Report

4th ESMA Stress Test Exercise for Central Counterparties

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Acronyms used

bps	Basis points
CCP	Central Counterparty
CM	Clearing Member
DF	Default Fund
EMIR	European Market Infrastructure Regulation – Regulation (EU) 648/2012 of the European Parliament and Council on OTC derivatives, central counterparties and trade repositories
ESMA	European Securities and Markets Authority
ESRB	European Systemic Risk Board
EU	European Union
ETD	Exchange Traded Derivatives
FX	Foreign Exchange
GEST	Group of Experts on CCP Stress Testing
LEI	Legal Entity Identifier
NCA	National Competent Authority
OTC	Over the counter
P&L	Profit and Loss
pp	Percentage points
PoA	Power of Assessment
RTS	Regulatory Technical Standards
SITG/SIG	Dedicated CCP Resources (“Skin in the game”)
WWR	Wrong-Way Risk

For CCP codes, please refer to Annex 1.

1 Executive Summary

Reasons for publication

The European Securities and Markets Authority (ESMA), in accordance with the European Market Infrastructure Regulation (EMIR), shall initiate and coordinate assessments of the resilience of Central Counterparties (CCPs) to adverse market developments. This report presents the results of the fourth ESMA CCP stress test exercise that includes both EU and Tier 2 Third Country CCPs.

Contents

In line with the methodology published in June 2021[1], the exercise covers both credit and concentration risks, with targeted improvements in the methodology compared to the previous exercises. In addition, the exercise includes for the first time an assessment of operational risk.

Given the scope and type of this exercise, a number of limitations and uncertainties remain and have been highlighted in the report. This is particularly true for the operational risk analysis of the exercise, the methodology and assumptions of which have been applied for the first time. Results are therefore presented on an anonymous basis.

As with previous exercises, the objective of the ESMA stress test exercise is to assess the resilience of CCPs to adverse market developments. This exercise is not aimed at assessing the compliance of the CCPs with regulatory requirements, nor at identifying any potential deficiency of the stress testing methodology of individual CCPs. Despite the fact that it is not aimed to do so, it may expose individual shortcomings in the resilience of CCPs, in which case ESMA will issue the necessary recommendations.

Analysis of CCP financial resources

Section 4.1 provides an analysis of the financial resources held by the 15 in-scope CCPs, as of 19 March and 21 April 2021. This data gives an overview of the size of the industry and sets the scene for the presentation of the core stress test results. Overall, the prefunded resources collected by CCPs have increased compared to the previous exercises. The CCPs reported in total 423 (resp. 409) billion EUR of required margin, default fund contributions and other committed prefunded resources for March 2021 (resp. April 2021). There was no significant structural change in the overall share of excess collateral or allocation of resources between margin and default fund contributions. The analysis shows that, while there was a general increase of provided resources by all clearing members, at the same time the top clearing members increased their relative share, indicating a concentration of clearing member activity compared to the previous stress test.

Credit Stress Test

The results of the credit stress test are presented in section 4.2. Two default scenarios have been run, combined with a common market stress scenario. In addition to the profit and loss balance of clearing member positions (P&L) stemming from this scenario, concentration costs and costs related to wrong-way risk were also taken into account for one of the dates. The first scenario is a Cover-2 per CCP, where ESMA assumes the default of two clearing member groups separately at each CCP.

The second scenario is the All-CCPs Cover-2 scenario, where ESMA assumes the default of the same two groups for all CCPs system-wide. The defaulting entities are selected as the groups which maximize the shortfall of prefunded resources, or alternatively the groups which maximize the overall consumption of prefunded resources. Both scenarios have been run on two different dates, 19 March 2021 (end of day) and 21 April 2021 (intraday snapshot).

Under the Cover-2 per CCP scenario, ESMA assesses the resilience of each CCP to the default of its top-2 clearing members groups under common price shocks. The prefunded resources were sufficient to cover the losses resulting from the core credit stress test scenarios with relatively low or moderate % consumptions. The sensitivity analysis also indicated that the conclusions seem robust to small changes in the baseline shocks. The impact due to concentration and specific wrong-way risk stemming from cleared positions led to higher losses and consumption for almost all CCPs but under the considered market scenario these were contained within the default waterfalls of the CCPs and there was no shortfall of prefunded resources.

During the time of finalisation of the exercise, Russia's invasion of Ukraine led to extreme market movements for instruments across the commodities and energy markets. A brief analysis of the stress scenarios in the light of this event is presented in Box 2.

The All-CCPs Cover-2 stress test scenario is designed to assess the resilience of CCPs collectively to the market stress scenario. Under this scenario, the same two groups of clearing members are assumed to be in default in all CCPs. The majority of CCPs would experience a default of at least one of their clearing members. However, these consistent scenarios did not put significant stress to any CCP with the % consumption of default fund-level prefunded resources being relatively low in all cases. This indicates that while CCPs are highly interconnected through common clearing participants, the exercise did not highlight any pairs of groups that are at the same time and under the common tested scenario highly impactful at multiple CCPs.

Finally, in the reverse stress analysis discussed in section 4.2.3 ESMA intentionally goes beyond what was considered as plausible for the purpose of this exercise by stepwise increasing the number of defaulting entities and the severity of the market shocks. Having considered the reverse stress test scenarios, ESMA has not identified any systemically relevant adverse impact as the result of small increases in market shocks and number of defaulters. Taking as a starting point the base scenario and two defaulting groups, the analysis shows that incremental changes in market shock severity are more harmful than increases in the number of defaulting groups.

Concentration Stress Test

The results of the concentration stress tests are presented in section 4.3. Based on the sensitivity data provided by CCPs, the market impact (liquidation cost) was computed for all identified concentrated positions on one reference date (19 March 2021).

The European-wide concentration analysis shows that concentrated positions represent a significant risk for CCPs. For most asset classes, concentrated position risk is clustered in one or two CCPs, in line with the findings of the previous exercise.

[1] Framework for the 2021 ESMA Stress Test Exercise for Central Counterparties: https://www.esma.europa.eu/file/119720/download?token=PtWBdAbz

System-wide, the largest concentration risk can be found in fixed income derivatives (around 29bn EUR). Bonds (including bonds from Repo clearing services) come next with a total concentration risk modelled at 11 bn EUR. Concentration in commodity derivatives and in the equity segment (securities and derivatives) is very significant as well, with around 7bn EUR each. There is a very large coverage gap between the system-wide estimated market impact under ESMA methodology and margin add-ons, for commodity derivatives and to a lesser extent for equity products.

The concentration risk is addressed explicitly by a majority of CCPs through dedicated margin add-ons. Although all CCPs face market impact, 4 CCPs (KDPW, CCPA, KELER, CCG) did not report any concentration add-ons. Since the data request date, KDPW and CCG have implemented or are in the process of introducing concentration add-ons. KELER relies on a monitoring system to require additional collateral in case of elevated concentration.

Operational Risk

The results of the operational risk analysis are presented in section 4.4. In his analysis, ESMA derived insights with respect to the level of operational resilience of CCPs for 14 CCPs (one was excluded due to the absence of historical operational events data) and took an in depth look at third-party risk.

Using information about internal incidents of CCP's systems and third-party providers ESMA developed two methodologies to measure operational risk from historical events. With the computed results, ESMA identified varying degrees of operational reliability for the CCPs included in the exercise and identified specific CCPs where further work should be conducted to understand the drivers of these differences, the root causes of the events and the remediation actions taken.

Through the use of a hypothetical scenario, ESMA evaluated the exposures to critical third-party providers and the ability of CCPs to reduce risk through operational risk management tools. Using exposure indicators, differences across CCPs in their relative level of third-party risk were identified. Further work should be conducted to evaluate the individual circumstances of these exposures and the suitability of taking corrective action to improve operational resilience against operational shocks affecting critical third-party service providers.

In the analysis of the network of critical third-party providers, ESMA aggregated the information provided by individual CCPs in order to understand and assess risks from common exposures to third-party risk. Overall, ESMA identified a number of critical third-party service providers, which have the potential to affect the critical functions of multiple CCPs in a correlated manner. In addition, ESMA identified the critical third-party service providers with highest systemic importance for the CCP sector due to both the criticality of their services and their level of interconnectedness with CCPs.

Overall Results

EU and Tier 2 CCPs proved to be overall resilient under the considered components, scenarios and assumptions. As with the previous exercise, the adverse scenario did not aim to cover all possible market movements but was designed to provide an internally consistent narrative to assess the resilience of CCPs to system-wide market shocks.

The concentration component highlighted once again the need for CCPs to accurately account for liquidation cost within their risk framework. Finally, the operational risk analysis highlighted a series of areas and entities where further work to assess differences in measured risks between CCPs should be conducted, and where risk mitigation measures may need to be further enhanced.

