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YE2017 Comparative Study on Market and Credit Risk Modelling

Table of Contents

1. Executive summary	3
2. Objectives of the study	6
3. Process and scope.....	7
4. Modelling approaches and limitations	9
5. Results and supervisory actions.....	11
5.1. Combined Market and Credit Risk, Benchmark portfolios.....	11
5.2. Drilling down	17
5.3. Supervisory follow-up.....	26
6. Outlook	27

1. Executive summary

Market and credit risk contribute significantly to the solvency capital requirement (SCR) of insurance undertakings¹ and is also of material importance for the majority of internal model undertakings. Consequently, the EIOPA Board of Supervisors decided to perform annual European-wide comparative studies on the modelling of market and credit risks, to be run by a joint project group of several National Competent Authorities (NCAs) and EIOPA, to continue the study based on year-end 2015 data (Solvency II “day-one”²). Undertakings with a significant exposure to assets denominated in Euro and an approved internal model covering market and credit risk shall take part in this annual study.

The ambition is to ensure a consistent and regular collection of information in order to carry out such comparative studies on internal model outputs efficiently, and have an up to date overview of the modelling approaches, as well as to further develop supervisory tools and to foster common supervisory practices.

This report summarises the key findings from the study undertaken in 2018 based on year-end 2017 data and provides an insight into the supervisory initiatives being taken following the conclusions of this study.

The year-end 2017 study focused on EUR denominated instruments. The 19 participants from 8 different Member States cover 98,5% of the Euro investments held by all undertakings with an approved internal model covering market and credit risk in the EEA.

It is important to note that the study focusses on drivers for the value of investments, but does not aim to cover the overall SCR. In particular, specific undertakings’ risk profiles, dynamics of liabilities under changing financial market conditions, the diversification effects between the market module and the other risk modules, tax impacts or matching adjustment are intentionally not considered – with the purpose of directly assessing the study’s key subject, taking into account the other aspects in the judgement of relevance of findings. Hence, no direct conclusion could be drawn with regards to a specific undertaking’s solvency position or the overall appropriateness of the model with this comparative study.

Nevertheless, extending the previous edition, this study refined the analysis of interest rate down movements, more relevant for liabilities, and started to explore the modelling of dynamics of selected non-EUR currencies, namely GBP and USD.

The overall results show significant variations in asset model outputs, which could be partly attributable to model and business specificities already known by the relevant NCAs, but also indicate a certain need for further supervisory scrutiny. Especially in this context, this report is part of an ongoing process of monitoring and comparing internal market and credit risk models. Refinements and developments since the last study will be further developed already with the next study. The results, tools and experience will be feeding in the Supervisory Review Process (SRP) on internal models and vice versa. E.g. data in the MCRCS format is not only used for the MCRCS itself but also to assess model changes or models in pre-applications.

As a final introductory remark, internal models under Solvency II are governed by strong regulatory requirements, as on statistical quality, validation, documentation, justification of expert judgements, internal controls and model change governance as

¹ Cf. e.g. page 23 of the report on the EIOPA Insurance Stress Test 2016: Market risk accounts for 64% of the net solvency capital requirement before diversification benefits for standard formula users.

² Please note that already during the preparatory phase of Solvency II two pilot studies were performed to support the internal model pre-application in advance of “day-one”.

well as reporting to supervisors and the public. On-going compliance to these standards is safeguarded under the SRP. As a consequence of the variety of business models and risk profiles and the freedom of modelling, a variety of models are being used, which contributes to mitigate a potential herding behaviour. Another consequence is that national supervisors, participants and further stakeholders need tools, such as European comparative studies, to be provided with a necessary overview of model calibrations.

Main results from overview on modelling approaches, consequences for the analysis

The update of the stock take from the previous study confirmed that there are two main approaches used by undertakings to model market and credit risk: integrated approaches and modular approaches (cf. section 4). Additionally, certain aspects of credit risk modelling are visible on portfolio level only. The study therefore took an extensive approach to enable a like for like comparison and ensure reliable conclusions can be drawn. In that spirit this report mainly presents results under the combined market and credit risk at the level of benchmark portfolios and supplementary from the drill down to facets of market and credit risk – enhanced and refined compared to the previous edition.

Sample size, data quality and implications

From a statistical point of view, although having a nearly full coverage, the sample size is not large – and will remain so in the short term at least. Consequently, to keep as many data points as possible, a high priority was assigned to data and model exploration including feedback loops with participants on the final results. Another finding was that some benchmark assets were not relevant or not material for certain participants, which led to model results of lower quality, causing distortions in the results. But due to the shift to synthetic³ assets (instead of real assets), this phenomenon was less material than in the previous study. Furthermore, the newly introduced 'relevance score'⁴ was useful and supported the analysis.

Importantly, given the small number of models in the market and in the comparative study, all results and statistical key figures in this report shall not be regarded as calibration target.

Main quantitative results

For the combined market and credit risk charge, i.e. relative loss in value at the level of benchmark portfolios, the results show a sizeable variation between undertakings, which in some cases require further review. In that respect supervisors have especially engaged with the undertakings in feedback meetings and will continue evaluating results at European level (see also 5.3 and 6). Overall, parts of the observed variations can be attributed to issues of data relevance and to risk management preferences. Drilling down from the level of benchmark portfolios into facets of risk and asset types confirms this. First steps in refining that analysis including clustering of models, requires further refinement and development of tools in order to better explore the underlying causes.

³ Synthetic instruments are defined by a number of criteria such as the instrument type, currency, sector, issuer, rating and maturity.

⁴ Please note that in the MCRCS YE 2017 these categories were intentionally not defined by concrete thresholds and thus will also reflect the participants' materiality concepts.

Three submissions were identified as outliers with regards to marginal shocks on single risk-free zero-coupon bonds for very short and long maturities and were therefore excluded.

Credit risk charges for sovereign bonds across groups of modelling approaches show relatively low variation for bonds issued by Germany, Netherlands, Austria, Belgium, and France. The variation is greater for the bonds issued by Ireland, Portugal, Spain, and Italy, which is influenced by a small number of firms showing unusually low credit risk shocks across the instruments. While this requires further investigation, these firms have disclosed only a low exposure to sovereign bonds.

Credit risk charges for corporate bonds are generally higher for bonds with lower credit ratings and also the variation increases materially with worsening credit quality. The deviation becomes substantial for BB-rated bonds. This demonstrates the variety of modelling assumptions being taken by firms, particularly for low rated bonds, for which the exposure materiality is generally low.

With respect to equity risk, undertakings show low variation in the risk charges for the major equity indices. However, risk charges applied to the strategic equity participation show higher dispersion. Risk charges applied to the five real estate investments vary to larger extent compared to equity. However, for asset categories like real estate, model calibrations might place more emphasis on the risk profile of the undertakings' actual investment portfolio and less on publicly available indices.

Thematic focus: Interest rate risk modelling

Given the specific relevance of interest rate risk (e.g. 62% of investments in the EEA insurance balance sheet are directly held in fixed income instruments), the current low yield environment and the credit spread volatility in the recent years, a certain focus still was set on fixed income instruments in case of an interest rates rise. But supplement with respect to downward movements and more detailed analysis of risky bonds. Most importantly, while five participants did not model negative rates at the date of the previous study, meanwhile all of the respective models have been adapted to incorporate this feature as at year-end 2017.

Way forward: Regular Studies and fostering the Supervisory Review Process ('SRP')

Finally, the findings highlighted by the study indicate the need for further supervisory scrutiny, including at the European level. Consequently, EIOPA has decided to perform regular annual studies to further develop supervisory tools and foster consistency of supervisory approaches. The next study will enrich the spectrum of analysis, as further described in section 6.

2. Objectives of the study

In general, market and credit risk contributes significantly to the overall SCR of internal model undertakings. In addition, the definition of market and credit risk as regards the fluctuations in the level and in the volatility of market prices of financial instruments is to a large extent common to most undertakings (e.g. identification of similar risk factors, use of the same or similar historic data).

The principal objective of the year-end 2017 market and credit risk modelling comparative study was to further develop and refine European comparative studies as a supervisory tool in the area of market and credit risk modelling, in order to support the supervision of models and foster convergence of supervisory approaches given the potential choices of mathematical, statistical and IT solutions to tailor models to the concrete risk profile. The main developments were the introduction of synthetic assets, intended to be stable over time, and the assessment of the relevance of these assets in terms of exposure and modelling for the participants. In the longer term, such tool should also allow for the analysis of changes, models, approaches and calibrations over time and spot potential trends. In practice, the tool has already been used by NCAs, or supervisory colleges when relevant, and the conclusions of the study provide input to the Supervisory Review Process, e.g. with regards to internal model changes. NCAs have engaged with undertakings for further analysis and follow-up actions were agreed, where necessary.

Given the complexities of the overall market risk modelling process and the different risk profiles, the data should allow reviewing the overall variability of model outcomes but also analysing single components of a model (e.g. risk factor model) more deeply in order to explain the overall behaviour. More concretely the objectives were:

- i. Comparing model outputs for a set of realistic asset portfolios that should reflect typical asset risk profiles of European insurance undertakings, e.g. by country.

Although the focus is on the asset side, the setup of the study should be flexible enough to analyse different exposures against different interest rate movements (e.g. interest rate up and down shocks).

