BERMUDA MONETARY AUTHORITY

2nd November 2017

Bermuda Monetary Authority

Catastrophe Risk in Bermuda

Stress Testing and Modelling Practice Analysis

2016 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 modelling practices in Bermuda is central to the Bermuda Monetary Authority's (Authority or BMA) 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 produces this report on an annual basis. The Report gives a high level overview of the catastrophe risk stress testing and modelling practices in Bermuda.

Compared to 2015, this year's (2016) gross catastrophe exposure assumed by Bermuda insurers increased by about 9%, while in parallel the insurers have also increased their statutory capital & surplus by slightly more than 9%[1],[2]. Consequently, the overall industry's resilience to potential catastrophe events has somewhat further strengthened compared to last year. In addition, the global share of gross estimated potential loss assumed by Bermuda insurers on the major catastrophe perils (combined) has increased by about 2%.

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

Craig Swan
Managing Director, Supervision (Insurance)

[1] Some of the increase is as a result of the change from legal entity reporting in 2015 to consolidated reporting in 2016.
[2] The report does not include Bermuda alternative capital market data.

This is the second annual Catastrophe Risk report published by the Bermuda Monetary Authority. We hope you will find the information in the report of interest. Should you have any questions, comments or suggestions to improve this report, please contact enquiries@bma.bm.

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
SPI	Special Purpose Insurer
SST	Sea Surface Temperatures
TVaR	Tail Value at Risk

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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 catastrophe (Cat) risk events underwritten by Bermuda insurers[3]. 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. 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 modelling practices in Bermuda.

Overall, the 2016 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 76% on a gross basis (before reinsurance) of their statutory capital & surplus, an increase of 4% from last year, after the largest single Cat underwriting loss event. On a net basis (after reinsurance), insurers will retain about 89% of their statutory capital & surplus, an increase of 5% from last year, 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. Overall, the global share of gross estimated potential loss assumed by Bermuda's insurers on the major Cat perils (combined) has increased by about 2%.

An analysis of the exceedance probability curve demonstrates that Bermuda insurers are more exposed to Atlantic hurricanes than any other peril, with gross median exposures over all companies stretching from US$553.3 million for the "1-in-50" year event up to US$1,031.21 million for the "1-in-1,000" year events. The use of reinsurance[4] is widespread with the Atlantic hurricane net median exposures stretching from US$201.0 million for the "1-in-50" year event up to US$590.5 million for the "1-in-1,000" year event. Reinsurance is generally more pronounced for lower frequency return periods for Atlantic Hurricane and North American Earthquake, while other named perils exhibit the opposite pattern such as Japanese

[3] Insurers also include reinsurers.
[4] Net results are also net of both reinsurance and reinstatement premiums.

Earthquake and Japanese Typhoon. Pricing data seems to confirm the overall softening of the market.

Average loading factors in the accumulation process have been declining steadily since 2012, reaching 5.4% in 2016 versus 9.2% in 2012 for Bermuda legal entities. For groups in 2016 the average loading factor was 6.8% compared to 8.9% in 2012. This could reflect (but not be limited to) improved modelling approaches, more robust model exposure coverage and/or greater modelling precision by insurers. Atlantic multi-decadal oscillation is taken into consideration in the long-term by more insurers in 2016 compared to 2015 both for legal entities and groups.

AIR and RMS are the most frequently used modelling software, while they are occasionally used in tandem with EQECAT. In-house modelling[5] is performed by 34.2% of legal entities and 44.4% of groups in 2016. 46.9 % of legal entities and 49.8% of groups report that they use more than one model in their accumulation process. Legal entities use their models more on a quarterly basis with 52.6% of insurers doing so, while 44.4% of groups accumulate on a quarterly basis.

[5] An 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 (Cat Return) together with a Schedule of Risk Management, as part of their annual statutory filing (Capital and Solvency Return (CSR)), 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 the results of stress tests that the Authority requires them to perform. 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, rely significantly 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 at 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 modelling 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 modelling 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 CSR consolidated filings of Class 3B, Class 4 and insurance groups[6] for the period ended 31st December 2016[7]. 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 only aggregated when it could be (for example, aggregated EP curve data was not used, while aggregated AAL data was used.) EP curves were not aggregated since they represent upper quantiles of distributions and quantiles are not additive functions. AALs on the other hand can be, since they represent averages over distributions that 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) and insurance groups. The exclusion of all other classes, including alternative capital such as 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

[6] Insurance Groups refers to group insurer for which the Authority is the Group Supervisor
[7] Not all insurers have 31st December year end, therefore, the data used in the report may fully reconcile with the BMA annual report which will include fall end underwriting data.

and not the entire exposure of the Bermuda insurance market[8] which is expected to be larger than what is 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 2016 and previous years' CSR filings. The accumulation process provides insights into the relationship between the modelling 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 50.0% or more unrelated business and with total net premiums (from unrelated business) of US$50.0 million or more. Class 4 (re)insurers have a minimum capital and surplus floor of US$100.0 million. In addition to the minimum capital and surplus requirements, both Class 3B and 4 are required to hold sufficient capital to withstand expected aggregate losses beyond the 99.0% percentile (TVaR99).

Aggregate Statistics for Classes 3B and 4, 2016. (In US$ billions)

Net Earned Premiums	**35.6**
Net Written Premiums	37.0
Net Income	10.0
Total Claims	19.8
Total Assets	191.1

Source: BMA

Aggregate Statistics for Insurance Groups, 2016. (In US$ billions)

Net Earned Premiums	**35.2**
Net Written Premiums	35.9
Net Income	4.0
Total Claims	19.7
Total Assets	204.3

Source: BMA

*Not all insurers have 31st December year end, therefore, the data used in the report may fully reconcile with the BMA annual report which will include fall end underwriting data

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

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[9].

Stress testing is a fundamental element of an insurer's overall risk management framework and capital adequacy determination. The main objective of underwriting stress testing is to assess the capacity of individual insurers, and the entire sector, to absorb shocks from adverse events 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 internally 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 highest 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. Third, 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 2016 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[10], 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[11] to statutory capital & surplus of 24% (and 11% net loss impact), followed by Northeast Hurricane and San Francisco Earthquake which had the potential to deplete 22% and 20%

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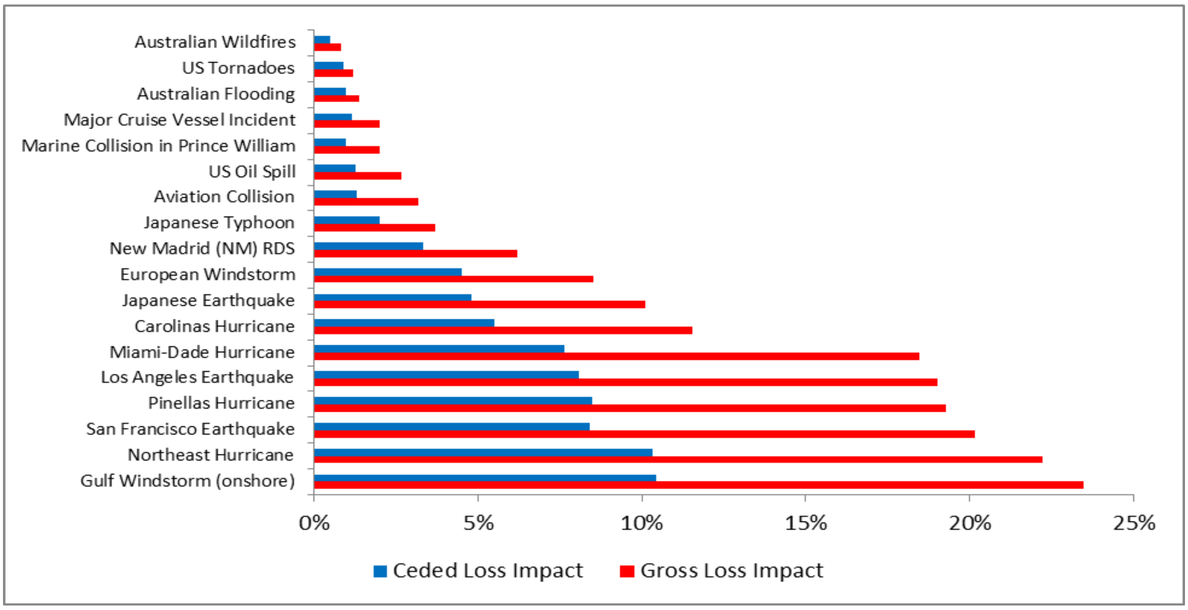
[9] Insurers are also required to conduct stress scenarios to assess their capital adequacy under an adverse financial market and a combination of an adverse financial market scenario with an adverse underwriting scenario. However, this report only discusses the underwriting loss scenarios from Cat events.

[10] The underwriting loss impact and associated assumptions reported by insurers are probabilistic outcomes and represent calculated estimates. Actual results if a peril is realised may significantly differ from these estimates.