During the time of finalisation of the exercise, Russia's invasion of Ukraine led to extreme market movements for instruments in the commodity and energy markets. ESMA, in coordination with the NCAs, closely monitored the impact that the outbreak has had on EU and Tier 2 CCPs. The analysis performed by ESMA confirmed that the CCPs active in commodities clearing were the most exposed, in particular the ones with relevant positions in power and to a lesser extent gas products. Moreover, the CCPs with a more diversified set of cleared products were not significantly affected primarily because of the lower experienced volatility in prices of other commodity and financial products. Overall, ESMA notes that CCPs remained resilient through the crisis, despite the increased market volatility.

Next Steps

In line with the EMIR mandate, where the assessments expose shortcomings in the resilience of one or more CCPs, ESMA will issue the necessary recommendations.

2 Introduction

2.1 Background

1. CCPs are systemically important, and their resilience is critical to the stability of the financial system in the EU. By their nature, CCPs are counterparties to all their clearing members. Failure of CCPs to mitigate risks could potentially lead to spill-over effects and may exacerbate systemic risk. Moreover, as evidenced in previous ESMA stress test exercises, CCPs are highly interconnected through common stakeholders, which may propagate failures in one CCP throughout the system. Stress testing CCPs, both individually and at financial system level, is an important supervisory tool to ensure the sector is safe and resilient to defaults of clearing member groups and market shocks. The Stress Test is a useful tool to assess the resilience of CCPs also from other angles, such as the capacity to withstand the costs arising from the liquidation of large positions or the operational resilience with respect to an outage of critical third-party service providers.

2. The ESMA stress test is different than the stress tests of individual CCPs. CCPs run daily stress tests on the basis of stringent prudential requirements that focus on their own environment, including participants and cleared products. By its nature, the individual CCP's stress test cannot consider how the default of one of its clearing members or third-party providers impacts other CCPs. Therefore, the ESMA stress test is a critical tool in assessing the systemic implications of system-wide events and thus the resilience of the system of European CCPs.

3. One of the objectives of Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4 July 2012 on OTC derivatives, central counterparties and trade repositories (EMIR) is to promote central clearing and ensure safe and resilient CCPs. Therefore, ESMA shall at least annually, in cooperation with the ESRB, initiate and coordinate assessments of the resilience of CCPs to adverse market developments. Following the amendments to Regulation (EU) No 648/2012 in 2019, these assessments should include both EU and third-country Tier 2 CCPs. Moreover, ESMA shall include both financial and operational risks. ESMA shall develop the following, for application by the competent authorities:

    - Common methodologies for assessing the effect of economic scenarios on the financial position of a financial market participant,

    - Common approaches to communication on the outcomes of these assessments of the resilience of financial market participants,

    - Common methodologies for assessing the effect of particular products or distribution processes on the financial position of a financial market participant and on investors and customer information.

4. Where the assessment exposes shortcomings in the resilience of one or more CCPs, ESMA shall issue the necessary recommendations.

5. The present report sets out the results of the 4th ESMA system-wide stress test exercise in Section 4, following a description of the employed methodology in Section 3. The objectives, scope and overview of the different tests performed are presented in the following paragraphs of this section.

2.2 Scope and Objectives

6. The objectives of the ESMA stress test exercise result directly from the legal mandate given to ESMA under EMIR. The objectives are to:

   - Assess the resilience of CCPs to adverse market developments,
   - Identify any potential shortcomings in the CCPs' resilience, and
   - Issue recommendations as appropriate.

7. The overall design of the stress test framework was also guided by a number of overarching principles. ESMA has assessed the resilience of all CCPs in scope, individually and as a system. This was done on the basis of, as much as possible, common methodologies and criteria. The ESMA CCP stress testing exercise is not aimed at assessing the compliance of the CCPs with regulatory requirements nor at identifying any potential deficiency of the stress testing methodology of the CCPs. It may however expose individual shortcomings, in which case ESMA will issue the necessary recommendations.

8. The exercise covers 15 CCPs, including all authorised EU CCPs as well as Tier 2 CCPs.

9. The scope of the stress test exercise developed over the years. The first exercise conducted by ESMA was focused on the counterparty credit risk that CCPs would face as a result of clearing member defaults and simultaneous market price shocks. The second stress test introduced several methodological improvements as well as incorporating an assessment of liquidity risk. The third exercise included a concentration risk component, with the aim of adjusting the losses arising from the credit stress test to account for the costs of liquidating concentrated positions. In this fourth exercise, the assessment of liquidity risk was paused, whereas the scope includes operational risk as a new component. The design of the new component is discussed in detail in section 3.6 and the results in section 4.4. Also, the integration of concentration with credit is an important new development in this fourth exercise that has further improved the detections of vulnerabilities in the European system of CCPs. The details of the methodology are provided in paragraph 3.4.3.3 and the results in paragraphs 4.2.1.1 and 4.2.2.1.

10. Counterparty credit risk and concentration risk are the core types of risks faced by CCPs. The methodology has evolved to cover additional risk sources and includes (i) the integration of concentration with credit on a mutual date, (ii) an intraday test for credit risk only on a second date.

11. In addition, an analysis of operational risk was performed. This analysis covered a general assessment of operational resilience of CCPs based on the analysis of past events, as well as specific analyses on third-party risk through the use of a hypothetical scenario and an analysis of the network of critical third-party providers.

12. While residual risks from the in-scope risk sources are analysed and highlighted in the framework, CCPs are also subject to other types of risks that are either not covered or are partially covered and could in isolation or in combination with assessed risks challenge their resilience. In particular, legal and any type of business risks are outside the scope of the exercise, because of their largely idiosyncratic nature. Also, potential shortcomings in policies and practices of individual CCPs, such as for example in the operationalisation of default handling procedures, can challenge their resilience but are beyond what was considered in the course of this exercise. Finally, environmental risk may be covered in a future exercise.

13. Furthermore, this exercise does not cover all possible scenarios to which CCPs may be exposed to. When modelling the scenarios and credit exposures, it is not possible to cover all possible risk factors and then all possible combinations of risk factor shocks for all CCPs. Indeed, while the architecture of this stress test is based on internally consistent scenarios, where N securities or contracts are cleared and possibly in the same portfolio, the number of possible basis risk movements is 2^N. The value of N is at least thousands in the case of an equity clearing service and thousands for derivatives. This makes it impossible to apply consistently all the potentially damaging scenarios consistently across all portfolios of CCPs.

3 Methodological Overview

3.1 Design and Components

14. This stress test exercise has the following components:

15. **Credit Stress**: Assess the sufficiency of CCPs' resources to absorb losses under a combination of market price shocks and member default scenarios.

16. **Concentration risk**: Assess the impact of liquidation costs derived from concentrated positions.

17. **Operational risk**: Analyse operational resilience with a focus on external operational dependencies that are needed by CCPs to provide their critical services.

18. **Reverse Credit Stress**: Increase the number of defaulting entities and level of market price shocks to identify at which point CCP resources are exhausted.

3.2 Overview of the Process

19. ESMA followed the same approach as during the previous exercises and key steps are further discussed in the next paragraphs.

FIGURE 1: OVERVIEW OF THE PROCESS

20. ESMA issued on 7 June 2021, the framework for the fourth CCP Stress Test Exercise[2], presenting the scope, the methodology and the details of the project. A market stress scenario for CCPs was built by the ESRB. During the data request, CCPs were provided with templates as well as detailed instructions on how to calculate and report the required information, including the calculation of P&L using market stress scenario, concentration metrics or operational risks and events.

21. A Group of Experts for CCP Stress Testing (GEST) with representatives from all national competent authorities for CCPs (NCAs) has been setup with the aim of contributing during the different steps of the project. ESMA and the Bank of England also collaborated during the different steps of the exercise involving UK Tier 2 CCPs. ESMA finally organised a workshop with EACH that was consulted on the overall framework and more specifically on the data request templates and the instructions.

[2] https://www.esma.europa.eu/file/119720/download?token=PtWBdAbz

22. The data request was launched on 8 June 2021 and the CCPs were asked to deliver by 20 August 2021 the completed data templates to the NCAs for EU CCPs or both ESMA and the Bank of England for UK CCPs.

23. The receipt of the files on 20 August 2021 was followed by the first data validation phase, where NCAs and the Bank of England validated the submitted data against the instructions and according to a common set of validation rules. ESMA also coded and offered to run a validation algorithm to facilitate this task. The first data validation phase lasted until 6 October 2021. Each Authority appointed one officer that was the single point of contact. Where needed, the appointed officers were in contact with ESMA staff and fellow officers from other NCAs in order to facilitate the consistent implementation of the framework across all CCPs. Moreover, in order to facilitate the convergence of the validation practices across different authorities, ESMA staff compiled and shared with the authorities a list of frequently asked questions, together with the respective answers.

24. The first validation phase was concluded with the delivery of the data templates in early October 2021 to ESMA that acted as a second line of defence in terms of data quality assurance. ESMA checked at least on a sample basis, that the reported data were consistent, reasonable and conform to the requirements included in the instructions. It finally assessed the overall plausibility of results, including a comparison between CCP results, to detect any outliers. The second validation phase was scheduled to last a total of 7 weeks. While the first set of findings were identified and addressed within this period, there were a significant number of issues that had to be followed-up multiple times, while in some cases, the correction of issues or the progress of the analysis raised new issues. Therefore, in practice the validation process continued in parallel with the analysis of the data that started immediately after resolving the first issues.