The metric of this comparison is the ratio of the asset Value at Risk (99.5%, 1 year) and the provided market value of the asset portfolio (this metric is called risk charge).

- ii. Highlighting the causes for the presumed variability in the risk charges by analysing additional information such as individual risk charges (e.g. individual asset classes such as Fixed Income, Equity, etc.).

In order to take an informed decision about the relevance of variations, beyond choosing realistic asset portfolios, it is important to distinguish the metric chosen (the 'risk charge') from the SCR, the latter especially considering both assets and liabilities, their interrelations, dynamics and potential mismatches. Furthermore, actual business and risk profiles as well as risk and investment strategies have to be taken into account in the judgment.

3. Process and scope

Process

A project group operationalised the objectives, deriving concrete goals and configuring a data request and questionnaire to undertakings, which was collected by the responsible NCAs ('participating NCAs') including first checks.

The project group processed the data and performed thorough data quality and sense checks, with the aim to ensure the reliability of the results. This step included feedback loops with undertakings and resubmissions when necessary. This also holds true for the analysis and its successive refinements.

The project group developed dedicated tools to carry out the analysis of the benchmark portfolios and individual instruments. These tools mainly consist in a programme written with the open source language R. This programme allows aggregating the data from different participants into a single database. This database can then be filtered to extract specific information in the form of tables, or to plot it for further visual exploration. All information used for this report is directly based on the data provided by the participating undertakings, which makes it easier for them to understand how comparisons are made. Only spot rates and spreads have to be calculated, as the collected data is based on values. The corresponding formulae are explained in the relevant sections.

The overall results based on anonymised data were discussed in the supervisory community, and dedicated feedback packages were prepared to be discussed by the participating NCAs with undertakings, and initiating follow-ups if deemed necessary. Where relevant, the results of these discussions were collated by the project group and fed into this report. The collected lessons learnt will feed the setup of the next study editions.

Last but not least, insights, methods and tools developed for analysis, comparison, data processing and data quality checks as well as collaborative experience will feed into supervision of the on-going appropriateness of internal model under the SRP and enhance the consistency of supervisory approaches.

Scope of the study: Risks

The subject of this study is the modelling of the market and credit risks related to investment instruments. As a consequence, the conclusions of the study allow a comparison between participating undertakings of model outputs for some of these risks only, and not in terms of overall capital requirements. In particular, several effects which drive the overall SCR are not considered in the study, such as the dynamics of liabilities under changing financial market conditions or tax impacts.

While the main components of **market** risk are interest rate risk, equity risk, property risk and currency risk, **credit** risk could be split into three components, namely "default risk", "migration risk" and "spread risk", where the first might be defined as the risk from the default of the issuer of securities, the second as the risk from spread movements related to rating migrations, and the third as the risk from spread movements within the same credit rating class in the one year horizon. It is important to note that market risk usually includes other sub-risks such as inflation, implied volatilities for equity risk and implied volatilities for interest rate risk. Most participating undertakings are modelling these sub-risks in their internal models, but these sub-risks are not included in the standard formula, and are not subject to a detailed analysis in the present report.

The data collected is composed of market values for a number of synthetic market instruments, as well as a few benchmark portfolios composed of a selection of these synthetic instruments. For each instrument and portfolio the participating undertakings were expected to send the complete set of values generated by their model (scenario-by-scenario data or selected percentiles depending on risk type and modelling approach), in addition to the initial market value of the instrument and the "modelled Value-at-Risk" (mVaR) estimate, where the latter Risk might differ from the 99.5% sample quantile on the simulated asset values, owing to the statistical estimator and e.g. include interpolation or smoothing schemes. For each instrument, the undertakings were expected to provide an assessment of the relevance of such instrument for the undertaking's own exposure, as well as in terms of modelling quality. This was supplemented by data on the own asset portfolio and qualitative information about the model and the approach to the study to support the quantitative analysis.

Concerning the concentration/accumulation of exposures, most undertakings take care of concentration implicitly through correlation matrix used in Monte-Carlo simulations or, less common, through concentration thresholds defined by the company in a specific policy. Some undertakings add explicit mark-up/penalisation for concentration calculated with standard formula or with a specific model.

Scope of the study: Undertakings

As market and credit risk models within groups typically are uniform, the 19 participants from 8 Member States mainly are international insurance groups with an approved internal model at group level⁵, covering market and credit risk, and with significant EUR exposure. The Euro investments (excluding unit-linked assets) of participants amount to 98.5% of the total Euro investments⁶ of EEA internal model undertakings fulfilling these criteria. The total assets of participants amount to 37% of total EEA assets.

⁵ Four participants are individual undertakings for which the group head is not participating in the study, but the model is the one used by the group.

⁶ Based on data submitted by EEA undertakings as of end-2017.

4. Modelling approaches and limitations

Qualitative analysis of modelling approaches

Two aspects are crucial for the interpretation of the results: first, the characterisation of various structural model setups and second the modelling of the one-year time horizon in the risk measure of Solvency II.

Regarding the structural model setup it is necessary to differentiate between integrated approaches covering both, market and credit risk, in one sole simulation from modular approaches covering most facets of market risk in one module while the remaining parts of market and credit risks are covered in another module. To simplify, we use the terms 'market module' and 'credit module' from this point forward. Also, the granularity of model outputs, provided for this study, varies along this dimension (e.g. scenario by scenario data vs. aggregated data).

Twelve participants use integrated approaches while seven participants use modular approaches. From the latter, two participants include some parts of credit spread risk in the credit module. Therefore, in order to have meaningful comparisons, clusters of similar model approaches (integrated vs. modular) have been built for certain detailed analyses, reducing the sample size.

Credit modules furthermore tend to use credit portfolio model approaches, which tend to reveal the real risk charge only at the overall portfolio level and not at instrument level. For this reason, results are best compared and analysed at the level of combined market and credit risk for portfolios.

With regards to the one-year time horizon required for Solvency II, two different approaches broadly exist: Fifteen⁷ participants apply so-called 'instantaneous shock models' on the Solvency II balance-sheet. Four participants modelled the evolution of the balance-sheet over the following year explicitly by taking into account ageing effects (e.g. remaining maturity of a bond is reduced by one year). This needs to be appropriately considered in the definition of the respective risk measure Value-at-Risk (VaR) underlying the Solvency Capital Requirement (SCR) and might deviate from a simple quantile estimator.

Furthermore, the qualitative scores collected from undertakings to indicate the exposure relevance showed that certain chosen test assets were not relevant, neither for the current exposure, nor for expected future investments. Consequently, in certain detailed analyses, some undertakings which are not exposed to some instruments or only provided rough proxies were excluded from the sample.

Limitations

Although the coverage of the study is very high – with reference to exposure to Euro-denominated investments, from a statistical point of view the sample is not large, as it includes 19 participants only.

Regarding credit risk, the number of instruments and issuers might still be considered low in order to explore portfolio models, but had to be limited for the sake of practicality for participants and analysis.

Finally, because most of the analyses were performed considering only the asset side of the balance sheet, the risk charges presented in this report represent only capital charges for investment. Therefore, they should not be interpreted or compared to Solvency II regulatory capital requirements which depends on the risk profile of each

⁷ One participant undertaking applies so-called 'instantaneous shock models' on the Solvency II balance-sheet only for the purpose of this comparative study.

undertaking and take into account the entire balance sheet. Furthermore, the risk charges presented in this report take into account the diversification effects within the market and credit risk modules, but not the diversification effects among other risk modules.

5. Results and supervisory actions

General remarks

Aiming to cover integrated approaches as well as modular approaches, the key idea is to focus the analysis on the combined market and credit risk. The key metric chosen for comparison is the 'risk charge':

The **risk charge** corresponds to the relative reduction of the initial value based on the modelled Value-at-Risk at one year horizon ("mVaR"⁸) not taking into account e.g. effects from liabilities or tax. Therefore, one can conclude that the findings of this report refer to the calibration of the models and not to the actual risk profiles of the undertakings.

5.1. Combined Market and Credit Risk, Benchmark portfolios

Introduction

Similar to the previous study a set of benchmark portfolios (BMPs) was specified consisting of linear combinations of various fixed income, equity and real estate instruments. The idea was to choose the BMPs in relation to real asset allocations of the insurance sector in the respective market. Therefore the representative portfolios used by EIOPA to derive the volatility adjustment (VA), for year-end 2017 for EUR and seven country VAs, namely for BE, DE, ES, FR, IE, IT and NL, served as a basis for the target allocations. Main criteria for the decomposition of fixed income instruments were sector (government, corporates), duration, maturity and credit quality step, using the usual mapping of ECAIs' credit assessments ('ratings') to credit quality steps. To supplement these, two portfolios were constructed purely consisting of sovereign bonds resp. corporate bonds, both with equal weights for all included instruments. Besides, only the most material and common financial instruments are used to construct these BMPs which include neither derivatives, nor inflation-linked bonds nor instruments sensitive to implied volatilities.

⁸ See above: The mVaR might differ from the 99.5% sample quantile on the simulated asset values, owing to the statistical estimator which can include e.g. interpolation or smoothing schemes.