[11] Gross loss impact is before any reinsurance and/or other loss mitigation instruments.

(and 10%, and 8% net loss impact) respectively of the total statutory capital & surplus[12]. The gross impact from each of all the other perils was below 20% with the majority of the perils (10) having gross loss impact of less than 10% (see Appendix 2).

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



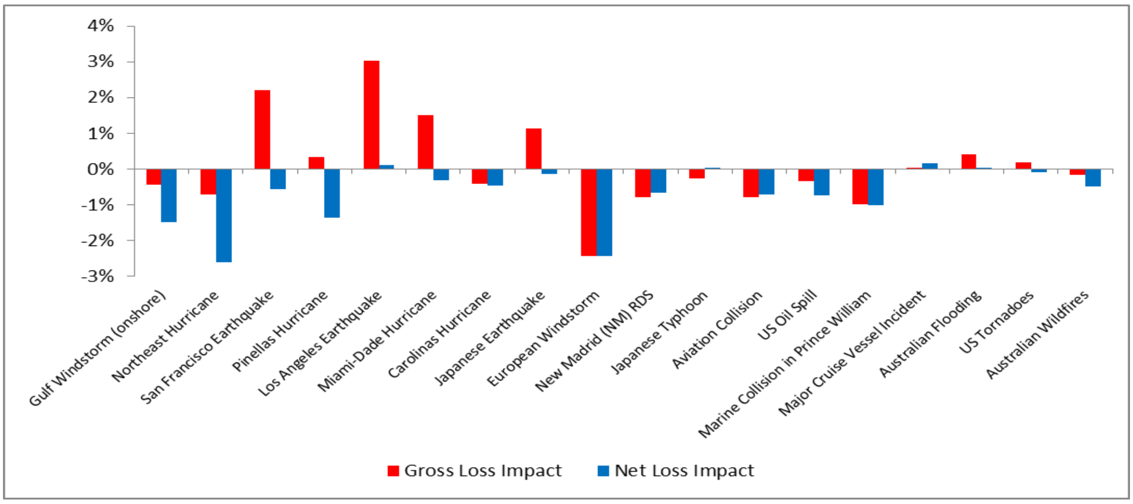
Source: BMA staff calculations.

While Bermuda insurers' gross loss impact exposure for 2016 increased by about 9% compared to 2015, in parallel the insurers have also increased their statutory capital & surplus by slightly more than 9%[13]. Consequently, the overall industry's resilience to potential Cat events has somewhat further strengthened compared to last year. The increase in total exposure is primarily driven by an increase on the gross loss impact of Los Angeles Earthquake (3%), Northeast Hurricane (2%) and Miami-Dade Hurricane (2%) compared to 2015. The majority of the perils have either seen a minor decrease of their gross loss impact or their impact has stayed relatively stable (see figure 2 below).

[12] 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.

[13] Some of the increase is as a result of the change from legal entity reporting in 2015 to consolidated reporting in 2016.

Figure 2 - Year on Year (2015 and 2016) Gross and Loss Impact Change



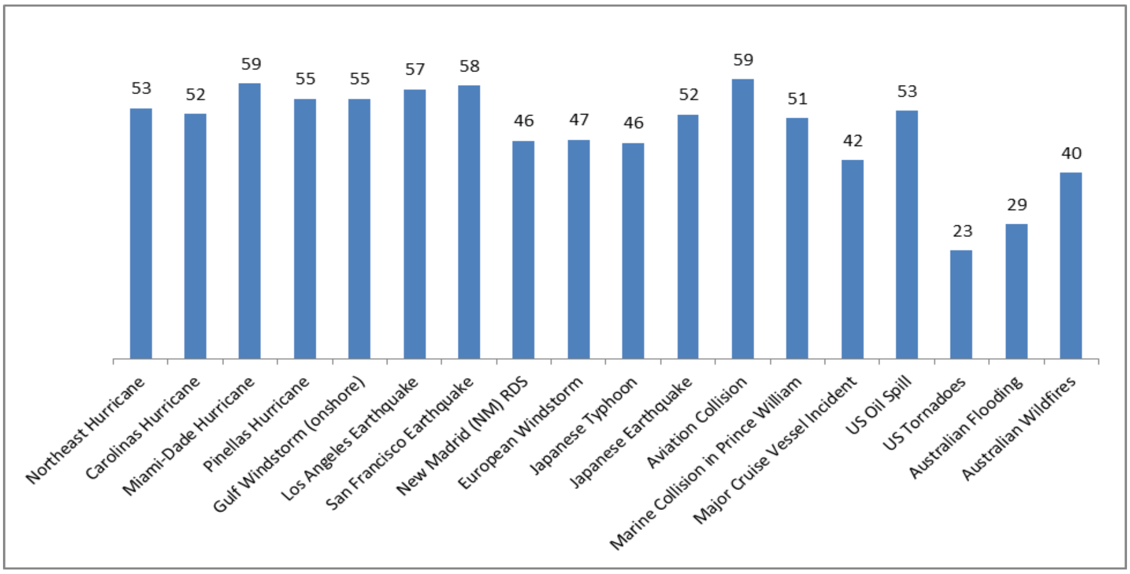
Source: BMA

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 98% of the statutory capital & surplus on a gross basis and 99% 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 showed that the level of reliance on reinsurance has increased compared to last year and varies across each peril. Typically, perils which have potential for the largest losses, such as Northeast Hurricane, Gulf Windstorm and San Francisco Earthquake are heavily reinsured.

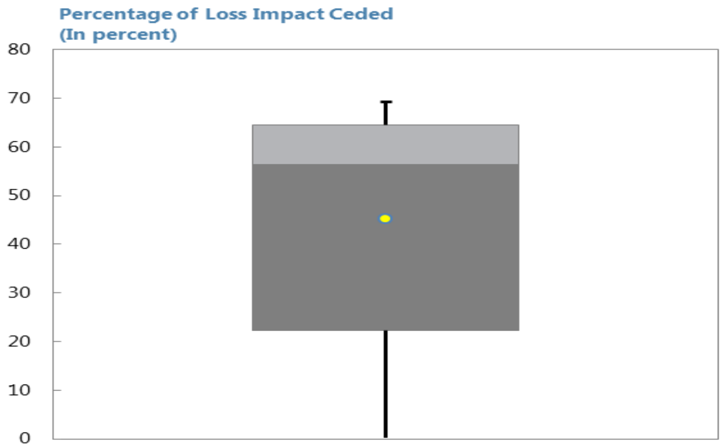
Figure 3. Gross Loss Impact Ceded (In percent)



Source: BMA staff calculations.

While the percentage of the aggregate loss impact ceded seems to imply a significant market wide reliance on reinsurance (figure 3 above) on average insurers ceded 45% of their loss impact (figure 4).

Figure 4. 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, which include the traditional property catastrophe contracts, quota share contracts, Insurance Linked Securities (ILS) protection and industry loss warranties contracts among others.

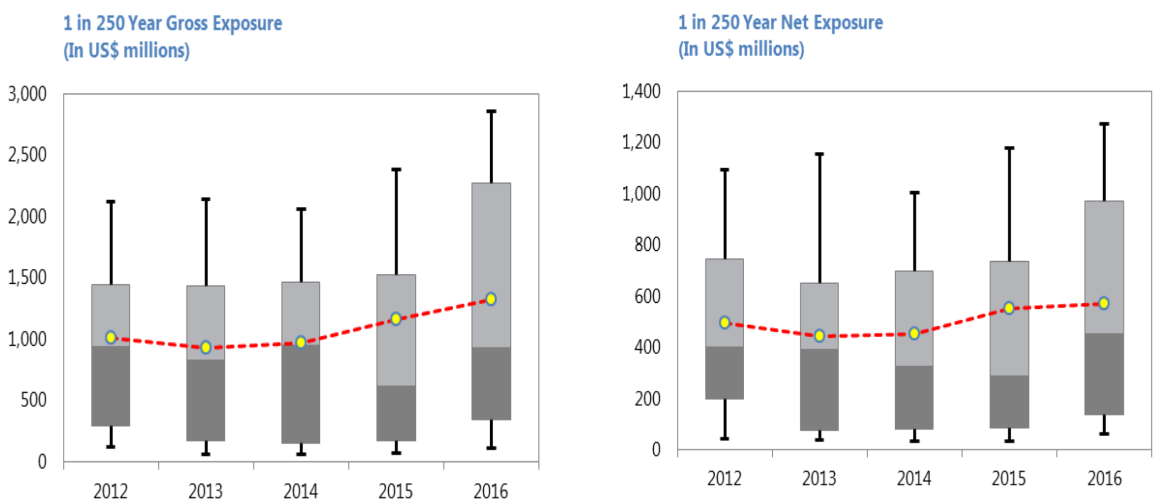
5. Exceedance Probability Curves[14]

This section presents some outputs from the catastrophe models in Bermuda on an aggregated basis for Bermuda legal entities. Insurers are asked to produce EP curves for named perils. These perils are Atlantic hurricane, North American earthquake, European windstorm, Japanese earthquake and Japanese typhoon.