25. When sufficient progress was made on data validation and analysis, the GEST set the sensitivity parameters used in the concentration component in January 2022. ESMA calculated and analysed the results of the stress test. The preliminary results of the stress test were first discussed in March 2022 with the GEST (and the Bank of England for UK CCPs) and then at the CCP Supervisory Committee in April 2022. As a final step, ESMA also reconciled in April 2022 the core stress results with each individual CCP in an effort to reconfirm their robustness. The reconciliation exercise was focused on CCP specific data. Systemic data could not be reconciled without revealing confidential information on other CCPs or clearing members. Again, sufficient time and effort were devoted to the reconciliation process in line with the previous exercise, in order to ensure that the participants had the time and information needed to confirm the interpretation of the sourced data and the correctness of the results. To take into account the constraints of Russia's invasion of Ukraine, the launch of this reconciliation exercise was delayed by a few weeks and when launched, two weeks were given to CCPs.

26. To a significant extent, the quality of the data and results still rely on the data submitted by the CCPs and the primary checks performed by the NCAs as ESMA lacks direct access to the CCPs and was not in a position to redo all the validation checks that have been performed by the NCAs.

3.3 Market Stress Scenarios

27. Similar to the previous stress test exercises, the ECB, in close collaboration with the ESRB and ESMA, has developed the narrative and has calibrated the adverse scenario for the 4th stress test exercise. The shocks were produced using the tool that is employed for the calibration of financial shocks for adverse scenarios at the ECB and has been in use for the calibration of financial shocks for the EBA, EIOPA and ESMA scenarios.

28. The scenario that was produced reflects the ESRB's assessment of prevailing sources of systemic risk for the EU financial system. It reflects the triggering of one or more of the sources of systemic risk to the EU financial system identified by the ESRB. These risks could materialise

jointly and reinforce each other. The results were derived using a methodology that considers the joint empirical distribution of historical observations of the risk factors deemed relevant to CCPs to produce a coherent market risk scenario.

BOX 1: NARRATIVE OF THE SCENARIO AS PROVIDED BY ESRB

The translation of the sources of systemic risk identified by the ESRB into instantaneous shocks following triggers initiated in various market segments is described below.

In this adverse scenario, ongoing concerns about the evolution of the COVID-19 pandemic and its economic ramifications trigger adverse confidence effects worldwide and prolong the unprecedented economic contraction. The worsening of economic prospects is reflected in a global decline in risk-free rates (from what is already a historically low level). Countries' fiscal positions weaken, as do corporate sector balance sheets. Despite the low risk-free interest rates, concerns about the sustainability of public and private debt resurface, leading to a sharp increase in credit risk premia and a widening of credit spreads worldwide. Countries with large spreads are particularly affected, whereas countries with few debt sustainability concerns experience somewhat more muted increases in sovereign spreads. As a result, the dispersion of sovereign bond yields across the EU increases. The reassessment of market participants' expectations amid declining corporate earnings results in abrupt and sizeable adjustments to financial asset valuations. Widespread downsizing of firms and rating downgrades trigger large-scale fire sales in the non-banking sector. Market volatility spikes, the correlation of asset returns increases, and borrowing costs surge on the back of expectations that non-financial corporations will default. Similarly, the global fallout in terms of economic activity and the sharp increase in non-financial corporate bond yields weigh on global investment and global demand for raw materials, causing an abrupt repricing of commodities. The risk of idiosyncratic failures by financial institutions intensifies, reflecting the deterioration of the macro-financial environment, with potentially severe consequences for the financial system as a whole.

The scenario has been obtained by choosing the mean response for each conditioned variable in an adverse scenario where the triggering variables are stressed over a two or five day horizon depending on the asset class. The sample chosen for the calibration spans the period from January 2005 to December 2020.

29. The system-wide stress scenarios should not be bound to only replicate past historical scenarios, but also use past observations in combination with a narrative that reflects the assessment of prevailing sources of systemic risk for the EU financial system, including the two Tier 2 CCPs in the UK, to produce shocks that model potential future market conditions.

30. When modelling the stress scenario, it is not possible to cover all possible movements of different risk factors and their co-movements within and across asset classes. The scenario constitutes a severe yet plausible scenario that could arise if a risk environment such as the one explained in the narrative were to materialise.

31. Overall, it is a very difficult task to produce potential future scenarios for such a wide range of financial variables covering all major asset classes, which are at the same time sufficiently severe, internally consistent and plausible. The methodological tool used can combine a large number of time series and has allowed for the calibration of a more granular scenario, covering

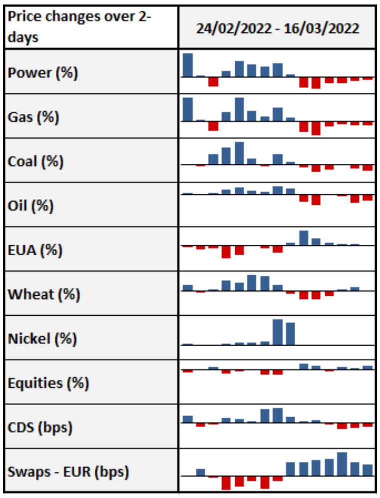
more than 800 risk factors. There is no single test that can ensure that all variables are jointly sufficiently severe and plausible.

32. During the time of finalisation of the exercise, Russia's invasion of Ukraine led to sharp and extreme market movements. An analysis of the stress scenarios in the light of these market moves is presented in Box 2.

BOX 2: THE MARKET STRESS SCENARIOS IN THE LIGHT OF THE RUSSIA'S INVASION OF UKRAINE

Russia's invasion of Ukraine on the 24th of February led to turmoil in the global markets. However, the severity of the movements was asymmetrical across asset classes with commodities being the most impacted one.

An overview of the evolution of the market moves for benchmark products in the main asset classes during the first three weeks of Russia's invasion is presented in the following figure.



The energy derivatives were the most impacted: a sharp increase in power and gas prices was observed on the day of the invasion, which marked the maximum upward movement over the considered period. Severe upward shocks for power and gas derivatives were observed also in the following week, together with a sharp increase in coal prices, while prices significantly decreased the week after. Oil benchmark products initially suffered from upward pressure as well, but the shocks were less severe than in the case of power and gas products. The role of Russia as the main EU supplier of crude oil, natural gas and solid fossil fuels led to price increases in energy products amid fears of reduction in Russian supplies.

The upward shocks on wheat prices, that mainly occurred during the first two weeks of the war, were also expected because Russia and Ukraine are significant exporters of wheat.

It is worth mentioning that nickel contracts trading was suspended after having reached all-time highs during the third week of the conflict. However, the CCPs involved in the current stress test exercise were not directly affected.

More details on the evolution of the market moves for benchmark products during the first days of the market turmoil are presented in the following figure. An arrow is shown on a date if the 2-day move (ending on that date) was 'high'[3], with the colour and direction of the arrow indicating the direction of the relevant move.

[3] i.e. higher than 50% of the period maximum. Notice that 5-day move was considered for 'CDS' and 'Swap (EUR)'.

	24.02	25.02	28.02	01.03	02.03	03.03	04.03	07.03	08.03	09.03	10.03	11.03	14.03	15.03	16.03
Power	↑		↓		↑	↑		↑		↓	↓		↓		
Gas	↑		↓		↑			↑		↓	↓				
Coal				↑	↑						↓				↓
Oil															
EUA				↓	↓					↑					
Wheat				↑		↑	↑			↓	↓	↓			
Nickel								↑	↑						
Equities															
CDS															
Swap (EUR)										↑	↑	↑	↑		

FIGURE 2: EVOLUTION OF 2-DAY (5-DAY) MOVES FOR BENCHMARK PRODUCTS DURING THE FIRST DAYS

After having analysed the experienced market movements for a number of benchmark products across all asset classes, ESMA staff compared them with the shocks used under the baseline common market stress scenario. For this purpose, ESMA staff used the maximum of 2-day moves over the period for all benchmark products with the exception of the primarily OTC-traded instruments (i.e. CDS and Swaps) for which the maximum of 5-day moves was used. This choice was made to reflect the EMIR requirement in terms of the minimum number of days that the CCPs need to consider when calculating the margin requirements for the different instruments and to remain consistent with the methodology used to calibrate the scenario shocks. It should also be noted that this analysis compares the shocks of the internally consistent stress scenario with the maximum moves observed during an event that unfolded over multiple weeks. Not all maximum moves happened on the same day, and these could not have hit a single CCP at the same time. On the other hand, no second-round effects were considered, that could have amplified the market moves in case a default would have happened. The figure below summarises the results of the analysis by comparing the maximum and minimum experienced market movements during the first days of the Russian invasion with the shocks of the stress test scenario used for this 4th stress test exercise.