The following table gives an overview of the portfolio compositions:⁹

Benchmark portfolios / \ Type of instrument	Euro currency	BE	DE	ES	FR	IE	IT	NL	SOV	CORP	Asset & Liab (1)	Asset & Liab (2)	Liabilities
	EUR_B MP_01	EUR_B MP_02	EUR_B MP_03	EUR_B MP_04	EUR_B MP_05	EUR_B MP_06	EUR_B MP_07	EUR_B MP_08	EUR_B MP_09	EUR_B MP_10	EUR_BMP_AL_01	EUR_BMP_AL_02	EUR_BMPL
Financial instruments	73.3%	83.2%	69.9%	78.6%	73.6%	57.3%	75.4%	72.2%	100.0%	100.0%	-13.7%	-17.1%	-100%
CORPORATES	40.7%	37.0%	46.8%	28.1%	38.1%	27.9%	25.1%	38.1%	0.0%	100.0%	40.7%	46.8%	0.0%
ESM	2.0%	0.5%	2.9%	0.8%	2.0%	0.3%	0.5%	2.1%	0.0%	4.3%	2.0%	2.9%	0.0%
Other CORP	38.8%	36.5%	43.9%	27.3%	36.1%	27.6%	24.6%	36.1%	0.0%	95.7%	38.8%	43.9%	0.0%
A	12.6%	11.0%	10.4%	7.9%	13.8%	9.1%	4.8%	12.2%	0.0%	17.4%	12.6%	10.4%	0.0%
AA	7.7%	6.9%	9.1%	3.5%	7.4%	5.7%	1.9%	6.0%	0.0%	17.4%	7.7%	9.1%	0.0%
AAA	6.3%	6.2%	15.1%	1.6%	3.6%	4.0%	0.4%	4.5%	0.0%	26.1%	6.3%	15.1%	0.0%
BB	1.3%	0.7%	2.1%	1.4%	0.9%	1.4%	2.1%	0.7%	0.0%	17.4%	1.3%	2.1%	0.0%
BBB	10.9%	11.7%	7.2%	12.9%	10.4%	7.5%	15.4%	12.6%	0.0%	17.4%	10.9%	7.2%	0.0%
GOVERNMENTS	32.6%	46.2%	23.1%	50.5%	35.5%	29.4%	50.3%	34.1%	100.0%	0.0%	32.6%	23.1%	0.0%
AT	1.3%	1.9%	2.0%	0.2%	1.4%	0.9%	0.2%	2.5%	11.1%	0.0%	1.3%	2.0%	0.0%
BE	2.7%	30.1%	1.7%	0.5%	2.0%	1.3%	0.4%	2.4%	11.1%	0.0%	2.7%	1.7%	0.0%
DE	4.6%	1.9%	10.9%	0.5%	0.7%	3.0%	0.7%	9.3%	11.1%	0.0%	4.6%	10.9%	0.0%
ES	3.3%	1.8%	1.4%	44.3%	2.1%	1.8%	2.4%	1.1%	11.1%	0.0%	3.3%	1.4%	0.0%
FR	9.8%	5.6%	3.1%	0.5%	24.8%	3.3%	0.7%	4.8%	11.1%	0.0%	9.8%	3.1%	0.0%
IE	0.3%	1.0%	0.4%	0.3%	0.5%	2.9%	0.3%	0.7%	11.1%	0.0%	0.3%	0.4%	0.0%
IT	7.9%	2.9%	1.4%	3.4%	3.4%	7.4%	44.9%	1.0%	11.1%	0.0%	7.9%	1.4%	0.0%
NL	1.7%	0.5%	0.8%	0.1%	0.4%	0.9%	0.2%	11.8%	11.1%	0.0%	1.7%	0.8%	0.0%
PT	0.3%	0.2%	0.1%	0.5%	0.2%	0.3%	0.1%	0.0%	3.7%	0.0%	0.3%	0.1%	0.0%
UK	0.2%	0.0%	0.4%	0.0%	0.1%	3.9%	0.0%	0.2%	3.7%	0.0%	0.2%	0.4%	0.0%
US	0.5%	0.3%	1.0%	0.2%	0.0%	3.7%	0.3%	0.3%	3.7%	0.0%	0.5%	1.0%	0.0%
Risk Free Rates	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-87.0%	-87.0%	-100%
Equity	22.7%	12.3%	26.6%	16.4%	21.4%	40.7%	21.0%	24.3%	0.0%	0.0%	22.7%	26.6%	0.0%
Real Estate	4.0%	4.5%	3.5%	5.0%	5.0%	2.0%	3.6%	3.5%	0.0%	0.0%	4.0%	3.5%	0.0%
Commercial	3.2%	3.6%	2.8%	4.0%	4.0%	1.6%	3.2%	2.0%	0.0%	0.0%	3.2%	2.8%	0.0%
Residential	0.8%	0.9%	0.7%	1.0%	1.0%	0.4%	0.4%	1.5%	0.0%	0.0%	0.8%	0.7%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	13.0%	13.0%	-100%

Table 1: Composition of the MCRCS benchmark portfolios

From the following graph it can be seen that the fixed income instruments of the BMPs have different maturity profiles and therefore lead to different portfolio durations:

⁹ The benchmark portfolios were constructed with the aim to mimic the EIOPA VA representative portfolios. However, since MCRCS portfolios are composed of a limited number of instruments the composition does not perfectly match the EIOPA VA representative portfolios. Please note: As the representative portfolios include unit linked assets, this partly leads to equity quotas, which are high compared to quotas observed in undertakings own investments. The next edition of the study intends to remedy this.

Maturity profile IR sensitive instruments

dashed line: weighted average maturity

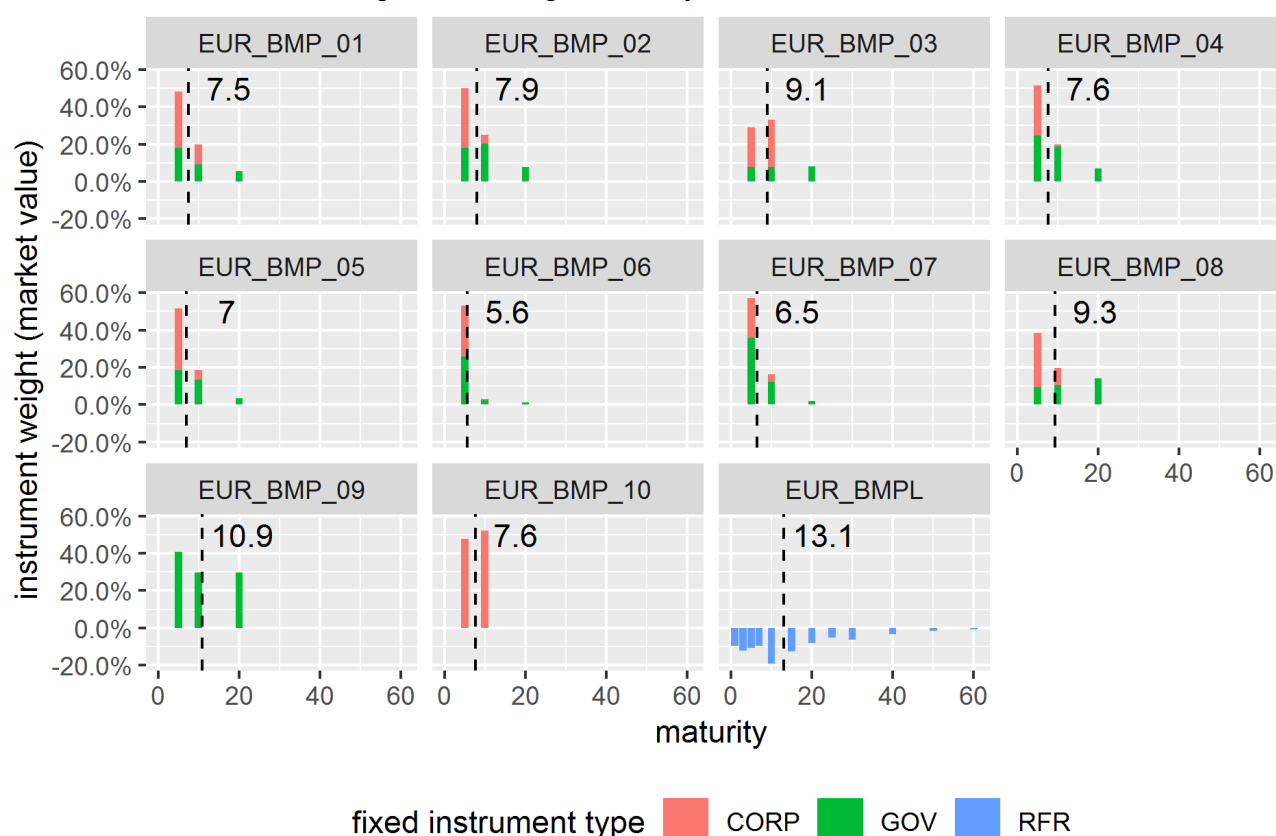


Figure 1: Maturity profiles of the asset benchmark portfolios and of the liability portfolio

The following plot displays the combined market and credit risk charges for the benchmark portfolios in the form of boxes, bounded by the 75% quartile at the top and by the 25% quartile at the bottom. It means that 75% and 25% of the risk charges from the sample are lower than the upper and lower line respectively. Additionally, the lines ('whiskers') at the bottom and at the top indicate the 10% quantile and the 90% quantile, i.e. the plot covers 80% of the sample. Note that the undertakings' results which fall outside of these 'boxes and whiskers' are not included in the chart. The magenta coloured dot represents the BMP specific risk charge based on the currently applicable standard formula.