We compile the data from the EP curves by drawing the distribution of EP curves in the cross section for firms for named perils across return periods. We plot for each peril and for each return period a box plot which includes the mean, median, 10th, 25th, 75th and 90th percentiles of the EP curves. As expected the higher the return period in years, the rarer the event and the EP curve is increasing in value. Or to put it in other words the rarer the event, the higher the impact if realised[15].

Historical trends of the gross and net EP curves for aggregate exposures for the past five years were evaluated as were "1-in-250" year events. The following panel presents the distribution of the 1-in-250 year events for the aforementioned return period.

Panel 1. Gross and Net 1-in-250



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).

[14] Some of the year on year changes (between 2016 and the previous year) are as result of the change from legal entity reporting in 2015 to consolidated reporting in 2016.

[15] EP curves cannot be aggregated by summing individual EP curves since an event for one firm can be completely unrelated with the event of another company even for the same peril and the same return period. For example a 1 in 250 year event in North America earthquake means something different for a company with exposures to San Francisco versus to a company with exposures to Northern California outside large urban centres. Moreover, the simple addition of EP curves does not recognise diversification benefits since it assumes that all events for all perils and for all return periods can occur at the same time even if some events may be mutually exclusive.

The insurers have increased their average gross exposure between 2015 and 2016 by 13.8% exceeding inflation. We also notice in the first box plot of panel 1 that the variation within the sample has increased as well with the 90th percentile of gross exposure reaching US$2.8 billion in 2016 compared to a 90th percentile exposure of US$2.3 billion in 2015.

Average net exposure increased by 4.0% between 2015 and 2016, while the variation of exposures within samples decreased as we can see in the second box plot in panel 1. The 90th percentile net exposure increased by 7.8% in 2016 and reached US$1.3 billion.

The largest exposure for Bermuda insurers is North Atlantic hurricane with average gross exposure between US$693.0 million for "1 in 50 years" event up to almost US$1.3 billion for "1 in 1,000" year event. This is an average figure with significant variation within firms. For example at the 90th percentile of losses there are firms with "1 in 50" year exposures north of US$1.6 billion, while there are firms who exceed US$2.8 billion exposures for "1 in 1,000" year event for the same peril. Net exposure is lower since it includes the purchase of reinsurance and reinstatement premiums. We calculate the net to gross exposure ratio and we present some descriptive statistics in the next table.

Table 1. Net to Gross Exposure for Atlantic Hurricane (In percent)

Return Period	1 in 50	1 in 100	1 in 250	1 in 500	1 in 1000
Mean	56.5	57.8	61.0	63.4	65.3
Median	46.4	48.5	54.1	58.2	61.1

Source: BMA

An interesting pattern that emerges is that purchase of reinsurance becomes less pronounced at higher risk layers. The median insurer retains 46.4% of the gross exposure for "1 in 50" year events, while the median insurer retains 61.1% of the gross exposure for "1 in 1,000" year events. We also show average exposure per peril, per return period both gross net in the next tables.

Table 2. Average Gross Exposure (In US$ millions)

Return Period	1 in 50	1 in 100	1 in 250	1 in 500	1 in 1000
Atlantic Hurricane	693.0	833.2	1012.1	1152.5	1296.0
NA. Earthquake	449.5	586.5	761.2	889.0	1021.2
European Windstorm	213.4	270.4	338.3	380.9	421.9
Japanese Earthquake	172.4	228.7	300.9	342.8	375.1
Japanese Typhoon	125.1	157.4	177.2	194.1	213.4

Source: BMA

Table 3. Average Net Exposure (In US$ millions)

Return Period	1 in 50	1 in 100	1 in 250	1 in 500	1 in 1000
Atlantic Hurricane	333.6	414.7	539.9	650.0	762.8
NA. Earthquake	205.1	272.0	378.3	470.4	574.6
European Windstorm	117.3	147.7	186.2	212.7	240.8
Japanese Earthquake	86.8	110.8	142.4	162.0	179.1
Japanese Typhoon	67.7	84.4	96.4	106.8	118.0

Source: BMA

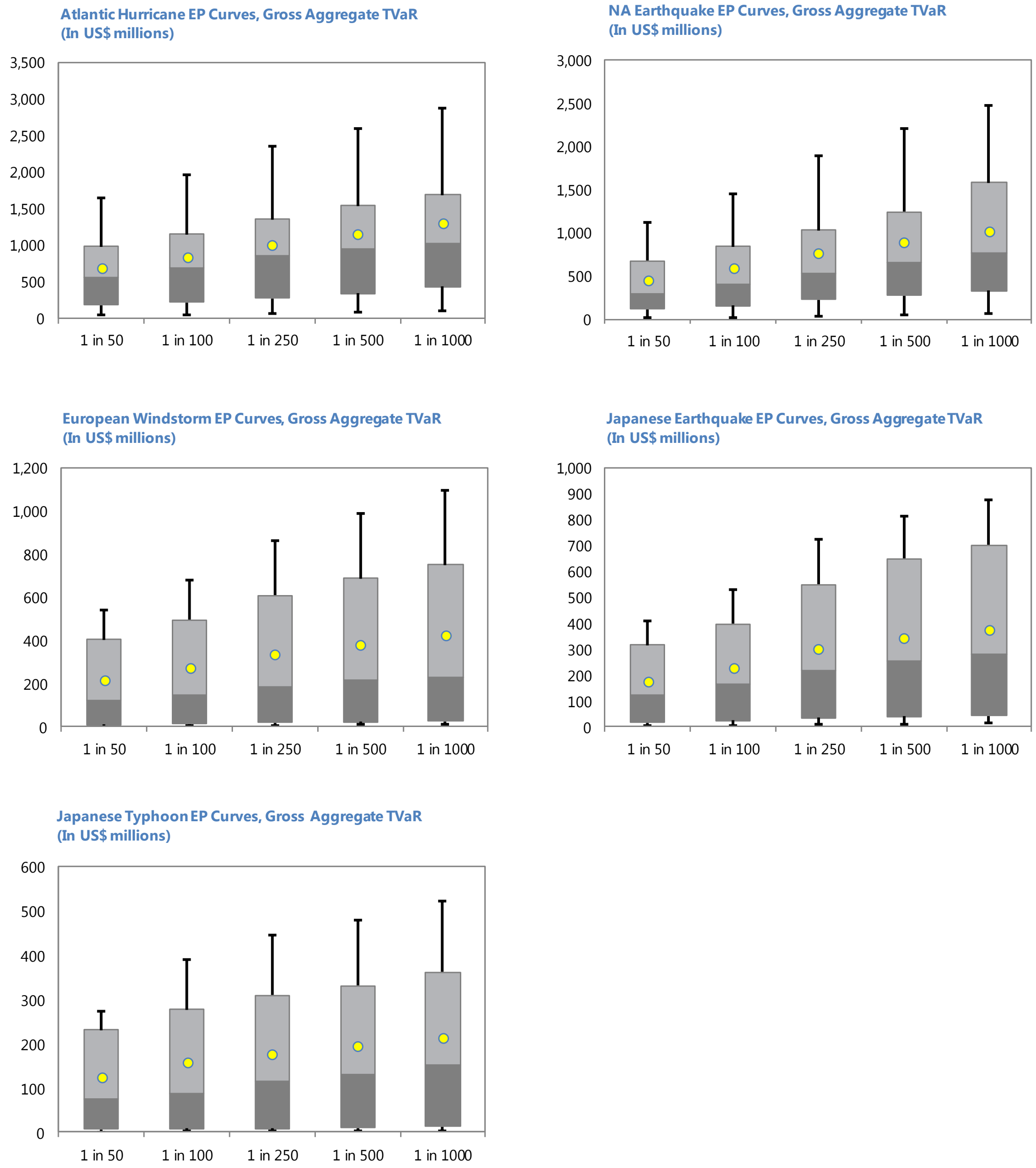
As we mentioned before, the largest exposure across all return period is Atlantic hurricane followed by North American earthquake. We also plot the aggregate gross and net EP curves which include all the catastrophic risks in an insurer's portfolio.