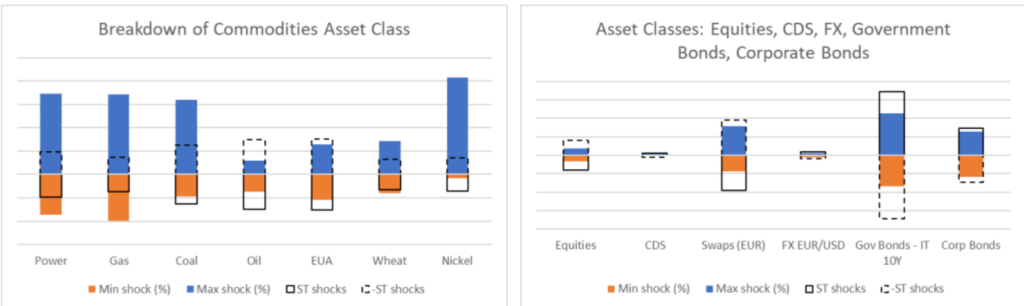


FIGURE 3: COMPARISON BETWEEN MOST SEVERE SHOCKS AND STRESS TEST SHOCKS

The comparison of the scenario shocks with the maximum market moves during the first days of the war showed that the ESRB scenario is overall of greater or comparable severity for most asset classes[4], but of a lesser severity for some commodities, mainly in the EU energy space. Moreover, different directions of shocks were observed in some cases, mostly in the commodities asset class.

The divergences highlighted can be explained by the scenario design, that was modelled based on the sources of systemic risk to the EU's financial system that have been identified by the

[4] Only a few outliers were observed.

ESRB. More specifically, it was built around ongoing concerns at the time of the design about the evolution of the COVID-19 pandemic and its economic ramifications. ESRB stress test scenarios typically model an economic downturn which is very different from shocks driven by supply concerns experienced during the war. The stress test cannot be used to assess resilience under specific historic events, but rather aims to assess the resilience of CCPs on a forward-looking basis and under a specific potential future scenario. Finally, ESMA staff would like to stress that the extreme market moves were really restricted to a few asset classes that account for a fraction of the cleared assets overall but could potentially put significant stress to particular CCPs.

In the context of risks linked to the clearing activity, a combination of clearing member defaults and simultaneous extreme market moves are needed to put a CCP at risk. In principle, if clearing members continue to post margin and meet their obligations, periods of extreme market volatility in isolation will not pose a specific market risk to a CCP. Moreover, the clearing members are required to collateralise on a daily basis their exposures and thus, the market risk is limited to the potential price movement from the last collateralisation of a defaulter's position until the time needed to hedge or close-out the position. Therefore, in terms of market movements, and always in combination with simultaneous defaults, it is generally the extreme short-term shocks spanning over a period of a few days that may put a CCP at risk and not medium or long-term moves.

The extreme market movements led to a sharp build-up of losses for many market participants, combined with margin calls from CCPs issued to collateralise the increasing exposures, also on an intraday basis. Despite the extreme pressure, the impact on CCPs in scope of this exercise was overall contained: no clearing member defaults were experienced in CCPs (except a small one) and no inherent weaknesses were found so far, although some CCPs are reviewing margin models and lists of eligible collateral.

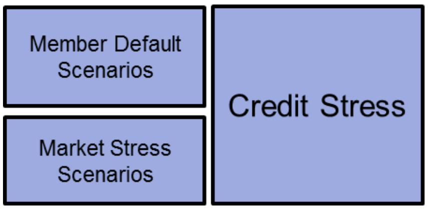
While being cautious about the uncertainties resulting from any attempt to conduct a comparison of this kind, ESMA staff has analysed the impact of using the shocks that actually occurred during the first days of the conflict as if they had materialised on the March date in 2021 used for the 4th stress test exercise. This analysis cannot lead to accurate and robust conclusions as different positions and margins were available on the days of the conflict, instrument prices were different, and a full revaluation of the positions was not performed. The tests that are run daily by CCPs are better placed to assess the impact of historic market moves on corresponding historic positions taking fully into account specificities of cleared products. The ESMA Stress Test aims to assess the resiliency of CCPs to adverse market movements on a forward-looking basis. It cannot be used to draw conclusions on the resilience of CCPs to specific historic events, as this would require the exact replication of historic exposures and eventually any conclusions drawn would be bound to a specific historic event of the past, with limited explanatory power for future events. However, the analysis performed by ESMA confirmed that indeed the CCPs active in commodities clearing would have been the most exposed, in particular the ones with relevant positions in power and to a lesser extent gas products. Moreover, the CCPs with a more diversified set of cleared products were not significantly affected primarily because of the lower experienced volatility in prices of other commodity and financial products.

To conclude, the scenarios that were used to run the ESMA CCP stress test are overall of greater or comparable severity to the overall actual market events in March/April with the commodity asset class being the only relevant exception. The used scenario remains valid and informative *as it stresses all CCPs as opposed to a single historic event that would only stress specific asset classes and specific CCPs. Nevertheless, this can be further analysed in the context of future exercises to understand if and how one could tweak the design of this exercise and these scenarios to also test for stresses to particular assets in a manner that remains internally consistent.*

However, one needs to be very careful when drawing conclusions, as the ESMA stress test is subject to several limitations and assumptions. Moreover, the unpredictability of the evolution of the conflict may lead to additional extreme moves and the CCPs need to be prepared to mitigate the resulting risks, especially if exposed to energy or agricultural products.

3.4 Methodology – Credit Stress Test

3.4.1 Overview



33. The goal of the credit stress test is to assess the sufficiency of CCPs' resources to absorb losses under a combination of market price shocks and member default scenarios.

34. The CCPs were asked to report, for each one of their members and for each date separately, the losses the CCP would face if a member would default following the market shocks dictated by the common Market Stress Scenario and the resources that would be available to cope with the default.

35. Since it is not feasible to define scenarios for each and every risk factor of all CCP-cleared contracts, the scenarios were defined for a set of high-level risk factors across different asset classes and the CCPs needed to translate the risk factor shocks into P&L for their cleared products and the members' portfolios. Therefore, the Group of Experts for CCP Stress Testing (GEST) developed and provided together with the data request and the market stress scenario a set of detailed instructions that explain how these are expected to be implemented. The instructions were drafted to provide clarity and address material implementation challenges. The instructions were shared with EACH[5] for consultation before the finalisation of the design. An overview of the rules, with a focus on the improvements compared to the previous exercises, is provided in paragraph 3.4.3.

36. After receiving the exposures of each CCP towards each clearing member, ESMA applied the conditions and assumptions underlying the Member Default Scenarios to identify the groups of clearing members that are assumed to be in default. The groups with the top exposures were identified by aggregating the losses across clearing members and, where relevant across CCPs (i.e. for the All-CCPs member default scenario). A detailed description of the member default scenarios is provided in the following paragraph (3.4.2).

37. The results are reported in terms of losses compared to the resources that were available to cope with the default and are subject to the assumptions and limitations as these are described in paragraph 3.4.4.

[5] European Association of CCP Clearing Houses

3.4.2 Member Default Scenarios

38. The member default scenarios define the conditions used to select the entities that are assumed to be in default. In all cases, the defaulting members were selected for each stress date individually and considering only the required margin (i.e. excluding excess). Central banks, governments and CCPs are not included in the list of entities that may be assumed to be in default for the purpose of this exercise. The following member default scenarios were employed:

Cover-2 groups per CCP: For each CCP, ESMA staff selects as defaulting entities the members belonging to the top-2 (corporate) groups of clearing members for that particular CCP. The defaulting clearing member groups are selected per CCP; hence they may be (and in most cases are) different for each CCP and they are not considered to be in default in other CCPs. When a group is assumed to be in default in one CCP, all clearing members that belong to the identified corporate group are assumed to default for the same CCP. ESMA staff first looks for pairs of groups that lead to the highest aggregate (EUR) loss beyond required margin collateral of the defaulter and beyond the Default-Fund-level prefunded mutualised resources, including the Default Fund, the “Skin-in-the-game” and other prefunded Default-Fund-level resources. Hence, ESMA staff first looks for pairs of groups that could together lead to a depletion of the prefunded resources. If such pairs of groups are not to be found (i.e. there is no shortfall of prefunded resources following the default of two groups), ESMA staff selects the two groups that would lead to the highest consumption of resources, measured by the aggregate (EUR) loss beyond Required Margin. The consumption can also be measured on a relative basis (i.e. % of resources consumed). This may lead to different results for CCPs that have more than one default funds. The selection of defaulting entities on the basis of the relative (%) consumption could focus on a smaller default fund that may be closer to creating a breach, instead of selecting pairs of groups that would cause larger (in absolute terms) losses at a larger default fund or even multiple default funds. Hence, while the core selection is done on the basis of the absolute (EUR) consumption, we also explore cases where there may be pairs of defaulting groups that would create a higher % consumption at such default funds. This impact is discussed when presenting the results as it may highlight a higher sensitivity at a smaller default fund.