BMP risk charges - part_01

magenta dots: SF charge

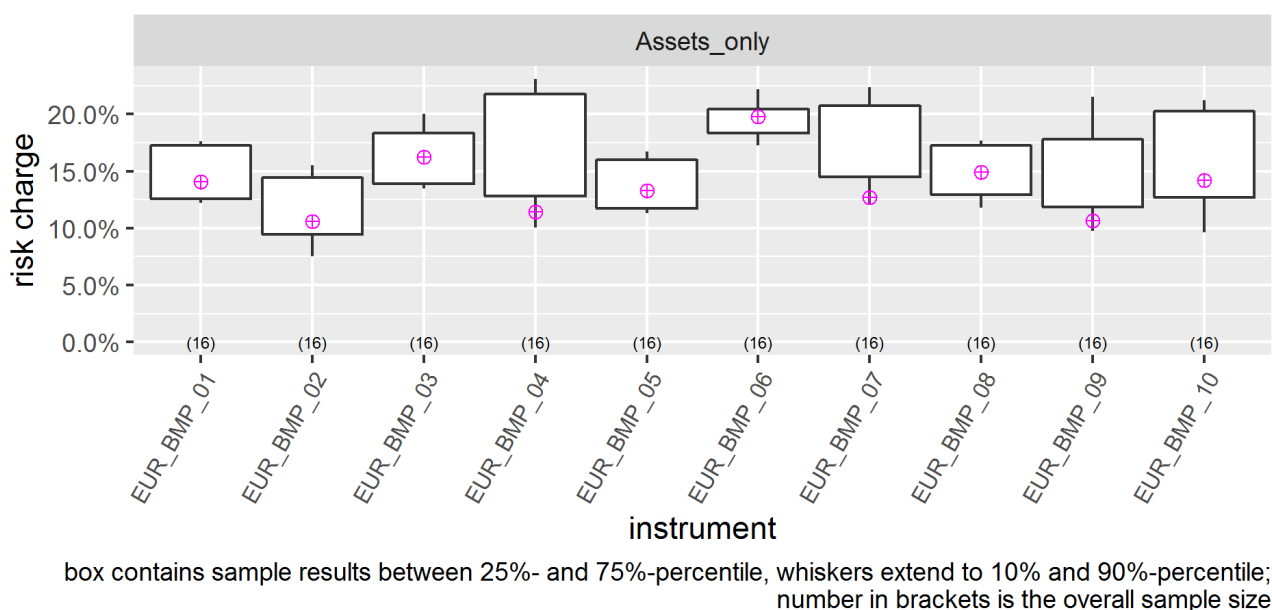


Figure 2: Risk charges for asset benchmark portfolios combined market & credit risk

Figure 2 shows sizeable variations but at the same time the risk charges give no indication of internal models being – globally speaking – systematically less prudent compared to the standard formula. On the contrary, BMPs 2, 4, 7 and 9 show higher internal model risk charges compared to the standard formula (albeit with a higher variation). These BMPs contain a large amount of sovereign bonds, which are generally reflected in the credit spread and/or credit risk for internal models, in contrast to the standard formula¹⁰.

Each of the boxes in figure 2 covers a set of 10 out of 16 relevant participants¹¹. The differences, i.e. size of the boxes, over all BMPs range between 2% and 9% (with a mean of 5%), and for 6 out of the 10 BMPs the range is between 2% and 5%. The highest difference (9%) is observed for BMP 4, the lowest difference (2%) is observed for BMP 6.

In order to extend the analysis towards a more realistic asset-liability perspective two additional BMPs were specified containing both long and short positions ("A-L-BMP"). More concretely, the following steps were taken:

- Asset allocations of EUR_BMP 1 ("EUR") and EUR_BMP 3 ("Germany"), were chosen respectively;
- Simplified liabilities, as a portfolio of risk-free zero coupon bonds as short-positions were added. The maturity profiles of these zero coupon bonds were chosen in a way to approximate the average cash flow profile of all European insurance undertakings (irrespective of the segment Life/Health and

¹⁰ All internal model results are purely related to the asset side, i.e. they do not include the risk-mitigating effect of the so-called 'dynamic volatility adjustment' which is applied by some undertakings. For details cf. sub-section below.

¹¹ This subset of 10 participants might be different from BMP to BMP.

- Property/Casualty) leading to a higher weighted average duration on the liability side compared to the fixed income assets (i.e. a 'negative duration mismatch').
- Assets and liabilities were scaled in such a way that the net asset value of the two A-L-BMP reflect the average NAV-to-total assets-ratio across all European insurance undertakings.

It is important to note that the simplified liability portfolio does not capture potential asset-liability interactions, different kind of products sold in the European market, loss-absorbing capacities of technical provisions or any other optionalities.

The following plot displays the risk charges for the A-L BMP 1 and 2 in terms of loss in the net value compared to the total initial asset value:

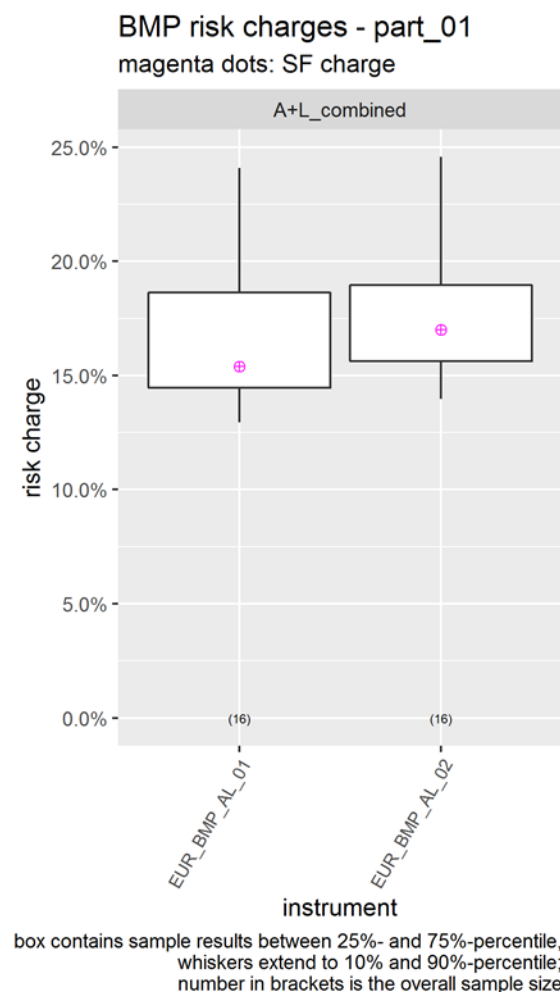


Figure 3: Risk charges for the simplified asset-liability benchmark portfolios without any VA

Again a significant variation of risk charges can be observed while the majority of participants show higher risk charges compared to the standard formula, when not accounting for the dynamic Volatility Adjustment (VA) approach used by certain undertakings (see the next subsection). Besides the above mentioned different treatment of sovereign bonds, this can also be attributed to the treatment of interest rate risk: The A-L BMPs are exposed to a decrease in interest rates and given the current low-interest rate environment this risk is not fully captured in the standard formula.

Impact of the dynamic Volatility Adjustment

The VA is applied to the risk-free interest rate curve under Solvency II. Its application by undertakings is optional, and in some Member States is subject to approval. The value of the VA depends on the currency (and possibly the country) of the liabilities; and it is set by EIOPA based on a formula using the average credit spread on reference portfolios of fixed-income instruments¹². Given that the VA depends on credit spreads, some internal model undertakings dynamically model the VA using their market & credit risk model – this is called the ‘dynamic Volatility Adjustment’ approach¹³. When an undertaking keeps the VA constant in its model, it is called the ‘static’ or ‘constant’ VA approach¹⁴.

This study has requested the participating undertakings to provide results for the VA approach used for the two simple asset-liability benchmark portfolios EUR_BMP_AL_01 and EUR_BMP_AL_02, laid out in the previous sub-section.

The following graph shows the ‘dynamic VA’ undertakings separately from the others. The vertical axis displays again the ‘risk charge’. For comparison, the risk charge given by the standard formula is shown as a purple dashed line.