Table 4. Average Exposure for all Perils (In US$ millions)

Return Period	1 in 50	1 in 100	1 in 250	1 in 500	1 in 1000
Gross	944.1	1104.8	1315.5	1476.3	1645.5
Net	469.0	569.1	723.5	856.3	997.8

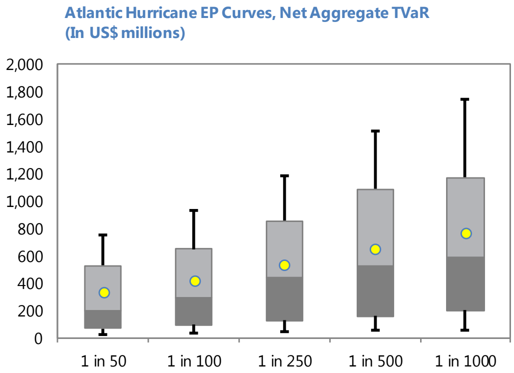
Source: BMA

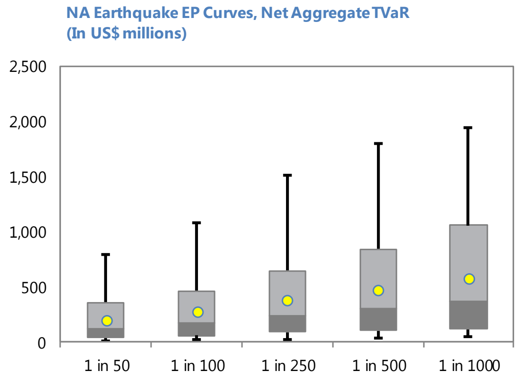
Panel 2. Gross EP Curves for Named Perils

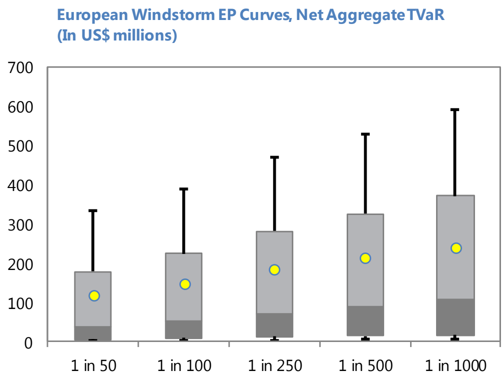


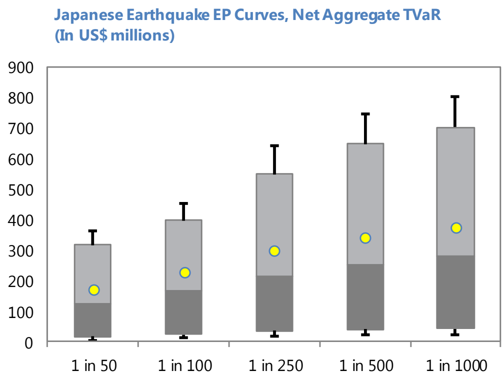
Source*:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

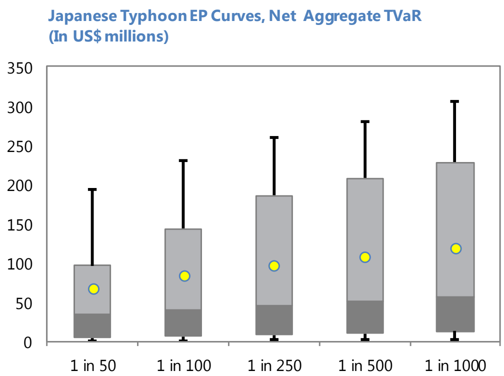
Panel 3. Net EP Curves for Named Perils





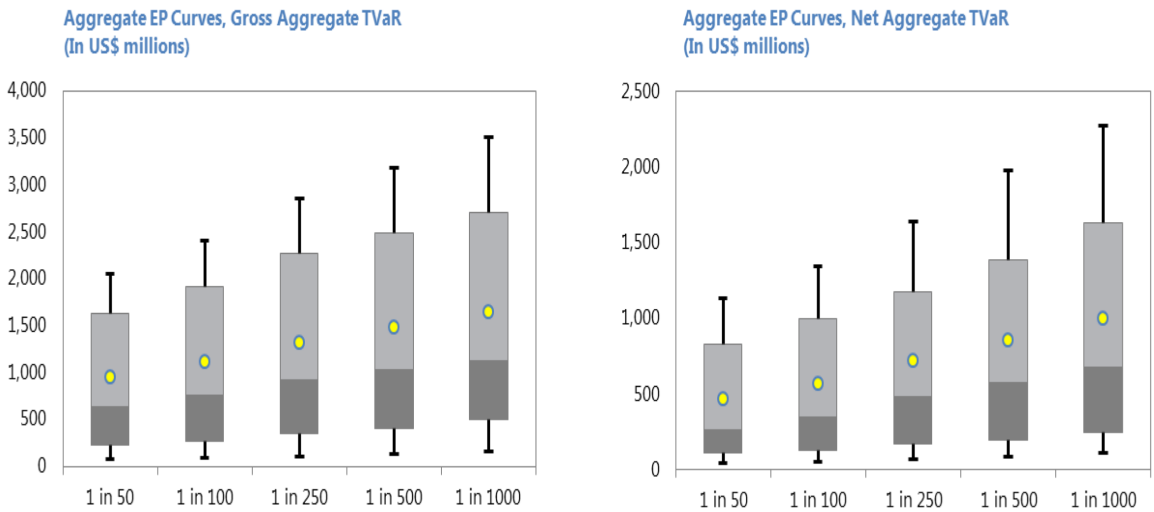






Source*:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

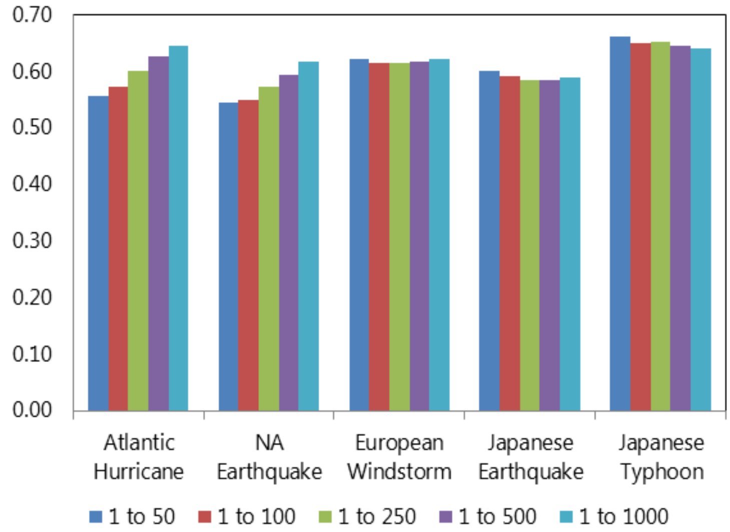
Panel 4. Gross and Net Aggregate EP Curves for all Perils



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).

Figure 5. Average Net to Gross EP Exposure per Peril and Return Period

(Aggregate EP Curves)



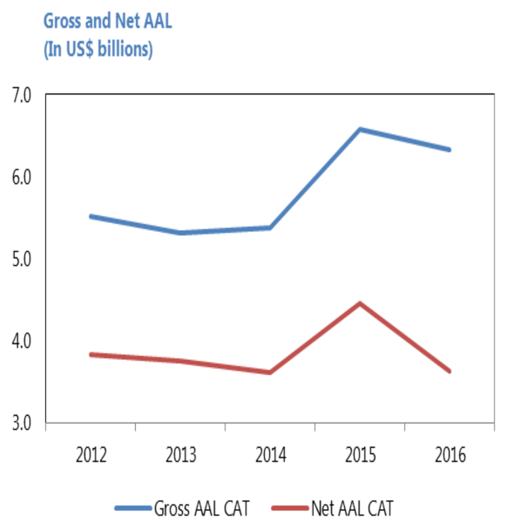
Source: BMA staff calculations.

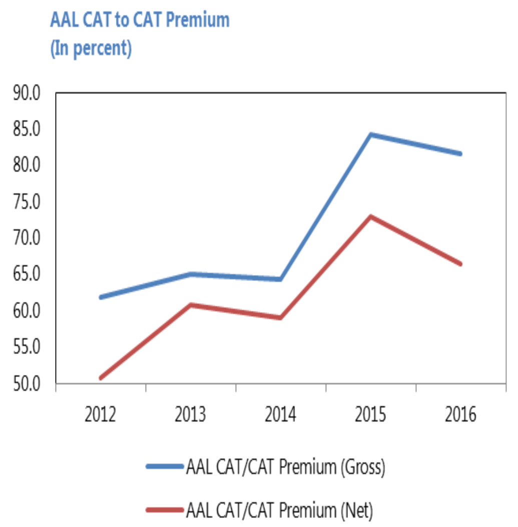
For the Atlantic hurricane the observations indicate that less reinsurance is being purchased proportionately for more rare events (“1 in 1,000”), compared to less rare events (“1 in 50”). This is true for all perils except Japanese earthquake and typhoon where rarer events appear to admit more reinsurance. The average of all net to gross ratios does not exceed 0.7. European windstorm exhibits flat demand for reinsurance across return periods.