39. **All CCPs Cover-2 groups**: Across all CCPs (full scope), ESMA staff identifies the two clearing member groups with the highest aggregate exposure under a particular market stress scenario. All clearing members that belong to an identified corporate group are assumed to default across all CCPs. Under this scenario, there may be CCPs with no clearing members defaulting, if none of the identified defaulters is a member at these particular CCPs. This scenario aims to give an aggregate view of the impact of the simultaneous default of the same two groups of clearing members at all CCPs. With regards to the exact condition used to select the clearing member groups, the first choice would be to select the top-2 groups that would lead to the highest aggregate shortfall of prefunded resources across all CCPs. However, the results did not indicate such cases. ESMA staff is therefore reporting the results after selecting the groups that lead to the highest aggregate (EUR) loss beyond Required Margin across all CCPs.

3.4.3 Calculation of Credit Stress Exposures

3.4.3.1 Stress Dates and modelling of the Default

40. The credit stress test was run for two reference dates, i.e. Friday, 19 March 2021 and Wednesday, 21 April 2021. For the first date (March), the default was modelled as a weekend

default, similar to previous exercises. For the second date (April), the default event was modelled as an intraday default and the CCPs were asked to report exposures and collateral as of a specific time window on this date.

41. For the March date (weekend default), all payments/obligations due on Friday prior to the default were assumed to be met in full. After the default (which occurs during the weekend), no payments were exchanged between the CCP and the defaulting member. Trading access was revoked in the weekend, so that no position changes were accepted after the last novation cycle of Friday. The positions therefore reflected the positions as of Friday end-of-day, including all transactions that were accepted for novation during Friday. All price movements were supposed to be happening instantaneously at the time the defaults are announced.

42. For the April date (intraday default), the assumption was that the defaulting clearing members had met all payments/obligations due before a cut-off time, excluding the settlement of any securities transactions that were to be settled on this date. After this time, no payments would have been exchanged between the CCP and the defaulting member. The exposures would have included any positions assumed by the member as a result of trading/novation during this date up to the cut-off time and any securities transactions that were due to be settled on or after this date[6]. The collateral included any collateral required and collected up to this cut-off time on 21/4/2021[7]. The underlying assumption was that the defaulting members met all payments before the start of the day and were allowed to trade normally until a specific time during the day. The members would have then stopped honouring any obligations after this time. The CCP would have stopped accepting new transactions from these members after this time and would have declared them in default later the same day. Finally, the CCP would have launched its default management procedures that would have allowed it to start the liquidation of the positions on the morning of the next day.

43. The intraday member default scenario aimed to test the intraday risk management procedures of the CCPs, including margining and settlement procedures, considering that clearing members may have increased their exposures during the day (day trading). This member default scenario explored for the first time the consequences of the CCP having to face the default of members carrying these increased positions, while having available only the collateral that was required and collected up to this time. The implementation of such a supervisory stress test scenario posed significant implementation challenges. Increased effort was required by all participants/stakeholders, including CCPs, NCAs and ESMA. As with all assumptions implemented for the first time, some uncertainties remained on the modelling of the relevant assumptions. Hence, results should be read with caution. Moreover, in order to manage the required effort, the cut-off time was not exactly the same for all CCPs and services but was set by each CCP according to the schedule of its margin calls subject to conditions. For this purpose, ESMA staff defined a common target time (14:00 CET) and each CCP was asked to identify the cut-off time to be used for the exercise as the cut-off time of its scheduled intraday margin calls that was (a) closer to the common target time and (b) in all cases after 12:45 CET and before 15:15 CET. The cut-off time selected reflected the time that was used to take a snapshot of the positions and collateral in order to execute the intraday margin call and not the time of executing the margin call or the time reflecting the deadline given to members to provide the collateral. Moreover, the CCPs were not asked to report the data at account level for this date (21/4/2021) but only at clearing member level, respecting of course any applicable segregation rules. This comes at the cost of the stress test results for this date not being able to reflect the additional stress assumptions (e.g. impact from concentration and wrong-way risk).

[6] The assumption is that the defaulting clearing member would not have settled any securities transactions on this date.
[7] The CCPs were allowed to adjust the collateral for cases where additional margin would have been required, called and collected by the CCP according to existing rules and procedures as a direct result of the assumption that no securities transactions were settled by the defaulting member on 21/4/2021.

44. For both dates, it was assumed that no porting of clients occurred, hence clients' portfolios were covered along with the proprietary positions of the defaulted clearing members and any losses resulting from clients' positions were included in the reported results. In the context of the credit stress test exercise, this is a conservative assumption as the margin allocated to client accounts can anyway not be used to cover losses of other client or proprietary accounts of the clearing member.

3.4.3.2 Calculation of stress P&L from closing the positions at stressed market prices

45. All positions were assumed to be closed, for each individual account, at the prices implied by the provided market shocks which were modelled as instantaneous shocks. No further price moves were assumed to occur.

46. The CCPs were instructed on how to identify or adjust when needed the shocks to be applied to their own products using the provided risk factor shocks and how to calculate the P&L stemming from those shocks. Specific rules were provided per product type or asset class to set how the shocks were to be adjusted, e.g. for similar underlyings or different maturities. For a few assets (e.g. dividend / inflation derivatives) for which no relevant risk factor has been provided, the shocks were to be modelled by the CCP using the stress scenarios used for their default fund sizing under the supervision of the NCA.

47. As a general rule, CCPs needed to operate a full repricing on the basis of the risk factor shocks and using the pricing models they normally use for the daily valuations of positions. Wherever they are available, the CCP needed to use actual market prices for the base price, i.e. the price to which the shocks are to be applied. Model-implied prices were only to be accepted where market prices are not available or not reliable.

48. Beyond the exposures using the common market shocks, the CCPs were asked to report the exposures as well after applying a number of multipliers on the shocks (i.e. x0.7, x 1.2, x1.5 and x2.0). Each value of the multiplier corresponds to a Reverse Stress Scenario and all shocks are to be simultaneously scaled. For each value of the multiplier, the CCPs ran a full repricing of the portfolios, as opposed to applying a multiplier to the result (P&L) of the scenario.

49. In the determination of losses, no hedging strategy was allowed to be acknowledged or modelled. In other words, the CCP was assumed to not have performed any risk mitigating transactions in order to limit the risk of the defaulting member's positions, but it has liquidated all the defaulting member's positions at the stressed price and has not introduced additional transactions such as an index trade to capture first order risk.

50. The reported losses reflected the full amount that the CCP would have collected / paid in case of the default, i.e. not only the profit or loss due to the stress shocks (stress P&L), but also any accumulated profit or loss that has not been settled until the default and would have to be settled when closing the position (non-stress P&L). This includes for example a loss due to actual market movements on Friday that should have been settled on Monday when the member would have been assumed to be in default.

3.4.3.3 Incorporation of impact from concentration and wrong-way risk

51. The methodology of the credit stress test component has now evolved to incorporate the impact from additional risk sources. In particular, the results for one of the dates (March) were also calculated to reflect the impact from concentrated positions and from wrong-way risk resulting from cleared positions.

52. The base methodology, parameters and assumptions used to calculate the P&L due to concentration and wrong-way risk are described in detail in 3.5 and 3.4.3.4 respectively. However, one of the challenges of including this type of risks in a supervisory stress test exercise is that the impact is dependent on the selection of defaulting clearing members. For example, a clearing member may have positions in instruments issued by another clearing member. The additional loss from wrong-way risk will only impact the CCP if the two members are assumed to default together. As a further example, the default of two clearing members that hold large same-direction positions on the same instrument may exacerbate the impact from concentration risk as the positions would have to be liquidated together. Hence, the impact can only be calculated in relation to a specific pair of defaulting members, while at the same time the selection of defaulters needs to consider this additional impact.

53. For ESMA to be able to seamlessly incorporate the additional impact from concentration and wrong-way risk, the CCPs were asked to report for one of the stress dates (March) the required data not only at clearing member level but also at account level. In particular, the stress P&L and corresponding collateral were reported at clearing member and account level and the concentrated positions only at an account level. The instructions and reporting templates were redesigned to allow ESMA to have the information required to aggregate results from account level to clearing member level, while incorporating the effects from these additional stress assumptions (concentration and wrong-way risk). Beyond allowing the assessment of the impact from concentration and wrong-way risk, the more granular reports enhanced the visibility in calculations and together with the detailed instructions helped to further strengthen the data validation process and the credibility of the exercise.

54. The CCPs were asked to report the data for the accounts that were active (i.e. had open positions or provided collateral) on this date, specifying also the relationships between different accounts and priorities in loss absorption reflecting their segregation rules in case of default. CCPs have in general very diverse account structures that go beyond the minimum set of accounts required by EMIR. They have different accounts that serve different purposes (e.g. position accounts, margin accounts, collateral accounts). For the purpose of this exercise, an account was defined as the level at which collateral can be fully offset against P&L from all positions recorded in the same account. Hence, CCPs were instructed to report at a level that would allow ESMA to correctly aggregate all fields from account to clearing member level by implementing the reported relationships / segregation rules.

55. Hence, for one of the dates (March) ESMA was able to run the stress test with and without these additional stress assumptions. In fact, three sets of results are presented:

a) Credit stress test results without concentration and wrong-way risk impact[8].

b) Credit stress test results with concentration impact (but without wrong-way risk impact).

c) Credit stress test results with concentration and wrong-way risk impact.