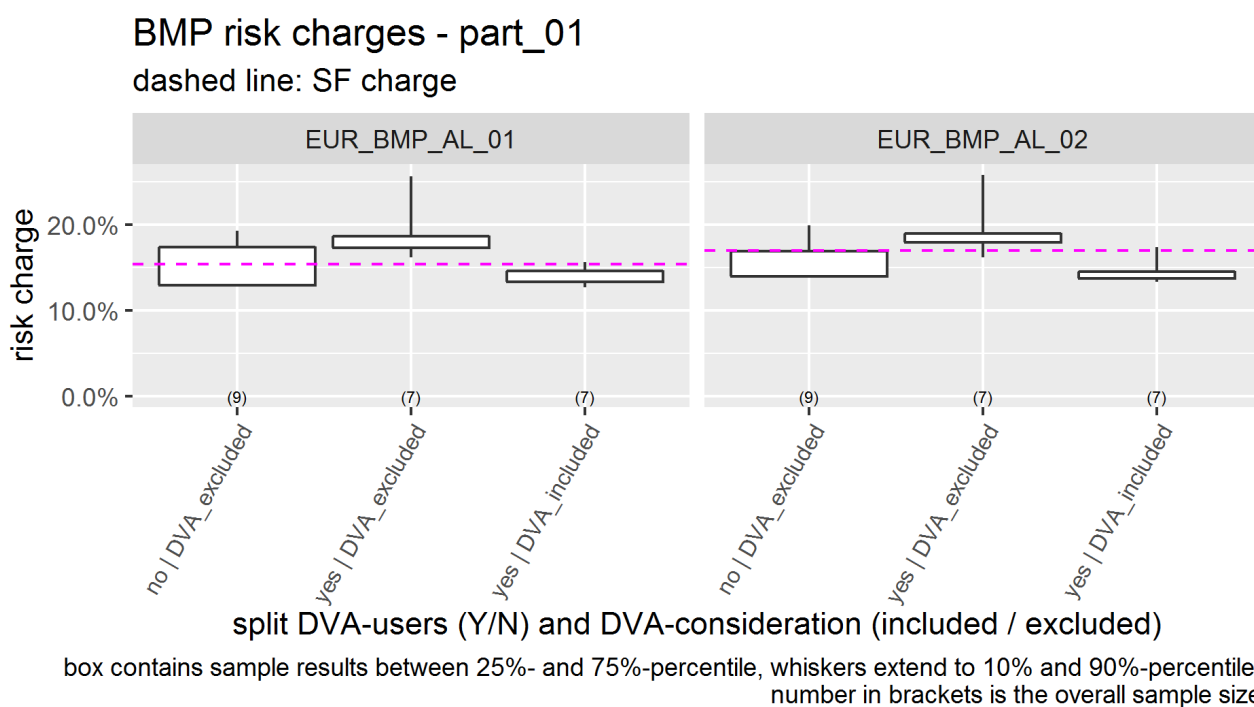


Figure 4: Risk charge for simplified asset-liability portfolios separately for non-dynamic VA users and for dynamic VA users (for these without and with dynamic VA impact)

¹² Please refer to section 8.A of the RFR Technical Documentation

https://eiopa.europa.eu/Publications/Standards/20180813_Technical%20Documentation%20%28RP%20methodology%20update%29.pdf

¹³ Please refer to EIOPA Opinion on the supervisory assessment of internal models including a dynamic volatility adjustment https://eiopa.europa.eu/Publications/Opinions/2017-12-20%20EIOPA-BoS-17-366_Internal_model_DVA_Opinion.pdf

¹⁴ Among the undertakings covered by this study, 11 don't use VA at all in their internal model calculations, 7 use the dynamic VA, and 1 use a constant VA.

Globally speaking, the behaviour for the asset-liability BMPs 1 and 2 (left resp. right) is relatively similar. The left part of figure 4 shows in three boxes the risk charge for the Asset-Liability portfolio based on the asset allocation of the "EUR" VA reference portfolio. The left-side box of each plot shows the risk charge for models not using the 'dynamic VA'. The right-side boxes convey the impact of activating the dynamic VA mechanism (for the models including 'dynamic VA'). Before activation, this group exhibits higher risk charges (see central boxes). Activation of the dynamic VA reduces these to a level within the lower part of the leftmost group of undertakings. When looking at either the activated or 'non-activated' VA (for the 'dynamic VA' undertakings), we see generally a lower variation of risk charges than in the group of undertakings without 'dynamic VA'.

5.2. Drilling down

Despite the limitations in model comparison due to differences in model types (see section 4), certain facets of market & credit risk were analysed, especially interest rate risk, spread risk, equity and property risk, to support the analysis of benchmark portfolios (BMP) and their individual calibration.

Interest rates – risk free

Unlike the standard formula, interest rate risk in internal models does not only comprise two scenarios, up and down, but a large set of simulated variations (including a change in slope and curvature of the interest rate curve).

The starting risk free rate curves for these simulations in the liquid part are essentially identical across participants, but in two cases differ in the extrapolated part, for which essentially 'flat extrapolation'¹⁵ is used. Although the EIOPA risk free rate curve is used by all undertakings for the valuation of technical provisions, for these two undertakings, the derivation of 'shocked curves' does not start from the EIOPA curve. Such a modelling choice is not considered to be per se critical: for certain assets and liabilities exposures only the liquid part of the curve might be relevant to calculate the risk, in other cases the modelled variations are independent from the base curve or a same base curve is used for assets and liabilities, based on market information, consistent with the classification of risk in the risk management system.

Unlike year-end 2015 and the standard formula, at year-end 2017 all models allowed for negative interest rates and also allowed for shocks to negative rates.

When restricting the comparison to single maturities, a significant variability in shocks can be observed. But as interest curve movements in general are more complex, this observation will partly require re-assessment (see below).

The following graphs illustrate the observed spectrum of marginal downward and upward shocks per term node in the sample for a EUR risk free rate:

¹⁵ i.e. essentially constant spot or forward rate after the last liquid point.

RFR distributions 'up' / 'down' (shocks): EUR

magenta triangles: SF RFR-shocks

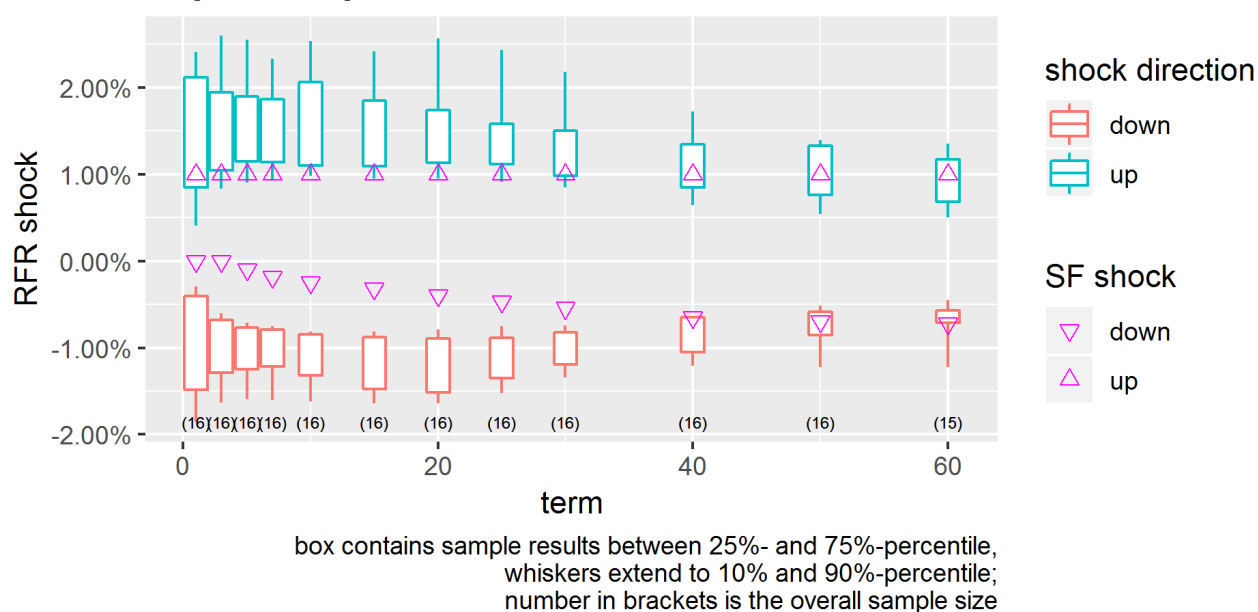


Figure 5: Downward and upward shocks on the spot rates for EUR risk free rates for single maturities (i.e. 'marginal' shocks on single nodes, not shocked curves)

Similarly to the graphs for the BMPs this plot displays marginal shocks on the initial spot rate¹⁶ for selected maturities from the sample of participants. Three submissions in the very short and very long maturities were identified as outliers and were therefore excluded. The boxes consequently include 8 from 16 submissions and the whiskers cover 13 submissions. Again, undertakings' results which fall outside of these 'boxes and whiskers' are not included in the chart.

Similar analysis has been carried out for GBP and USD and in general shows more variation, which can especially be attributed to the fact that these currencies are less material than EUR for most participants. Furthermore, specifics of these curves also show up. E.g. for USD the spot level for short maturities is significantly higher than for EUR and GBP, leading to higher shocks in absolute terms. The analysis will be refined in the next study.

As stated, movements of yield curves are more complex than variations in single maturities. As a first step to further explore these aspects, the study comprises also a simplified portfolio of short positions in risk free instruments. This portfolio was derived from the cash flow profile and duration of the combined liabilities of all European insurers and can be thought of as a simplified and deterministic liability portfolio (cf. section 5.1 A-L BMP). Evaluating this portfolio is a first step in analysing the characteristics of interest rate modelling beyond parallel shifts, although it only provides a global picture of the aggregated impact of the modelled rate curve shapes.