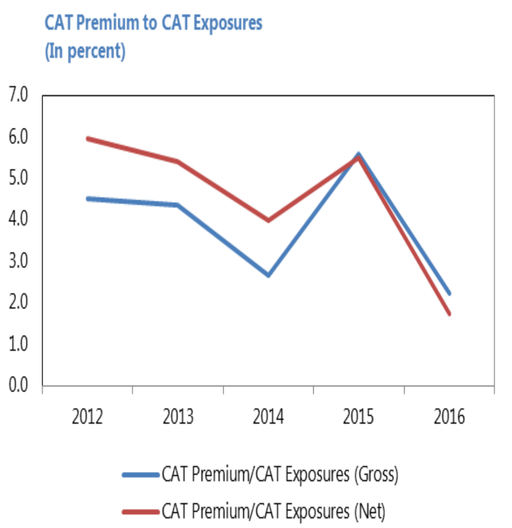
6. Pricing Dynamics[16]

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

Panel 5. Average Annual Loss, Risk & Pricing Ratios[17]







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

The gross Average Annual Loss (AAL) dropped between 2015 and 2016 and has reached US$6.3 billion compared to US$6.6 billion in 2015. Likewise the net AAL has reached US$3.6 billion in 2016 compared to US$4.5 billion in 2015.

[16] Some of the year on year changes (between 2016 and the previous year) are as result of the change from legal entity reporting in 2015 to consolidated reporting in 2016.
[17] We use only modeled exposures and premium.

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 modelled estimation of the expected Cat losses, while the gross premium 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 with some drop in 2016 compared to 2015.

Higher AALs have been combined, on average, with lower proportionate premiums and the ratio has increased from 64.2% in 2014 to 84.1% for gross exposures in 2015 and has dropped to 81.5% in 2016. For net exposures the ratio has increased from 57.3% in 2014 to 72.9% in 2015 and currently stands at 66.3% in 2016. This statistic could be reflective of the overall softening in the reinsurance market and especially for Cat exposures. It seems that the pricing dynamics persist even for 2016.

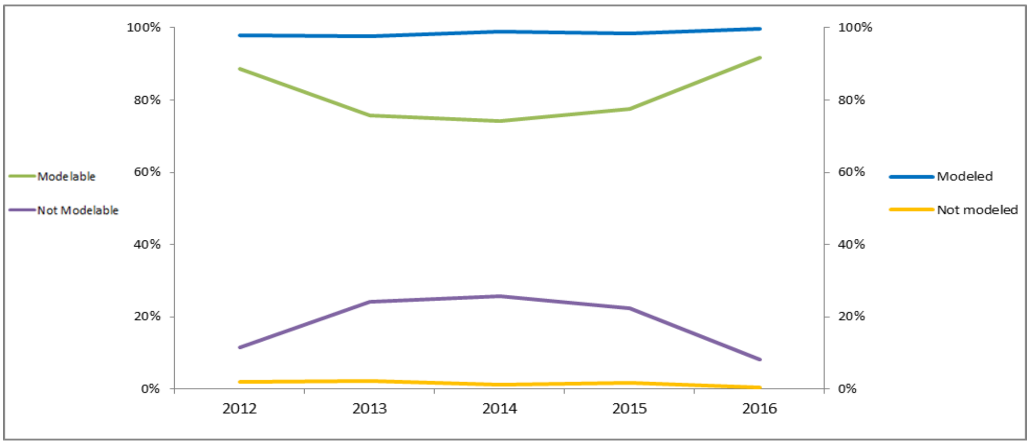
We also plot the ratio of Cat premium to Cat exposures which can be seen in the second row of panel 5. This ratio dropped significantly between 2015 and 2016. This ratio implies that more cat exposure is exposed with fewer premiums received.

7. PMLs and Accumulation Process[18]

The accumulation process is an important component of the modelling process and 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 2016 CSR filing showed that 92% of the Cat risk exposure underwritten in Bermuda is modelable and that almost 100% of the modelable risk was modelled. The percentage of modelable exposure increased from 78% in 2015 to 92% in 2016; the modelled exposure (as a percentage of modelable) has gradually increased during the last five years[19].[20].

Figure 6. Modelable and Modelled Exposure



Source: BMA staff calculations.

In the following section we will present results regarding catastrophe modelling practices that we collect from Class 3B and 4 legal entities as well insurance groups which are domiciled in Bermuda and have the BMA as group-wide supervisor. In the next section wherever we use the term legal entities we imply Class 3B and 4 Bermuda insurers.

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[18] Some of the year on year changes (between 2016 and the previous year) are as result of the change from legal entity reporting in 2015 to consolidated reporting in 2016.

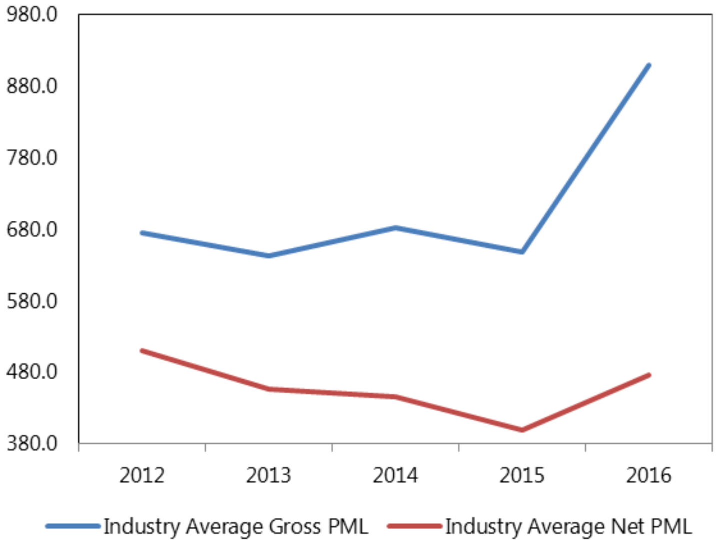
[19] **Modelable exposure** refers to the exposure that can be simulated through a vendor catastrophe model; **Non-Modelable exposure** refers exposure that cannot be simulated through a vendor catastrophe model or where there are no catastrophe models that assess the risk of the region-peril under consideration;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

[20] 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 modelling 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.

7.1 PMLs and Accumulation Process - Legal Entities

In this section we will present aggregated results from the statutory filings of insurers for the year 2016. As mentioned, Bermuda Class 3B and 4 insurers are required to file the catastrophe risk schedule which is a questionnaire about the modelling practices. It also includes quantitative information about catastrophe exposures. Considering quantitative factors, Bermuda insurers report metrics on the AAL, PML and factor loadings. The latest data is provided in the next figures and tables.

Figure 7. Gross and Net Average Industry PML (In US$ millions)



Source: BMA staff calculations.

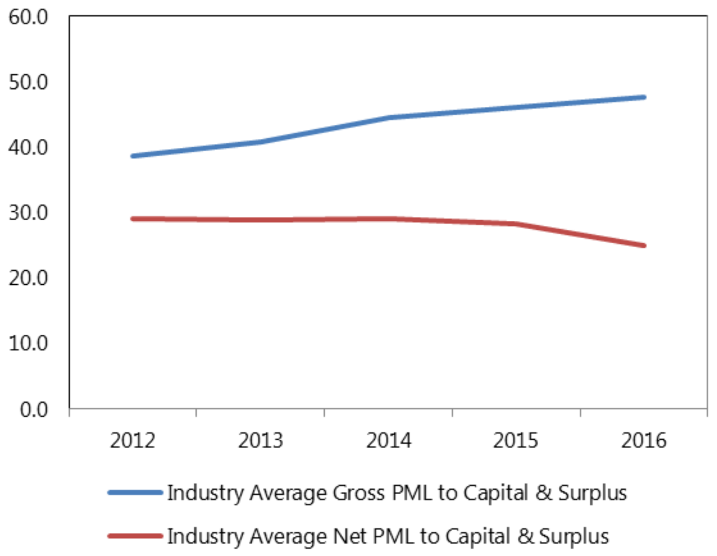
Table 5. PML (In US$ millions)

	2016	2015	2014	2013	2012
Industry Average Gross PML to Capital & Surplus	910.0	648.9	682.0	642.4	674.7
Industry Average Net PML to Capital & Surplus	476.2	398.1	445.2	456.0	509.5

Source: BMA

The PML is defined as the 99.0% TVaR. All PMLs refer to aggregate exposures and not to per-occurrence exposure. Table 5 represents the average PML for legal entities in dollar amounts. The PML for 2016 has had a significant increase on a gross basis while on a net basis the figure is lower due to extensive use of reinsurance.

Figure 8. Capital and Surplus to Gross and Net Industry PML (In percent)



Source: BMA staff calculations.

Table 6. PML Ratios (In percent)

	2016	2015	2014	2013	2012
Industry Average Gross PML	47.7	46.1	44.6	40.8	38.6
Industry Average Net PML	24.9	28.3	29.1	29.0	29.2

Source: BMA

Table 6 presents ratios of the gross and net PML to capital and surplus. This ratio expresses whether the available capital and surplus can withstand a loss equal to 99.0% TVaR. On a gross basis a 99.0% TVaR loss is expected to consume 48% of available capital and surplus. This ratio has been steadily increasing over the past years. However, on a net basis after reinsurance the ratio drops to 24.9% in 2016 down from 29.2% in 2012, indicating more pronounced use of reinsurance.