56. For the second date (April), the data was reported by CCPs only at clearing member level[9] in order to manage the overall effort. Hence, one cannot reflect the impact from these additional stress assumptions for the April date or for the reverse stress test scenarios.

[8] The stress results without the concentration and wrong-way risk could be calculated both by starting from the account-level reports or by starting from the clearing member reports as CCPs reported both for the March date. This was used to confirm the correctness of the aggregation algorithm.

[9] In all cases, even where results were reported by CCPs at clearing member level, the reported data reflected all applicable segregation rules, e.g. that client's resources cannot be used to cover losses from proprietary positions.

57. The following figure provides an overview of the different results obtained.

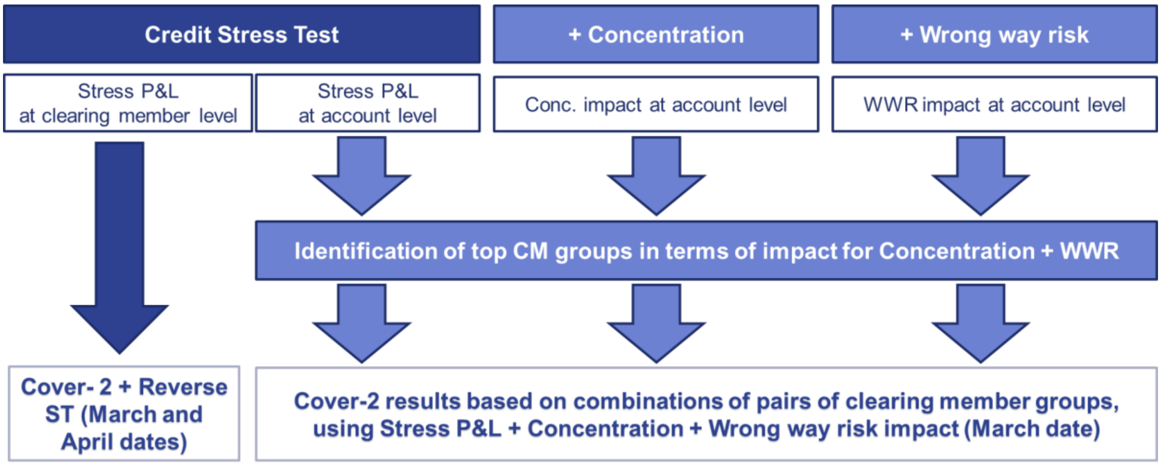


FIGURE 4: OVERVIEW OF CREDIT STRESS TEST RUNS

58. As explained above, the concentration and wrong-way risk impact stemming from one defaulting clearing member group may vary depending on the selection of the second defaulting group. Therefore, results would ideally need to be computed for all possible combinations of pairs of clearing member groups before selecting the top defaulting pair for each scenario. However, the number of scenarios, CCPs and Clearing Member Groups implies that there are too many combinations, that could not be exhaustively computed in a timely manner. In order to address this issue while reasonably trying to make sure that all relevant pairs of clearing member groups are analysed, ESMA staff implemented the following heuristic two-step approach. This was applied when calculating the results with concentration and wrong-way risk.

- First select a subset of clearing member groups to be considered for Cover- 2.

    a. Calculate results per single clearing member group taking into account stress scenario losses and concentration impact and select the top-10 clearing member groups impacting mutualised prefunded resources.

    b. Select the top-10 clearing member groups in terms of potential (aggregate across all members) wrong-way risk impact.

    c. Combine both lists and create a combined list of clearing member groups that are relevant from a concentration and/or wrong-way risk perspective.

- Then consider all possible pairs between the clearing member groups[10] belonging in the relevant shortlist and compute results for each pair to identify the top pair based on the member default scenarios (3.4.2)[11].

59. It is acknowledged that this approach has some limitations. Not all possible pairs of clearing member groups are tested. However, it would be extremely difficult, resource- and time-consuming to calculate the combined concentration impact for each possible pair needed to exhaustively test all possible cases. Nevertheless, in order to provide some level of comfort that

[10] i.e. up to 20 clearing member groups per scenario leading to 190 pairs of groups to compute per scenario
[11] The concentration-only run was based on the shortlist identified in terms of concentration risk while the concentration- and wrong way risk- run was based on the combined shortlist of clearing member groups.

no pairs with a potentially significant impact are left out, ESMA staff has still tested all possible combinations of clearing member groups but without considering the combined impact on concentration costs, i.e. the concentration impact was calculated for each clearing member group separately without considering that positions would have to be liquidated together in the market.

3.4.3.4 Estimation of wrong-way risk

60. One of the improvements incorporated in this exercise is the enhancement of the wrong-way risk adjustment for cleared positions.

61. Ideally, when assuming that an entity is in default, one should also reflect this in the price of the cleared instruments and collateral for all clearing members and CCPs. In the previous exercise the CCPs were instructed to incorporate in the P&L calculations for each member this effect for all cleared instruments issued by this specific clearing member or its affiliates. This means that, with regard to cleared instruments, CCPs did not model the effect from the default of all entities, e.g. when one assumed the default of two clearing members, one would only have for each clearing member the effect from instruments issued by itself. Therefore, the scope of this adjustment was limited and was also not applied consistently across all members.

62. The more granular reports of the new exercise allowed us to address this limitation. The CCPs reported stress data and concentrated positions at account level for one of the dates (March). Moreover, CCPs were asked to identify which cleared instruments (or underlyings of cleared instruments) are issued or guaranteed by one of their clearing members or affiliates. Hence, where reported positions referenced instruments issued by a defaulting entity or its affiliates, ESMA was able to estimate and incorporate in the stress test results the impact that the default of the entity will have on the positions of all clearing members.

63. In order to ensure internally consistent results, and in contrast to what was done in the previous exercise, the wrong-way risk adjustment was applied independently of whether it would result to a loss or a profit[12]. Overall, ESMA staff has noticed that incorporating a positive wrong-way risk (right way risk) would have not significantly impacted the end results as these are always based on a worst-case scenario assumption, e.g. selection of members that would have resulted to the highest losses.

64. The methodology that was used to perform the wrong-way risk adjustment per type of instrument is described below. The adjustment was calculated as the impact on top of the stress shocks, i.e. on top of the stress P&L already reported by CCPs (e.g. if a shock of -15% is applied in the market scenario to a stock, the P&L from the wrong-way risk adjustment as indicated below was added to the stress P&L calculated from this shock).

- Security (e.g. stock) issued by the clearing member or one of its affiliates: assume a shock of -50% to the position value reported in the relevant concentrated position file.

- Equity derivatives (e.g. Single stock derivatives) having as an underlying a security issued by the clearing member or one of its affiliates: assume a shock of -50% on the position value reported in the relevant concentrated position file.

- Corporate[13] bond issued by the clearing member or one of its affiliates: revalue at 40% of face value,

[12] e.g. for a short position equity derivatives position on a defaulted entity.
[13] The impact was not calculated for sovereign bonds or other public bonds as reported by CCPs.

- Covered bond/MBS issued by the clearing member or one of its affiliates: revalue at 88.75% of face value,

- Single-name CDS referencing the clearing member or one of its affiliates: revalue assuming a recovery rate of 40%.

65. In the interest of avoiding complexity, products (e.g. derivatives, warrants, ETFs) on an index where one of the constituents is issued by the clearing member or one of its affiliates were not adjusted for wrong-way risk. Similarly, index CDS's with constituents referencing the clearing member or one of its affiliates were not adjusted for wrong-way risk.

66. In general, the direct incorporation of wrong-way risk for cleared exposures improves the consistency and credibility of the exercise but the estimation of the relevant impact is still subject to model risk[14]. As a mitigation measure, ESMA staff shared the impact estimation with the CCPs and asked them to provide a more accurate estimate where needed together with a justification. Finally, any wrong-way risks towards issuers & custodians of collateral and other resources were also not acknowledged in the context of the credit stress test component.

3.4.3.5 Default Waterfall and Collateral

67. CCPs collect margins, default fund contributions and keep dedicated own resources that can be used to cover losses stemming from a clearing member's default. The scope and priority in use of the different resources are set in regulation and the rules of CCPs. A typical default waterfall is presented below, only for illustration purposes. The actual default waterfall of each individual CCP, as this was reflected in the data reported, has been considered to calculate the absorption of losses in the EU-wide CCP stress tests.

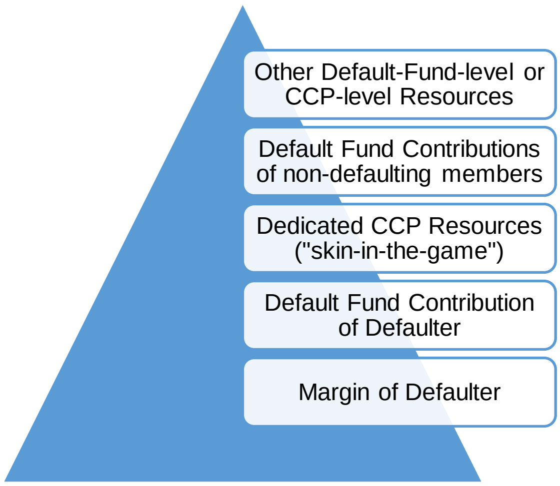


FIGURE 5: ILLUSTRATIVE TYPICAL DEFAULT WATERFALL

[14] For example, for Equity Options the adjustment was based on the delta-equivalent position values reported by the CCPs. For corporate (covered) Bonds the impact was calculated as the difference between the reported present value and 40% (88.75%) of the face value derived from the present value using available prices. For CDS the impact was calculated as 60% of the notional estimated using the reported sensitivity to credit spread changes and the maturity aggregated into maturity buckets.