The following graph shows, similarly to the BMPs, the relative risk charges:

¹⁶ Spot rates are derived from risk free zero coupon bonds by discrete compounding, e.g. for maturity T and currency ccy: $spot\ rate(ZCB^{rf}(T, ccy)) = \sqrt[T]{\frac{notional(ZCB^{rf}(T, ccy))}{value(ZCB^{rf}(T, ccy))}} - 1$

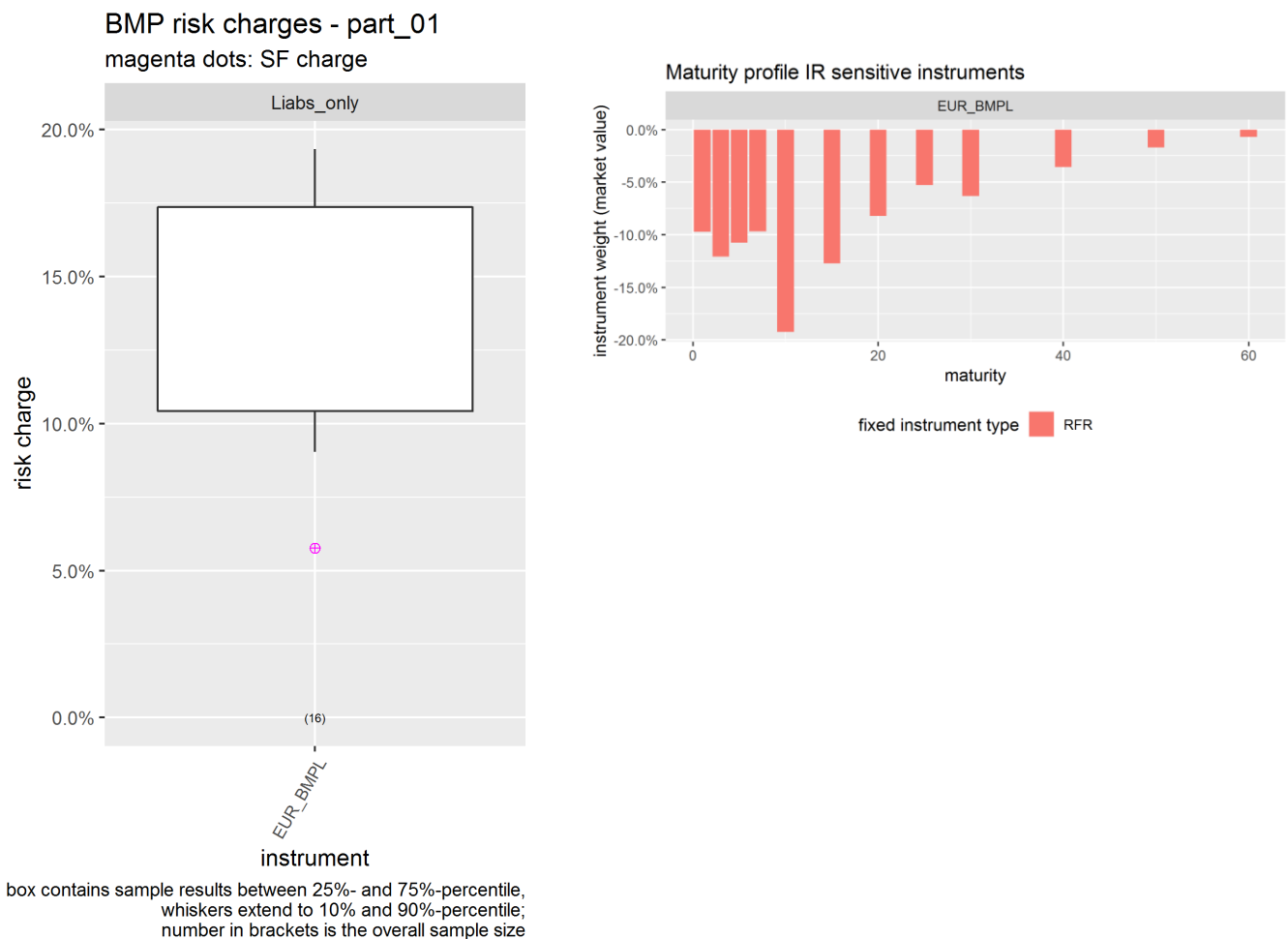


Figure 6: Risk charge and maturity profile for the simplified liability portfolio (short position in risk free rates, no options and guarantees)

The box shows that for 50% of this sample (comprised by the box, excluding the whiskers) the variation is around 7%. The risk charges are significantly higher compared to the standard formula. As noted above, this is due to the fact that internal models reflect the current low interest rate environment more appropriately. It should also be noted that solely looking at an asset or liability portfolio does not allow capturing the impact of rate curve movements on the combination of assets and liabilities, as encountered in an undertaking's balance sheet.

Credit spreads on Corporates and Sovereign bonds

The study required participating undertakings to represent the credit risk associated with a selection of synthetic corporate and sovereign bonds. Unlike the standard formula, credit risk is effectively, in general, modelled for sovereign bonds in the presented internal models.

The values of corporate bonds and sovereign bonds are driven by the overall risk-free interest rate level and by the instrument-specific credit risk. The study has been structured to enable these aspects to be differentiated.

However, analysis of the observed credit risk charges is complicated by the different model types encountered. In particular, model outputs for integrated models have generally covered all facets of credit risk, while model outputs for modular approaches

could generally not provide data including migration risk or default risk on single instrument level. As an aside, the approach taken in this edition of the study might be re-assessed in the future studies.

The analysis of credit risk modelling focused on credit spread information which was derived from the data submissions¹⁷. Analyses have been grouped as follows:

- Participating undertakings were combined into two groups: undertakings using an integrated modelling approach, i.e. for which instrument level data on credit spread risk, migration risk, and default risk is covered in one simulation; and, undertakings using a modular approach, for which the market module was used to provide instrument level data in general for credit spread risk only.
- Corporate bonds were combined into three groups: financial; non-financial; and, supranational.

Corporate Bonds

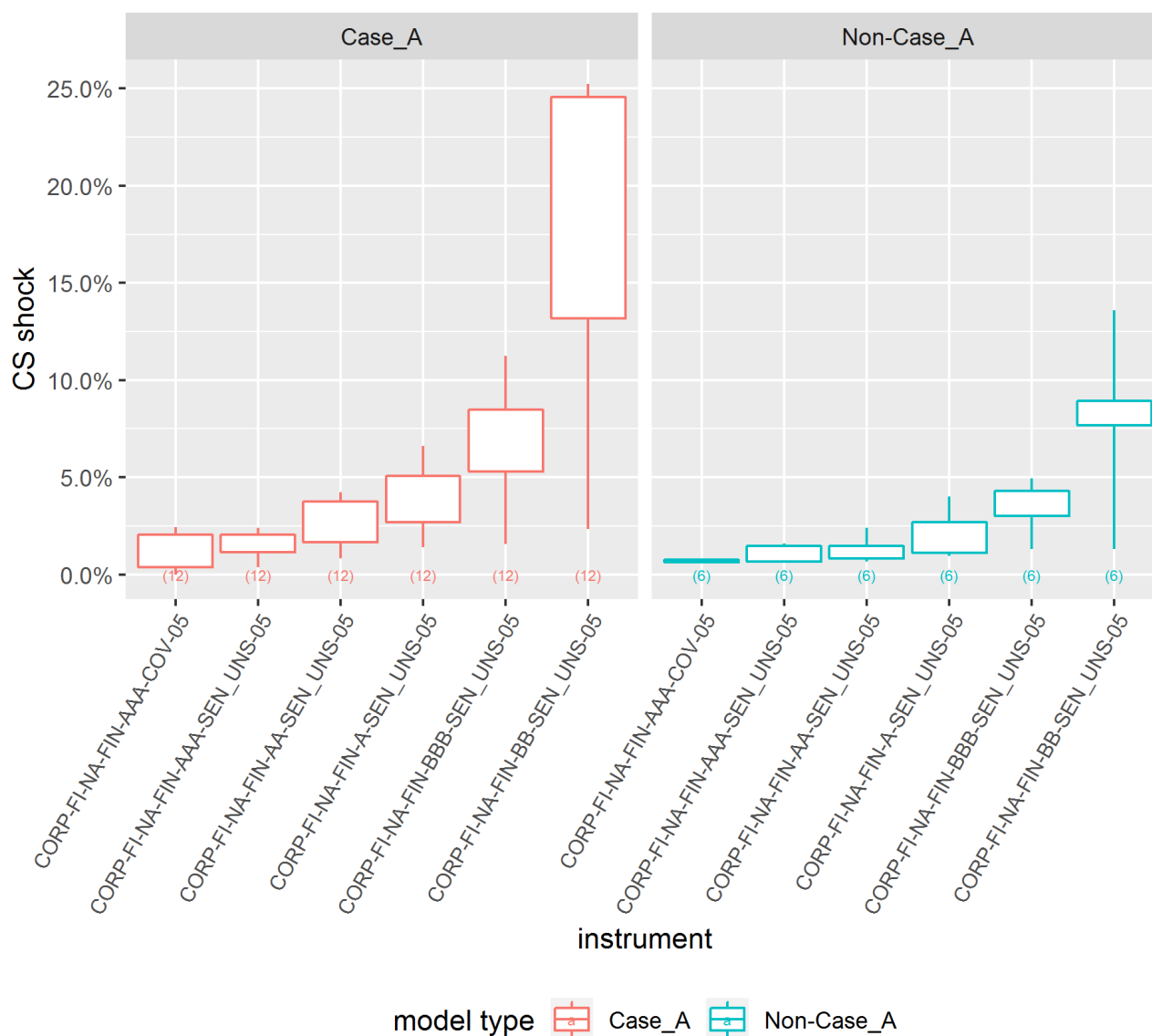
Data submitted by firms reveal certain risk factors which are important drivers of modelled credit risk charges and others which are not. Significant variation in firms' sensitivity to certain risk factors, such as bond credit ratings, were observed. Mixed treatments of bond issuers, bond durations, and bond security (covered or unsecured) were evident.