Table 7 presents the loading factors that are used as add-ons to the output of catastrophe modelling. These factors compensate for model error as well increased conservatism in the modelling process and they are applied on the PML. For example if the catastrophe model yields a PML of US$100.0, a 5.0% factor would raise the PML to U$105.0.

Table 7. Loading Factors (In percent)

	2016	2015	2014	2013	2012
Average Loading Factor	5.4	5.9	8.3	8.4	9.2

Source: BMA

In 2016 the average loading factor reached 5.4% which has steadily declined since 2012. One should be cautious on the interpretation of the factor since models themselves become more reflective of underlying risk exposure and data quality improves, thus reducing the need for higher safety buffers. In addition, vendors recently started to supply models for certain regions which previously had no models. This reduced the need for additional loading factors to compensate for the lack of models. Finally, higher quality data is becoming available to more accurately assess the impact of catastrophic events.

Another interesting modelling practice is the usage of 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 the near-term or long-term views of hurricane frequency as the default usage in their modelling process.

Table 8. AMO Factor Consideration (In percent of respondents)

	2016	2015	2014	2013	2012
Near-Term Frequency	74.3	89.5	89.2	89.2	86.1
Long-Term Frequency	25.7	10.5	10.8	10.8	13.9

Source: BMA. Restated from last year report.

We observe that in 2016, 74.3% of insurers consider the AMO for their near term modelling of Atlantic hurricane exposures. The AMO factor has to do with trends that should be taken into account in modelling Atlantic hurricane exposures and the financial losses that stem from hurricane activity. Near-term frequency and long-term frequency estimations have been converging and this explains the fact that more insurers are using the long term view - more information on the AMO factor can be found in Appendix IV.

Part of the questionnaire asks about the vendors that insurers use. This gives an indication on whether insurers are forming their modelling opinions on one or multiple models, while we can see which vendors are more prevalent in the market. Moreover we ask how frequently insurers perform modelling (accumulations) and whether insurers develop their own models apart those from vendors. The next table summarises these responses.

Table 9. Vendor Model Usage (In percent of respondents)

Model Usage	2016	2015	2014	2013	2012
AIR only	12.5	9.1	16.7	11.4	8.8
EQECAT only	0.0	0.0	0.0	0.0	0.0
RMS only	40.6	39.4	30.6	28.6	26.5
AIR and RMS	43.8	45.5	38.9	45.7	44.1
AIR and EQECAT	0.0	*0.0*	0.0	0.0	0.0
EQECAT and RMS	0.0	0.0	0.0	0.0	2.9
AIR, EQECAT and RMS	3.1	6.1	13.9	14.3	17.6
Model Licensing	**2016**	**2015**	**2014**	**2013**	**2012**
AIR only	13.9	7.7	15.0	10.3	8.3
EQECAT only	0.0	0.0	0.0	0.0	0.0
RMS only	25.0	17.9	10.0	15.4	11.1
AIR and RMS	58.3	66.7	60.0	46.2	44.4
AIR and EQECAT	0.0	0.0	0.0	0.0	0.0
EQECAT and RMS	0.0	0.0	0.0	0.0	0.0
AIR, EQECAT and RMS	2.8	7.7	15.0	28.2	36.1

Source: BMA

RMS seems to be the most commonly used standalone model with increasing share in combination with other vendors. However, the use of three models in tandem seems to be the exception with a declining share of EQECAT use.

Table 10. Model Frequency Usage (In percent of respondents)

	2016	2015	2014	2013	2012
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	0.0	0.0	3	3	6
Quarterly	52.6	43.9	35.0	38.5	38.9
Monthly	26.3	24.4	25.0	20.5	22.2
Weekly	2.6	2.4	5.0	5.1	2.8
Daily	13.2	22.0	20.0	20.5	13.9
Real time	5.3	7.3	12.5	12.8	16.7

Source: BMA

Insurers use catastrophe modelling in fixed periods usually quarterly and monthly. Each quarter either renewals or supervisory reporting are the most common reasons to run the catastrophe models, with 52.6% of insurers reporting quarterly use in 2016 up from 38.9% in 2012. Real time use has declined to 5.3% of insurers in 2016 compared to 16.7% in 2012.

Table 11. Model Frequency and Business Units Differences (In percent of respondents)

	2016	2015	2014	2013	2012
Yes	39.5	36.6	32.5	35.1	28.6
No	60.5	63.4	67.5	64.9	71.4

Source: BMA

Insurers were asked whether different business units use catastrophe models at different frequencies. In 2016, 60.5% of respondents said that they do not perform accumulations at different frequencies decreased by almost ten percentage points since 2012.

Table 12. Internal Model Usage (In percent of respondents)

	2016	2015	2014	2013	2012
Yes	34.2	39.0	42.5	43.6	38.9
No	65.8	61.0	57.5	56.4	61.1

Source: BMA

In 2016, 34.2% of insurers developed their own stochastic model. Insurers with very specialised lines of business outside the cover of traditional vendors are more likely to develop such in-house models to capture their unique risks. In this sense we can observe that the same insurers seem to be in lines of business which require such bespoke modelling.

We also asked insurers on how Cat risk modelling accounts for reinsurance and retrocessions. The responses are shown in table 13.

Table 13. External Reinsurance Model Usage (In percent of respondents)

	2016	2015	2014	2013	2012
The company has minimal catastrophe exposure protection and as such gross is effectively net.	10.5	12.2	15.0	12.8	8.3
The accumulations are calculated on a gross basis with reinsurance protections calculated approximately outside the system.	2.6	0	0	0	2.8
The accumulations are calculated on a gross basis with reinsurance protections calculated explicitly outside the system.	5.3	7.3	7.5	7.7	5.6
The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for some types of protection within the system.	31.6	26.8	25.0	20.5	33.3

The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for each type of protection within the system.	50.0	53.7	52.5	59.0	50.0

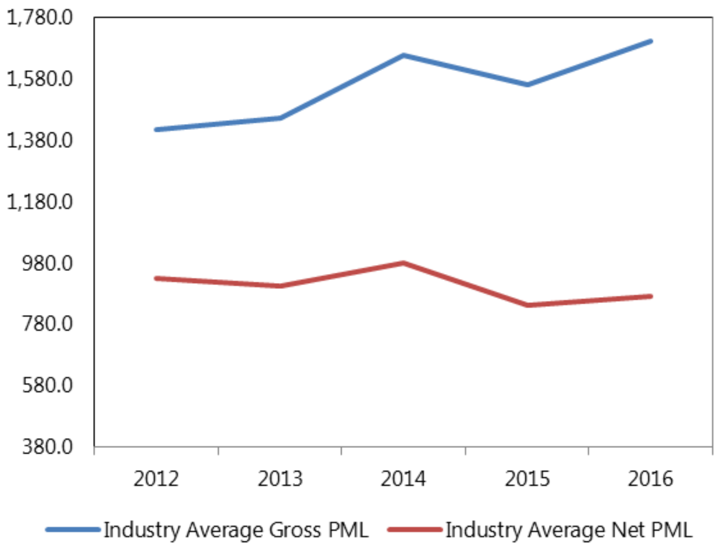
Source: BMA

We observe that very few insurers purchase minimal catastrophe reinsurance, namely 10.5% of respondents in 2016 versus 8.3% of respondents in 2012. The majority of insurers model catastrophic risk by taking into account explicitly external reinsurance either for some types or for each treaty separately. In 2016 81.6% of respondents consider explicitly either some external reinsurance or all reinsurance treaties in their catastrophe modelling. Compared to 2012 the percentage was 83.3%. In 2016 only 7.9% of respondents do not consider directly external reinsurance in their modelling practices, compared to 8.3% in 2012. Overall there is stability in the responses, indicating that companies have fixed modelling practices with regards to external reinsurance.

7.2 PMLs and Accumulation Process - Insurance Groups

The same data as for legal entities are also recorded for insurance groups.

Figure 9. Gross and Net Average Industry PML (In US$ millions)



Source: BMA staff calculations.

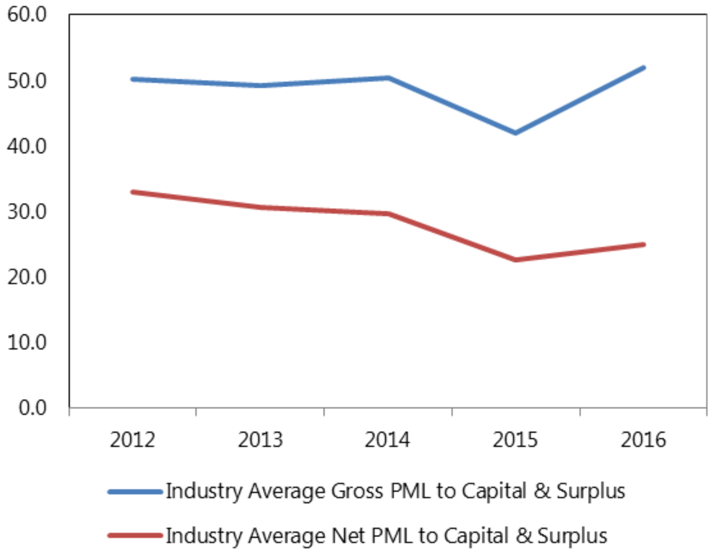
Table 14. PML (In US$ millions)

	2016	2015	2014	2013	2012
Industry Average Gross	1705.7	1563.0	1659.0	1451.7	1415.7
Industry Average Net PML	870.2	842.9	979.7	905.4	930.0

Source: BMA

We again observe the increase in gross exposures which is less pronounced on the group level than for legal entities.

