$1.0 billion from a major product manufacturer's product liability policy(ies) and/or traffic control liability policy(ies), where applicable.

Consideration should be given to other exposures on the ground and all key assumptions should be stated clearly.

The information should include:

a. The city over which the collision occurs;

b. The airlines involved in the collision;

c. Each airline's policy limits and attachment points for each impacted (re)insurance contract (policy);

d. The maximum hull value per aircraft involved;

e. The maximum liability value per aircraft involved;

f. The name of each applicable product manufacturer and the applicable contract

g. (Policy) limits and attachment points (deductibles); and

h. The name of each applicable traffic control authority and the applicable contract (policy) limits and attachment points (deductibles).

f) Marine Event

The insurer/group is to select one scenario from below which would represent its largest expected loss.

13. Marine Collision in Prince William Sound

A fully-laden tanker calling at Prince William Sound is involved in a collision with a cruise vessel carrying 500 passengers and 200 staff and crew. The incident involves the tanker spilling its cargo and loss of lives aboard both vessels.

Assume 70% tanker owner and 30% cruise vessel apportionment of negligence and that the collision occurs in US waters.

Assume that the cost to the tanker and cruise vessel owners of the oil pollution is US$2.0 billion. This would lead to oil pollution recoveries on the International Group of P&I Associates' General Excess of Loss Reinsurance Programme of US$1.0 billion from the tanker owner and US$0.5 billion from the cruise owner.

Assume: 1) 125 fatalities with an average compensation of US$1.5 million for each fatality, 2) 125 persons with serious injuries with an average compensation of US$2.5 million for each person, and 3) 250 persons with minor injuries with an average compensation of US$0.5 million for each person.

14. Major Cruise Vessel Incident

A US-owned cruise vessel is sunk or severely damaged with attendant loss of life, bodily injury, trauma and loss of possessions. The claims were to be heard in a Florida court.

Assume: 1) 500 passenger fatalities with an average compensation of US$2.0 million, 2) 1,500 injured persons with an average compensation of US$1.0 million, and 3) assume an additional Protection and Indemnity loss of US$500.0 million to cover costs such as removal of wreck and loss of life and injury to crew.

15. US Oil Spill

The insurer/group is to assume an oil spill releasing at least five million barrels of crude oil into the sea. In addition to property, the insurer/group is also to consider in its assumptions the following coverage: business interruption, workers compensation, directors and officers, comprehensive general liability, environmental / pollution liability and other relevant exposures. Assume 1) 15 fatalities, 2) 20 persons with serious injuries, and 3) an estimated insured industry loss of US$2.1 billion.

16. US Tornadoes

The insurer/group is to assume an EF5 multiple-vortex tornado touching down in several heavily populated cities and towns in the South and Mid-West regions of the US. Assume 1) 125 fatalities, 2) 600 persons with mild-to-serious injuries, 3) 20,000 people are displaced and left homeless, 4) 50% to 75% of the 10,000 buildings (commercial, residential and other outbuildings included) have been damaged by the tornado's wind field, and 5) an estimated insured industry loss of US$5.0 billion. Consideration should be given to the cumulative effect of such a large number of total losses.

17. Australian Flooding

The insurer/group is to assume heavy rainfalls across major cities in Australia causing severe flooding and/or repeated flash flooding. Assume 1) 40 fatalities, 2) 200,000 people are affected and displaced, 3) 190 persons with mild-to-serious injuries, 3) 70% of the 8,500 homes and businesses that are flooded could not be recovered, 4) suspension of all agricultural and mining operations, and 5) an estimated insured industry loss of US$2.2 billion. The insurer/group is to include landslides following flood.

18. Australian Wildfires

The insurer/group is to assume a series of bushfires during extreme bushfire-weather conditions across Australian states affecting populated areas. Assume 1) 180 fatalities, 2) 500 people with mild-to-serious injuries, 3) displacement of 7,600 people, and 4) destruction of over 5,000 buildings (commercial, residential and other outbuildings included). Assume an estimated insured industry loss of US$1.3 billion.

Appendix 2 - Underwriting Loss Impact Analysis

Table 1. Impact of Names Perils (In US$ millions)

Standardised Cat Peril	Gross Loss Impact	Ceded Loss Impact	Net Loss Impact	Gross Loss Impact Ceded (In percent)
Gulf Windstorm (onshore)	18,656.16	9,077.05	9,579.10	51
Northeast Hurricane	18,529.19	10,085.04	8,444.14	46
Pinellas Hurricane	15,295.24	7,675.16	7,620.08	50
San Francisco Earthquake	14,350.58	7,061.59	7,288.99	51
Miami-Dade Hurricane	13,438.12	6,293.40	7,144.72	53
Los Angeles Earthquake	12,772.40	6,173.77	6,598.64	52
Carolinas Hurricane	9,411.62	4,816.71	4,594.90	49
European Windstorm	8,959.64	5,162.42	3,797.22	42
Japanese Earthquake	6,990.15	3,830.39	3,159.75	45
New Madrid (NM) RDS	5,716.12	3,105.28	2,610.84	46
Aviation Collision	3,018.75	1,528.52	1,490.24	49
Japanese Typhoon	2,838.96	1,709.58	1,129.38	40
Marine Collision in Prince William	2,334.81	1,273.89	1,060.93	45
US Oil Spill	2,150.35	1,236.06	914.30	43
Major Cruise Vessel Incident	1,709.24	943.34	765.90	45
US Tornadoes	1,180.26	865.47	314.78	27
Australian Flooding	1,103.66	945.49	158.17	14
Australian Wildfires	735.88	490.34	245.54	33
Total Loss Impact	**139,191**	**72,274**	**66,918**	**52**

Table 2. Bermuda's Estimated Loss Impact Share Using Lloyd's Developed Realistic Disaster Scenarios (In US$ millions)

Standardised Cat Peril	Estimated Total Industry Loss	Estimated Bermuda Share (Gross)	Bermuda Share (In percent)
Gulf Windstorm (onshore)	107,000	18,656	17%
Northeast Hurricane	78,000	18,529	24%
Pinellas Hurricane	125,000	15,295	12%
San Francisco Earthquake	78,000	14,351	18%
Miami-Dade Hurricane	125,000	13,438	11%
Los Angeles Earthquake	78,000	12,772	16%
Carolinas Hurricane	36,000	9,412	26%
European Windstorm	24,604	8,960	36%
Japanese Earthquake	45,758	6,990	15%
New Madrid (NM) RDS	47,000	5,716	12%
Japanese Typhoon	13,727	2,839	21%

Notes: The data provided in these tables above is for class 3B and 4 insurers only and was extracted from the CSR annual filings. The CSR filings for a handful of insurers that fall within these classes where still under review when this report was put together and that data was not included in this report. Therefore one should view the results as being reflective of a segment of the industry and not the total potential total impact. Total Estimated Industry Loss numbers were taken from Lloyd's Realistic Disaster Scenarios report - January 2016 and exchange rates are as at 31st December 2016.