3.4.3.6 Identification of Collateral

68. Concerning the default fund contributions, the reported amount reflected the required amounts, i.e. no excess collateral reported for the default fund contribution. In terms of margin, the CCPs were asked to report separately the minimum required collateral, not including any excess amounts, and the total available collateral.

69. The minimum required collateral is meant to reflect a scenario where defaulting members would have withdrawn under stressed conditions any collateral exceeding the minimum required. In fact, any member experiencing financial difficulties would most probably post only the minimum required collateral. Nevertheless, the CCPs have been asked to report also the actually held (total available) collateral, including excess amounts. Therefore, although the base stress results only considered the required collateral, ESMA staff also presented in some cases for completeness the stress test results using the excess collateral. In order to make the two sets of results (with / without excess) directly comparable, the same defaulting entities have been considered and in particular, the defaulting entities have always been selected using the minimum required collateral without the excess.

70. The required margin was identified as the sum of the margins required to be paid on the morning of the day of the default, any payment issued and paid during this day (and up to the cut-off time for the intraday default) as a result of margin calls and any of the collateral previously held as excess but consumed by the member's activity or intra-day valuations and offset against the computation by the CCP of margin requirements during this day, the absence of which would have led to a margin call according to the CCP's existing rules and procedures. Moreover, for the intraday default scenario the CCPs were allowed to consider margin that would have been required, called and collected by the CCP according to existing rules and procedures before the exercise cut-off time as a direct result of the assumption that no securities transactions were settled by the defaulting member on this date.

3.4.3.7 Valuation of Collateral

71. The CCPs were asked to revalue the collateral alongside the cleared products using the market stress scenarios shocks. Therefore, ESMA staff did not rely on the haircuts applied by CCPs.

72. Although in principle, valuing collateral using the same stress shocks improves scenario consistency and gives us the ability to check haircut adequacy, it is not necessarily in all cases the most conservative choice. For example, it can be that the collateral value increases following the shocks, while when relying to CCPs' haircuts the collateral value is always reduced. Moreover, the CCP may have re-invested the actually provided collateral and the P&L from the actually available resources may be different (higher or lower) than the P&L from the provided collateral.

73. The following modelling assumptions were used. The CCPs were asked to report and use the stressed values of margin & default fund collateral actually provided by clearing members (as opposed to the stressed values of relevant resources following re-investment). Since the credit stress test is based on the provided (as opposed to invested) collateral, any market or credit risks stemming from the re-investment of collateral are not reflected in the exercise.

3.4.4 Residual Limitations of Credit Stress Test

74. As in all exercises of this scale and type, there are residual limitations.

75. The credit stress test exercise has evolved to include the impact from concentrated positions for one of the stress dates. However, the estimation of this impact is subject to limitations, which are described in the relevant methodology, including due to the restricted modelling of the default management procedure, the model granularity and the uncertainties around the estimation of the market impact parameters.

76. Investment risks, including credit risks arising from the default of an issuer or custodian of collateral or other resources are not assessed in the exercise. The exercise does incorporate an assessment of the market risk for provided collateral using the common market stress scenarios. Any additional market or credit risks resulting from the re-investment of provided collateral are not covered. These limitations are due to the fact that these risks are linked to the individual actions and rules of the CCP and are thus difficult to model consistently across CCPs.

77. The wrong-way risk adjustment is applied for one of the stress dates and has been enhanced to also reflect the risk that would materialise if one defaulting clearing member clears instruments issued by another defaulting clearing member. However, the estimation of this impact is subject to limitations, including due to uncertainties in the estimation of the recovery values. Moreover, in the interest of avoiding complexity, the wrong-way risk effects on cleared index products are not modelled.

78. Operational risks, including those that may lead to increased credit risks, such as the operationalisation of default procedures, are also not reflected in the credit stress test results. The ESMA stress test exercise includes for the first time an assessment of operational risks in a separate component, but these are not reflected in the credit stress test results.

79. Any additional second round effects to prices following the default of entities will not be modelled (i.e. the price shocks are the ones provided by the ESRB and the number of defaults are the ones described above, but the two are taken exogenously). Also, the default of additional entities due to losses accumulated from non-cleared portfolios will not be modelled because the scope of the exercise is limited to CCPs exposures.

80. When modelling the scenarios and credit exposure, it is not possible to cover all possible risk factors and then all possible combinations of risk factor shocks for all CCPs. That would require modelling several thousands of risk factors and then all their co-movements. Since the exercise has to be run on the basis of common methodology and criteria, it cannot be aimed to identify topical deficiencies of individual CCPs. This includes for example the change of spread between two markets. Moreover, the shocks are modelled using a very large but still limited number of risk factors. CCPs' models are in most cases more sophisticated and cater for additional sources of risk, such as jump-to-default-risk for CDS.

3.5 Methodology – Concentration Stress Test

81. The objective of the concentration cost analysis is to assess the concentrated positions present in the portfolios of CCPs, estimate the potential liquidation costs that could be derived from their closing out, and assess the potential implications to CCP resources these positions pose.

82. For this exercise, the market illiquidity (or concentration) risk is defined as the added cost of liquidating in the market a position (or hedging it) in a short amount of time (in practice the time allocated to the management of a default by a CCP).

83. Initial market shocks apply to the mid-price of all positions regardless of their size and direction. However, it is likely that CCPs would incur costs beyond this price, depending on the size of their positions and the depth of the markets they clear.

84. Under the Article 53(3) of the RTS (Commission Delegated Regulation EU No 153/2013), a CCP shall conduct a thorough analysis of the potential losses it could suffer and shall evaluate the potential losses in clearing member positions, including the risk that liquidating such positions could have an impact on the market and the CCP's level of margin coverage.

85. Under the 2017 CPMI-IOSCO report (*Resilience of CCPs: further guidance on the PFMI*), a CCP's margin model should incorporate estimates of market liquidation costs, including bid-ask spreads not otherwise modelled in the price returns or explicit fees paid to trading platforms or liquidation agents. These market liquidation costs should also reflect the market impact of liquidation activity, when applicable. When a portfolio liquidation requires the disposal of concentrated positions or portfolios that are otherwise significant in terms of anticipated impacts on market liquidity in the relevant product, a CCP should contemplate the possibility that assumed market liquidation costs, such as bid-ask spreads or mid-market pricing, will not in fact be actionable or otherwise predictable in the face of an actual liquidation.

86. ESMA incorporated the above requirements in the design of this exercise to develop a methodology to include concentration risk in the CCP stress test exercise.

3.5.1 Scope and methodological principles

3.5.1.1 Market Scope

87. The exercise covers securities (equities and bonds) and derivatives (equity, fixed income, commodities, credit, freight and emission allowance).

88. To limit the overall complexity, other markets have been excluded on the following grounds:

- Small volumes in CCPs (structured finance products, ETCs and ETN bond types, securitised derivatives, CFDs)
- Highly liquid markets (Foreign exchange derivatives)
- Complex sub-asset classes decided on a case-by-case basis to limit the overall computational complexity (volatility index derivatives, dividend derivatives, inflation and cross-currency swaps).

3.5.1.2 Position type coverage

89. The framework design ensures that most concentrated spread positions, even market neutral ones, are captured.

90. As the transaction costs add up, spread positions between two correlated but different underlyings are not offsetting. For example, a large short position in one equity and a large long position in another equity do not offset each other's costs. Likewise, electricity or commodity derivatives with different delivery points will be captured.

91. Curve / calendar spreads on the same underlying are captured unless all components fall in the same maturity bucket. Hedges with economic rationale such as delta hedging single stock derivatives with the underlying stock are considered.

3.5.2 Concentration modelling overview

General principles

92. This exercise does not model the whole default management procedure, for example, there is no attempt to factor in the impact of an auction which could lead to smaller or bigger concentration costs. Rather, ESMA staff assessed the market impact of liquidating positions or setting up hedges, compared these to available concentration add-ons, and combined the findings with the credit component to improve the methodology of the stress test.

93. The market impact can be broken down in two parts:

- An exogenous factor which is the relative size of the bid-ask spread. Spreads would represent a cost even for small positions.

- An endogenous factor, when positions are too large and cause the market to move against them (one can think of a forced liquidation). Market impact depends on the position size relative to the market depth, which is the ability of the market to absorb a substantial amount without materially impacting the mid-price.

94. Exogenous liquidity adjustment is of negligible importance for the world's main futures and currency markets, but more significant for other markets, such as credit or energy markets.