At the highest level, a variety of expected features were observed in the submitted data. Generally speaking, comparing across the groups of modelling approaches, credit risk charges on instrument level were higher for those firms with integrated approach ('case A', covering all facets of credit risk in an integrated simulation) versus modular approaches ('non-case A'), for which this part on instrument level only covers credit spread risk. Credit risk charges were also generally higher for bonds with lower credit ratings.

The following graph demonstrates the variation of modelled credit risk charges depending on the type and credit quality of 5-year bonds. The variation increases materially as the credit rating underlying the bond decreases. The deviation becomes substantial for BB-rated bonds. This demonstrates the variety of modelling assumptions being taken by firms, particularly for low rated bonds, for which the exposure materiality is generally low.

¹⁷ Credit spreads are calculated from the credit risky zero coupon bonds values analogously to spot rates but subtracting the risk free portion from the yield, e.g. for maturity T and currency ccy: $credit\ spread(ZCB^{risky}(T, ccy)) = \sqrt[T]{\frac{notional(ZCB^{risky}(T, ccy))}{value(ZCB^{risky}(T, ccy))}} - spot\ rate(ZCB^{rf}(T, ccy)) - 1$. As, in general, quantiles from risk-free and risky instruments do not coincide, spreads are calculated on scenario-by-scenario data. This data includes market and credit risk for integrated modelling approaches and market risk for modular approaches.

Credit spread marginal up shocks - Corporates



box contains sample results between 25%- and 75%-percentile, whiskers extend to 10% and 90%-percentile; number in brackets is the overall sample size

Figure 7: Credit spread marginal up shocks on instrument level: integrated approaches ('case A') with all facets of credit risk, modular approaches ('non-case A') without migration, default

Other notable features which were observed were as follows.

- On average, firms using a modular modelling approach, for which solely credit spread risk was analysed, showed no material difference between the modelled credit spread shocks for 5Y bonds and for 10Y bonds, although there was some variability in firms' individual practices.
- For firms with an integrated modelling approach, for which all facets of credit risk were analysed, the difference between modelled credit shocks for 10Y bonds and for 5Y bonds depended on a bond's credit quality. For higher credit ratings, 10Y bonds experienced a larger credit shock than 5Y bonds. For lower credit ratings, 10Y bonds experienced a lower credit shock than 5Y bonds. While this trend is

clear to see on average, there was also considerable variability in firms' individual practices.

- For approximately half of the firms, the models consistently produced higher credit risk charges for financial bonds than for the equivalent non-financial bonds. For the other firms, no appreciable difference was observed.
- For the majority of firms, models produced a higher credit risk charge for senior unsecured bonds than for the equivalent covered bond. For a small number of firms, the models produced higher credit risk charges for the covered bonds, while no appreciable difference was observed for the remaining firms.
- A small number of firms for which only credit spread risk was analysed showed very low credit shocks for all corporate bonds, despite holding material exposures to similar bonds.

Finally, the study specified a benchmark portfolio, BMP 10, which was comprised entirely of the 24 specified corporate bonds with uniform weights. The portfolio had a weighted average duration of 5.9 years. The analysis presented in section 5.1 shows a higher variation in model output for BMP 10 than for the single closest equivalent instrument. This is reasonable as section 5.1 analyses all sources of market and credit risk, whereas this section has isolated only credit risk – with all facets of credit risk for integrated approaches and only credit spread risk for modular approaches.

Sovereign Bonds

Sovereign bond data showed little variation in credit risk charges between firms with integrated approaches (all facets of credit risk covered in this part) and those with modular approaches (credit spread risk covered in this part). This appears to demonstrate that credit risk for sovereign bonds is largely driven by pure spread risk, while default risk is on average considered less relevant. (All firms also produced integrated model output covering market and credit risk for a portfolio of sovereign bonds – see below regarding BMP 09.)

Credit risk charges also across groups of modelling approaches showed relatively low variation among firms for the bonds issued by Germany, Netherlands, Austria, Belgium, and France. The variation is greater for the bonds issued by Ireland, Portugal, Spain, and Italy. The following graph demonstrates this for 10 year bonds¹⁸. The graph is influenced by a small number of firms which showed unusually low credit risk shocks across the instruments. While this requires further investigation, these firms have disclosed only a low exposure to sovereign bonds.

By contrast, the standard formula does not introduce a credit risk charge for the sovereigns¹⁹ which are examined in this study. We therefore omit any comparison to the standard formula in the analysis.

¹⁸ For Portugal, only a 5 year bond was specified as part of the exercise and so the variation of modelling output for that issuer is not shown in the graph. A similar pattern was observed for 5 year bonds, with Portuguese bonds showing a similar variation to Spanish and Italian bonds.

¹⁹ Note also that the standard formula keeps the volatility adjustment constant.

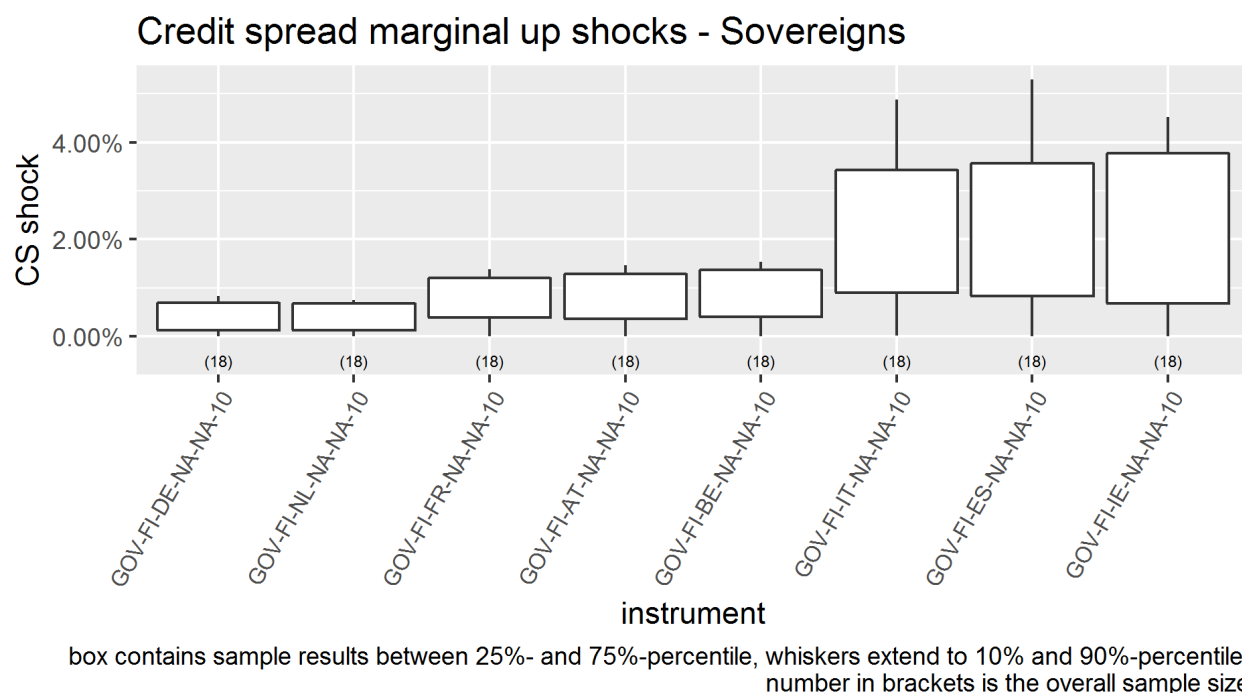


Figure 8: Credit spread marginal up shocks on instrument level for 10 year sovereign bonds across modelling approaches

Finally, the study specified a benchmark portfolio, BMP 09, which was comprised entirely of the 27 specified sovereign bonds with uniform weights. The portfolio had a weighted average duration of 10.7 years. The analysis presented in section 5.1 shows a higher variation in model output for BMP 09 than for the single closest equivalent instrument. This is reasonable as section 5.1 analyses all sources of market and credit risk, whereas this section has isolated only credit risk – with all facets of credit risk for integrated approaches and credit spread risk only for modular approaches.

Equity and property

The study indicates that internal model firms apply a wider variation in risk charges for property risks when compared to equity risks. The study has also indicated that the undertakings' equity risk exposure is higher when compared to the property risk; and also the equity risk modelling is more sophisticated when compared to the property risk modelling.

Significant variation is also observed in the firms' assumed expected growth for the synthetic equity and property risks. This means that a degree of caution needs to be taken when interpreting the risk charge that is applied by an undertaking in its capital calculation (for example at the 99.5th percentile), as it is unclear what adjustments (if any) firms make for expected growth. The following analysis for equity risk and property risk is based on the "Modelled Value-at-Risk (mVaR)" information provided by the undertakings.