Figure 10. Capital and Surplus to Gross and Net Industry PML (In percent)



Source: BMA staff calculations.

Table 15. PML Ratios (In percent)

	2016	2015	2014	2013	2012
Industry Average Gross PML to Capital & Surplus	52.0	42.0	50.4	49.3	50.2
Industry Average Net PML to Capital & Surplus	25.0	22.6	29.7	30.7	33.0

Source: BMA

As in the case of legal entities we report the average loading factors for groups in table 16.

Table 16. Loading Factors (In percent)

	2016	2015	2014	2013	2012
Average Loading Factor	6.8	7.6	5.9	7.2	8.9

Source: BMA

As in the case of legal entities, the loading factor for groups has been dwindling which does not necessarily imply less conservatism but the fact that models are incorporating more additional assumptions themselves (making the need of externally imposed assumptions less important). The overall quality improvement of data, as well the existence of models for perils and regions that had previously no models, have contributed to the reduction of the loading factors.

Table 17. AMO Factor Consideration (In percent of respondents)

	2016	2015	2014	2013	2012
Near-Term Frequency	58.8	64.7	66.7	76.2	85.0
Long-Term Frequency	41.2	35.3	33.3	23.8	15.0

Source: BMA

Similar to legal entities but to a lesser extent, 58.8% of groups use the near term frequency of the AMO compared to 85.0% in 2012. The convergence of the expected effect of both frequency types explains the convergence of the usage of both frequencies.

We also have statistics on the model vendor licensing and usage for Bermuda groups.

Table 18. Vendor Model Usage (In percent of respondents)

Model Usage	2016	2015	2014	2013	2012
AIR only	18.8	6.3	11.8	20.0	10.5
EQECAT only	0.0	0.0	0.0	0.0	0.0
RMS only	31.3	37.5	41.2	45.0	31.6
AIR and RMS	43.8	56.3	29.4	25.0	42.1
AIR and EQECAT	0.0	0.0	0.0	0.0	0.0
EQECAT and RMS	0.0	0.0	5.9	0.0	0.0
AIR, EQECAT and RMS	6.3	0.0	11.8	10.0	15.8
Model Licensing	**2016**	**2015**	**2014**	**2013**	**2012**
AIR only	16.7	5.9	11.1	9.5	9.5
EQECAT only	0.0	0.0	0.0	0.0	0.0
RMS only	16.7	17.6	11.1	19.0	14.3
AIR and RMS	61.1	70.6	55.6	47.6	47.6
AIR and EQECAT	0.0	0.0	0.0	0.0	0.0
EQECAT and RMS	0.0	0.0	5.6	4.8	0.0
AIR, EQECAT and RMS	5.6	5.9	16.7	19.0	28.6

Source: BMA

In groups, RMS is taking the largest share either as standalone or in combination with other models.

Table 19. Model Frequency Usage (In percent of respondents)

	2016	2015	2014	2013	2012
Ad-hoc	0.0	0.0	0.0	0.0	0.0
Annual	5.6	5.9	11.1	9.5	4.8
Semi-annual	5.6	5.9	5.6	4.8	4.8
Quarterly	44.4	35.3	27.8	33.3	33.3
Monthly	27.8	35.3	33.3	23.8	28.6
Weekly	0.0	0.0	0.0	9.5	4.8
Daily	11.1	11.8	11.1	9.5	14.3
Real time	5.6	5.9	11.1	9.5	9.5

Source: BMA

Accumulation frequency follows similar patterns for groups and legal entities as well. Most groups perform accumulations quarterly as 44.4% of respondents did in 2016 compared to 33.3% in 2012. Unlike legal entities some groups also perform annual accumulations at 5.6% of respondents in 2016 compared to 4.8% 2012.

Table 20. Model Frequency and Business Units Differences (In percent of respondents)

	2016	2015	2014	2013	2012
Yes	64.7	52.9	56.3	57.9	40.0
No	35.3	47.1	43.8	42.1	60.0

Source: BMA

When it comes to whether different business units employ different frequencies of accumulations, the picture is reverse for groups compared to legal entities. 64.7% of groups have frequency differences whereas only 39.5% of legal entities do. The diversity of the groups is much more pronounced than that of legal entities and it is expected that groups will employ different modelling practices across their entities.

We also surveyed groups on the use of internal models.

Table 21. Internal Model Usage (In percent of respondents)

	2016	2015	2014	2013	2012
Yes	44.4	47.	38.9	42.9	38.1
No	55.6	52.9	61.1	57.1	61.9

Source: BMA

In 2016, 55.6% of groups use internally developed models while 44.4% do not, whereas 65.8% of legal entities use internally developed models. Groups seem to be more willing to use vendors. On the other hand the specialisation of specific legal entities to special lines of business requires them to have more bespoke modelling approaches.

Table 22. External Reinsurance Model Usage (In percent of respondents)

	2016	2015	2014	2013	2012
The company has minimal catastrophe exposure protection and as such gross is effectively net.	0.0	0.0	0.0	0.0	0.0
The accumulations are calculated on a gross basis with reinsurance protections calculated approximately outside the system.	0.0	0.0	0.0	0.0	0.0
The accumulations are calculated on a gross basis with reinsurance protections calculated explicitly outside the system.	5.6	5.9	5.6	4.8	5.0
The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for some types of protection within the system.	22.2	29.4	33.3	23.8	30.0
The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for each type of protection within the system.	72.2	64.7	61.1	71.4	65.0

Source: BMA

Unlike legal entities, all groups seem to have substantial Cat exposures requiring reinsurance treaties compared to 10.5% of legal entities with minimal Cat exposure in 2016. 72.2% of groups compared to 50.0% of legal entities model explicitly for all treaties within the Cat model. At the same time 22.2% of groups consider some reinsurance treaties within their Cat model, compared to 50.0% of legal entities in 2016.

Appendix I – 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$0.53 billion

d. Marine US$0.27 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$2.25 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$107.0 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 €23.0 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 ¥50.0 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.

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 groups 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 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 US Waters

A cruise vessel carrying 2,000 passengers and 800 staff and crew is involved in a high-energy collision with a fully laden tanker of greater than 50,000 DWT with 20 crew.

The incident involves the tanker sinking and spilling its cargo; there are injuries and loss of lives aboard both vessels.

Assume 30% tanker owner/70% cruise vessel apportionment of negligence, and that the collision occurs in US waters. **Please note this is a reversal of the apportionment used in prior years**.

Assume that the cost of pollution clean-up and compensation fund amounts to USD2bn. This would result in claims against the International Group of P&I Associations' General Excess of Loss Reinsurance Programme, and any other covers that might be in force.

Assume an additional compensation to all passengers and crew for death, injury or other costs of US$1.15 billion and removal of wreck for the Tanker of US$100 million. The Cruise ship is severely damaged but is towed back to a safe harbour (repair estimate US$50 million and US$10 million for salvage operations).

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 II - Underwriting Loss Impact Analysis

Table 23. Impact of Names Perils (In US$)

Standardised Cat Peril	Gross Loss Impact	Ceded Loss Impact	Net Loss Impact	Gross Loss Impact Ceded (in Percent)
Northeast Hurricane	19,201,291,669	10,245,257,711	8,956,033,957.987	53%
Carolinas Hurricane	9,976,580,853	5,197,824,534	4,778,756,319.016	52%
Miami-Dade Hurricane	15,946,356,924	9,333,017,029	6,613,339,894.266	59%
Pinellas Hurricane	16,657,139,811	9,220,814,168	7,436,325,643.261	55%
Gulf Windstorm (onshore)	20,289,292,335	11,225,565,947	9,063,726,388.568	55%
Los Angeles Earthquake	16,403,949,906	9,408,803,509	6,995,146,397.414	57%
San Francisco Earthquake	17,402,937,430	10,130,551,129	7,272,386,301.216	58%
New Madrid (NM) RDS	5,347,279,147	2,482,020,911	2,865,258,236.137	46%
European Windstorm	7,371,546,713	3,438,222,166	3,933,324,547.267	47%
Japanese Typhoon	3,212,586,494	1,477,238,550	1,735,347,943.572	46%
Japanese Earthquake	8,724,961,889	4,538,450,409	4,186,511,480.099	52%
Aviation Collision	2,758,620,954	1,640,769,394	1,117,851,559.923	59%
Marine Collision in Prince William	1,737,093,391	890,612,574	846,480,816.386	51%
Major Cruise Vessel Incident	1,730,986,402	732,236,506	998,749,896.433	42%
US Oil Spill	2,297,596,373	1,212,942,827	1,084,653,546.962	53%
US Tornadoes	1,030,851,670	238,246,776	792,604,894.117	23%
Australian Flooding	1,208,787,608	345,703,039	863,084,568.293	29%
Australian Wildfires	727,581,551	288,335,532	439,246,018.978	40%
Total	**152,025,441,120**	**82,046,612,710**	**69,978,828,410**	**54%**

Table 24. Bermuda's Estimated Loss Impact Share Using Lloyd's Developed Realistic Disaster Scenarios (In US$)

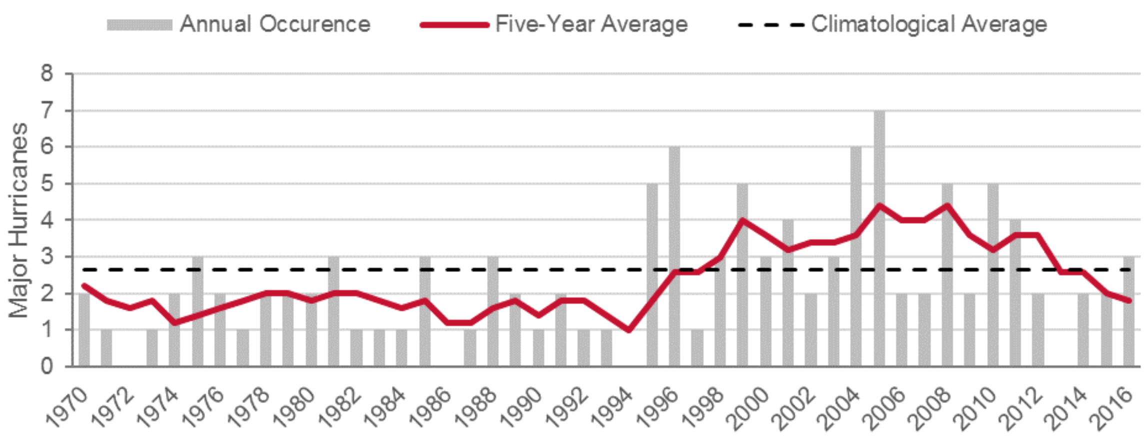
Standardised Cat Peril	Estimated Total Industry Loss	Estimated Bermuda share (Gross)	Bermuda share (In percent)
Gulf Windstorm (onshore)	107,000,000,000	20,289,292,335	19%
Northeast Hurricane	78,000,000,000	19,201,291,669	25%
San Francisco Earthquake	78,000,000,000	17,402,937,430	22%
Pinellas Hurricane	125,000,000,000	16,657,139,811	13%
Los Angeles Earthquake	78,000,000,000	16,403,949,906	21%
Miami-Dade Hurricane	125,000,000,000	15,946,356,924	13%
Carolinas Hurricane	36,000,000,000	9,976,580,853	28%
Japanese Earthquake	45,758,000,000	8,724,961,889	19%
European Windstorm	24,604,000,000	7,371,546,713	30%
New Madrid (NM) RDS	47,000,000,000	5,347,279,147	11%
Japanese Typhoon	13,727,000,000	3,212,586,494	23%

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.

Appendix III - Atlantic Multi-decadal Oscillation (AMO)

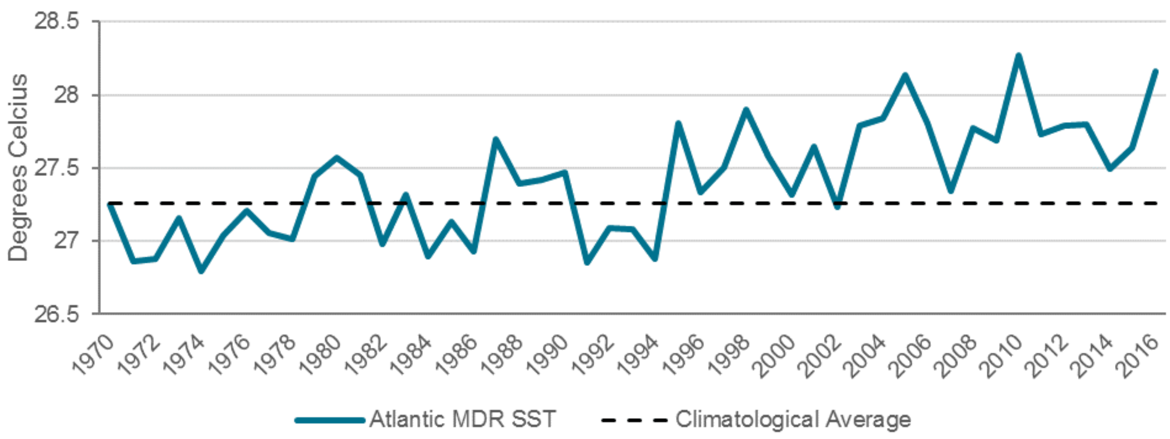
The AMO is a switch in many catastrophe risk models and is used as a predictor of future hurricane activity. As a predictor it uses sea surface temperatures (SST) in order to estimate hurricane activities since warm water is one of the fuels of a hurricane. In the past SSTs have been rising but the last four year trend shows that hurricanes are declining in numbers. This is shown in figures 11 and 12.

Figure 11. Number of Hurricanes



Source: RMS

Figure 12. Sea Surface Temperature



Source: RMS

Assuming a four to five year near tem trend, catastrophe models would show that the number of hurricanes is expected to decline, while a longer term view over the past twenty years could indicate that this is a temporary phenomenon. According to RMS, for the first time since its introduction, the RMS medium-term rate forecast (MTRof) has dipped slightly below the long-term rate. For the U.S. as a whole, the new 2017-2021 medium-term rate forecast MTRof hurricane landfall frequency is now one percent below the long-term rate for Category 1–5 storms, and six percent for major hurricanes (Category 3–5 storms). Therefore for conservatism more companies are switching to the long-term view.

Appendix IV - Bermuda Framework for Catastrophe Risk Supervision

As one of the largest property catastrophe reinsurance centres in the world, Bermuda has a comprehensive framework of catastrophe risk supervision. The supervisory framework rests on an assessment of the ability of insurers to withstand severe catastrophic shocks and also public dissemination of catastrophe risk data on an aggregated basis

The capital requirements include a catastrophe risk charge which comprises aggregate probable maximum loss at 99% Tail Value at Risk (TVaR) over a one year time horizon. To further evaluate the ability to withstand catastrophic shocks and the reasonableness of catastrophe model outputs, additional information is collected in a catastrophe risk return.

The catastrophe risk return contains both qualitative and quantitative information. This includes qualitative information on the process of catastrophe risk modelling such as the type of models, the frequency of the modelling process, data quality, whether certain switches are turned on (e.g. secondary uncertainty, storm surge, demand surge, fire following and sprinkler et al, long-term versus medium term hurricane frequency), etc. In addition to the qualitative information, the insurer provides quantifications of loadings to account for unmodeled risks, model error and other deficiencies. The insurer also provides quantitative information such as AALs, PMLs and EP curves for major perils and for the entire portfolio from a 1-in-50 to 1-in-1,000 TVaR, (occurrence and in the aggregate). Percentage of limits modelled and un-modelled within the accumulation framework are also provided.

The supervisory process validates and assesses the prudential filings. Since part of the calibration of the catastrophe risk capital charge hinges on the assumptions of the insurer, the BMA validates the results with a set of tools. Industry peer comparisons on selected metrics as well as consistency between pricing and accumulations are checked to give a picture of the insurer's solvency and the market's.

The catastrophe risk return is one source of cross validation. Another source of validation is the stochastic scenario generator that has been developed in house by the BMA. This model performs Monte Carlo simulations on the balance sheets of individual insurers by shocking assets and liabilities and producing income statements which are used to estimate probabilities of future insolvency as well as financial results based on different return periods.

Finally the BMA prescribes a set of stress tests based both in BMA-designed scenarios and the Lloyd's Realistic Disaster Scenarios (RDS) and they are reported in the prudential filings. The insurer has to show the capital position before and after the relevant RDSs while the insurer also provides its own scenario RDSs quantifying a worst case scenario. The insurer is also obligated to provide a reverse stress test that will render its business non-viable.

When weather stations show that a hurricane is about to hit land, or shortly after catastrophic events, such as earthquakes, the BMA uses its exposure data to conduct preliminary capital adequacy assessments on insurers to estimate likely impact. To verify preliminary results, industry surveys are conducted. Usually a data call is asked where insurers are asked to gauge their exposures. Based on the catastrophe risk submissions insurers are reassessed regarding their ability to withstand the losses. The BMA publicly publishes aggregated data of the catastrophe risk returns for information purposes of the market as well as for its macroprudential surveillance framework for the insurance sector.

Source : BMA