Equity risk

The study indicates that the undertakings have less variation in the risk charges for the major equity indices such as EuroStoxx50, MSCI Europe, FTSE100 and S&P500, when compared to the risk charge applied to the strategic equity participation.

There is also a relatively small difference between the variation in risk charges that is applied by an undertaking with either a higher or a lower²⁰ equity exposure.

The box plots below compare quartiles for each equity index for all the undertakings (on the left) and only for the undertakings that have higher exposure in a given synthetic equity risk (on the right).

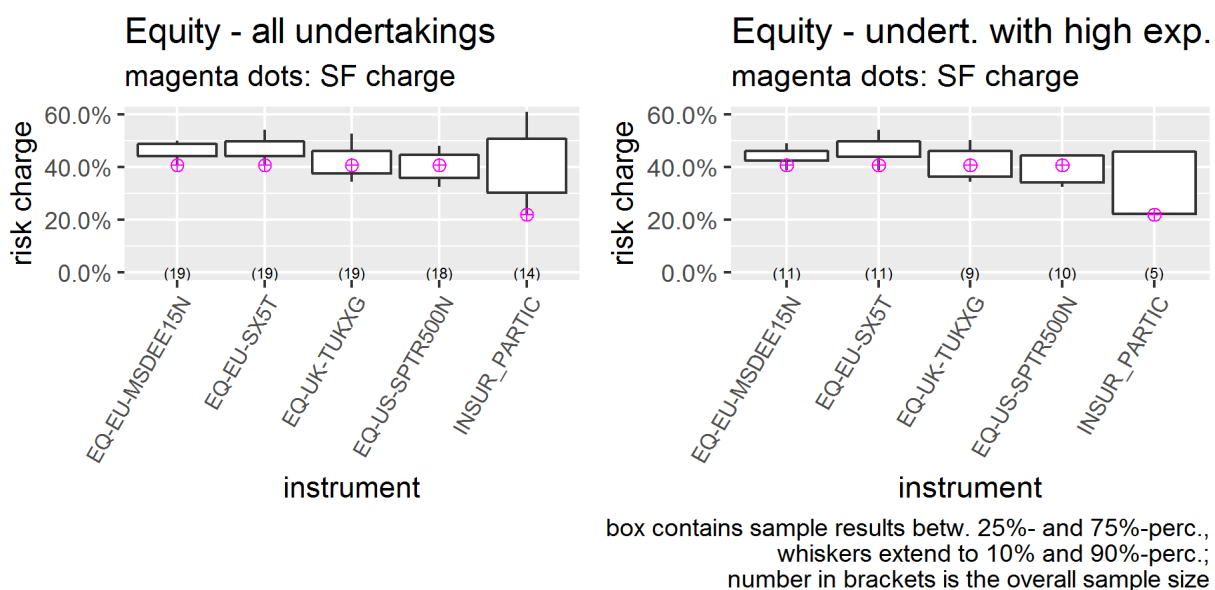


Figure 9: Risk charges for equity indices and participations for the overall sample (on the left) and for undertakings with higher exposure (on the right)

Property risk

For the four commercial property risk metrics, the study indicates that there is a large variation in the risk charges that are applied by the undertakings with a higher exposure, when compared to the risk charges applied by all the undertakings (i.e. including the undertakings with low exposures).

The Box plots below compare quartiles for each property risk metric for all the undertakings (on the left) and only for the undertakings that have higher exposure in a given synthetic property risk (on the right).

²⁰ Higher exposure is defined as the undertakings that have reported exposure relevance score of 3 (medium exposure) or 4 (high exposure). Lower exposure is defined as the undertakings that have reported exposure relevance score of 1 (not relevant) or 2 (immaterial). Please note that these categories were intentionally not defined by concrete thresholds and thus will also reflect the participants' materiality concepts.

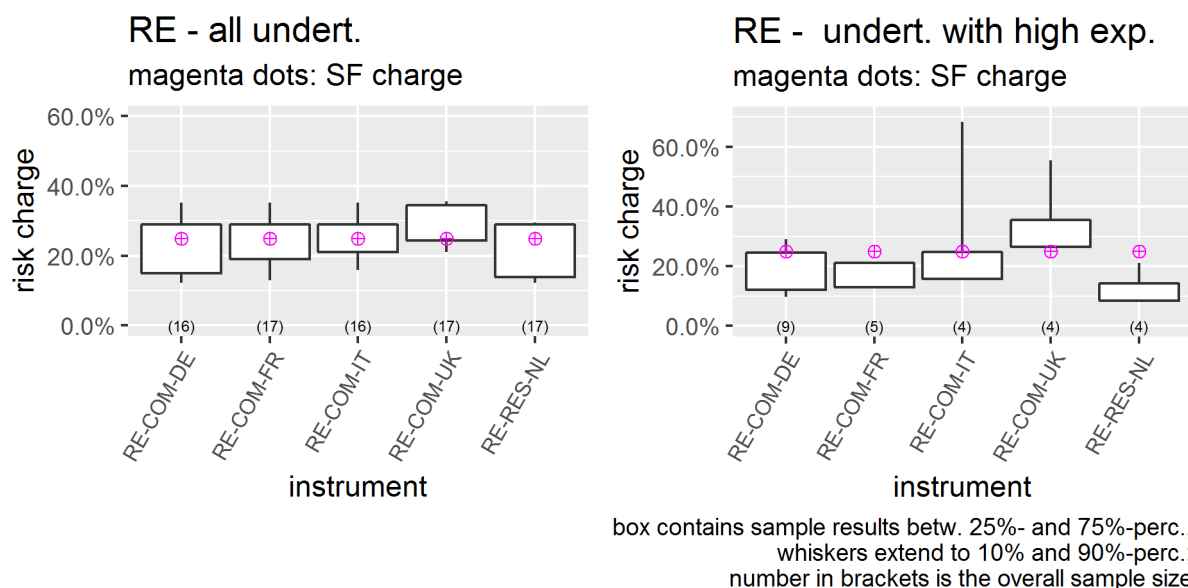


Figure 10: Risk charges for real estate for the overall sample (on the left) and for undertakings with higher exposure (on the right)

For certain asset categories, such as real estate, model calibrations might place more emphasis on the risk profile of the undertakings' actual investment portfolio and less on publicly available indices. Lower stresses compared to other participants or standard formula results can therefore also be an indication for a more defensive investment strategy of an undertaking in a particular asset class.

5.3. Supervisory follow-up

The responsible NCAs started discussing and challenging the participating undertakings based on feedback statements, prepared for each undertaking that go beyond the global image outlined in this report.

Three examples of topics being discussed and challenged: (i) Regarding three outliers identified for interest rate risk figures, a better understanding is sought. (ii) For credit spread risk, a variation in undertakings' credit risk charge is observed. One example is that certain submissions included higher credit risk charges for covered corporate bonds than for unsecured bonds. (iii) Furthermore, the variation of risk charges for property and strategic participations, accounting for the materiality of the respective exposures, is also looked into.

Also, the interactions with the undertakings comprise aspects of data quality and improvements of the coverage of single submissions. The undertakings were additionally asked to provide written feedback on the results and their evaluation of these. Furthermore, the NCAs' feedback on the set-up of the study itself and potential future improvements was collected. The outlook for the next edition of this study can be found in the next section.

It should be noted that some undertakings have already planned to incorporate remarkable observations from the study into their regular model validation activities. In some selected cases this could even trigger model changes. For instance, at least one undertaking has planned a model change that is informed by the outcome of the YE 2015 study.

The continuous engagement between NCAs and undertakings will allow the project group to enhance the annual MCRCS analyses throughout the next editions, thereby fostering a positive dynamic to further support on-going internal model supervision. At the level of each individual undertaking, this will concretely be achieved in conjunction with its NCA's Supervisory Review Process. Therefore responsible group supervisors are encouraged to inform about the study and discuss relevant insights with the supervisory authorities concerned.

6. Outlook

The supervisory community appreciated the insights gained from the year-end 2015 study and acknowledged the findings identified. Therefore EIOPA decided to perform regular studies on the market and credit risk modelling in internal models starting from year-end 2017. The scope, legal references, objectives and process of these studies have been published on EIOPA's website²¹.

The year-end 2017 edition of the study was built on the lessons learnt from the previous edition and again focussed on risk charges for benchmark portfolios under the combined market and credit risk. To enhance the analysis of combined risks, the tools were refined. Specifically, to enrich the spectrum of analyses, the study also explored interest rate down shocks via a simplified liabilities portfolio consisting of short positions in zero coupon bonds. The study furthermore relied on synthetic assets instead of real assets, aiming to remain, to a large extent, stable in order to support comparison over time and limit the effort of execution for participants. Finally, qualitative scores for the test assets were collected to indicate both the modelling quality and exposure relevance of the respective asset.

The data requested for future studies, and in particular the next "year-end 2018" edition will follow, as closely as possible, the scope and extent of the current data request. However, EIOPA plans to include an analysis of derivatives and extend the analysis of foreign currencies in the next study.

21

<https://eiopa.europa.eu/Publications/Protocols/Decision%20on%20the%20Annual%20Market%20and%20Credit%20Risk%20Modelling%20Comparative%20Study.PDF>