95. For large positions, market impact is usually much larger than bid-ask spreads.

96. In the context of a portfolio containing a single asset, e.g. an equity, the concept is quite straightforward. There is only so much the market can absorb in one day before the market price of the security moves in an adverse direction. For derivatives such as swaps or options, the concept is more complex and market specific.

97. The importance of managing concentration risk was illustrated in a recent market event. Following the default of a clearing member on the 11/09/2018 at Nasdaq Clearing, it was assessed that its positions were too large to be closed in the market. The illiquidity of the positions made the final losses to largely exceed the mark to market losses prior to the default.

Overview of the methodology

98. The computations performed by ESMA staff are based on three main data sets reported by the CCPs and further described in section 3.5.2.1:

- concentrated positions of each of the CCP clearing members at account level,

- Average Daily Notional Amount (or Average Daily Volume) metrics for the relevant asset classes,

- sensitivity tables estimating the liquidation costs for the different asset classes as a function of the position size relative to the Average Daily Notional Amount (or Average Daily Volume).

99. ESMA staff performed three main steps in the computation phase:

- aggregation of the size of the position to be liquidated under the no porting assumption, as detailed in a)[15],

- computation of the size of this position (or its hedge) relative to the Average Daily Notional Amount (or Average Daily Volume), as detailed in b),

- estimation of the liquidation market impact of the position as a function of the ratio between the size of the position (or its hedge) and the Average Daily Notional Amount (or Average Daily Volume), by using the common ESMA sensitivity tables and as detailed in c).

100. Further details on the different steps and methodological assumptions are provided in section 3.5.2.2.

3.5.2.1 Input data submitted by the CCPs: positions, reference volumes and liquidation costs

101. ESMA requested CCPs to report the concentrated positions of each of their clearing members at account level following prescribed aggregation rules for each asset class. The target sub-classes are built from tables of the annex III of the Commission Delegated Regulation 2017/583 on MiFID II, dealing with transparency requirements. The segmentation criteria are complemented where necessary to improve the granularity, with for instance, the introduction of a delivery / cash settlement location for some commodity derivatives.

102. For each given aggregation level, each CCP also reported a common reference volume for all its positions. This reference volume is usually reported as an Average Daily Volume (ADV) for securities, and an Average Daily Notional Amount (ADNA) for derivatives. For securities, the primary source for ADVs is the systematic internaliser data[16] computed and published by ESMA. In most other cases, the reference volume was set using the CCP's own submitted data, as they reflect the markets the CCP can readily access and for which it has in place the operational arrangements to readily execute transactions. For equity index derivatives, the cash turnover of the underlying index is used when relevant.

103. Finally, each CCP provided sensitivity tables estimating the liquidation costs for the different asset classes it clears. Typically, for any given asset class or sub-class, the tables give the cost (in bps or % market value) for executing trades that are 0.5, 1, and 2 times the average daily volume (or average daily notional amount when relevant). Market-wide baseline sensitivity tables for each asset class were built by ESMA and discussed by the Group of Experts on CCP Stress Testing (GEST).

3.5.2.2 Computation steps

a) Aggregation and reporting of positions

104. As instructed, CCPs calculated and reported the aggregated positions per instrument/asset class for each clearing member house/ client account.

[15] The porting assumption means that the CCP has committed to trigger the procedures for the transfer of the assets and positions held to another clearing member following a client(s) request.
[16] The "systematic internaliser calculations" data files can be downloaded from ESMA Website: https://www.esma.europa.eu/data-systematic-internaliser-calculations

105. The first step performed by ESMA staff was computing the size of the position to be liquidated at Clearing Member level and for each instrument/asset class, aggregating the data at account level provided by the CCPs.

106. The aggregation was based on the following high-level principles:

- For securities, the positions are aggregated at the ISIN level.
- For other derivatives, non-linear positions (e.g. options) are aggregated with linear positions (e.g. futures/forwards) using their delta. The vega is also reported for equity and commodity derivatives.
- Single stock equity derivatives are aggregated with the underlyings through the net delta at ISIN level. For the rest of derivatives, the aggregation follows class specific criteria and maturity buckets.
- Fixed income and credit derivatives positions are reported through aggregated risk sensitivities.

107. To limit the data volume and focus on concentrated positions, CCPs have only reported relevant positions above class-specific thresholds for bonds, equity and equity derivatives.

108. To allow for a simpler implementation:

- the positions are valued without the impact of any market risk scenario.
- no porting of accounts is assumed.

b) Computation of the relative size of the positions to be liquidated

109. Once the size of the positions to be liquidated were determined, ESMA staff computed the ratio between the size of each position (or its hedge) and the to the Average Daily Notional Amount (or Average Daily Volume).

110. The ratio is an estimate of the size of the position, and it is used as entry in the baseline sensitivity tables to estimate the liquidation market impact.

c) Estimation of the liquidation market impact

Sensitivity tables

111. Each CCP provided sensitivity tables estimating the liquidation costs (in bps or % market value) as a function of the ratio between the size of the positions to be liquidated and the Average Daily Notional Amount (or Average Daily Volume), as described in the previous computation step.

112. The sensitivity tables were provided by each CCP for the different asset classes it clears. The number of CCPs providing estimates varies widely across asset classes. For instance, only 2 CCPs clear freight derivatives, but 10 CCPs clear equities.

113. The third computation step started by summarising all the sensitivity tables provided and produce a single market-wide baseline sensitivity tables for each asset class. ESMA staff typically chose the median contribution to reduce the influence of outliers. This step involves the

scrutiny for accuracy and plausibility as well as the removal of outliers. For instance, emission allowance sensitivities were increased to match the energy commodity ones.

114. Yet, additional methodological choices had to be made to calibrate the sensitivity tables.

115. Sensitivity tables give the cost for executing trades that are 0.5, 1, and 2 times the average daily volume (or average daily notional amount) and other values ranging from 0.5 to 2 are then interpolated.

116. For positions far exceeding 200% of the reference volume, extrapolation assumptions have a huge impact. To avoid unrealistic estimates for larger positions (in relation to the reference volume), it was decided to extrapolate flat the market impact in basis points beyond the last point provided by CCPs (i.e. 200% of the reference volume). In other words, the total market impact will scale linearly with the notional but not quicker. Positions smaller than 25% of the reference volume are not contributing to the concentration risk.

117. For credit and fixed income derivatives, note that this extrapolation was made for values beyond 500% of the reference volume (i.e. beyond the last point provided by CCPs for those asset classes), for the same reason of avoiding unrealistic huge impacts.

118. Fixed income derivatives and Credit derivatives follow a different methodology[17]. A hedging cost (as opposed to a liquidation cost) of the reported positions was computed using a limited number of hedging instruments.

Concentration PnL at account level

119. The final step consisted in using the proper market-wide sensitivity tables for each asset class to retrieve the market impact (in bps or % market value) of the positions to liquidate, as a function of the relative size computed in b).

120. ESMA staff first determined the size of each position (or its hedge) relative to the average daily volume (or such relevant parameter), and then its liquidation market impact using the baseline sensitivity tables.

121. Finally, the concentration PnL was allocated at account level as a function of the position size at account level and the market impact estimated. The concentration PnL computed at account level allows to include the concentration costs into the waterfall, as described in 3.4.3.3.

122. In case of multiple clearing member defaults (as part of one or more groups), the total position was used to get the total market impact, which was then apportioned to the different clearing members and their client / house accounts.

3.5.3 Known limitations of the Concentration Risk Analysis

3.5.3.1 Limited scope

123. The exercise does not model the whole default management procedure. More specifically, there is no attempt to factor in the impact of an auction which could lead to smaller or bigger

[17] The Fixed Income derivatives and Credit derivatives methodologies are described in more details in the Annex (section 6.2.2).

concentration costs. This impact could be significant for credit and fixed income derivatives that are modelled through their hedging portfolios.

124. Although most cleared asset classes are covered, markets like cross-currency basis swaps, longer term foreign exchange derivatives or less liquid foreign exchange pairs were not in scope. Contract for differences (CFDs) were also not included.

125. Therefore, concentration risk on these segments is not quantified and there may be an underestimation of the concentration risk for default funds that include such asset classes.

126. To reduce complexity, some calendar / curve risks within asset classes are not being considered when they are categorized within the same buckets. Likewise, for some asset classes, market practices could allow for more aggregation than considered in the framework.

127. The liquidation of collateral is not covered to avoid making the exercise overly complex. For instance, it would have been necessary to model the change in the order with which resources are used for each CCP and depending on which CM is in default.

3.5.3.2 Model and calibration risk

128. The model chosen may be insufficiently accurate and / or fail to consider properly specific features of some asset classes[18]. However, its results explain well some of the CCPs' own concentration risk models.

129. As the market impact estimates are provided by the CCPs, there is a risk to have a biased estimation of the real risks in stressed markets. For the same asset class, estimates submitted by different CCPs varied significantly. This already suggests a very different sensitivity toward concentration risk of different CCPs, which impacts the overall exercise. In some cases (freight or emissions), few CCPs contributed, and it was difficult to challenge the CCPs and get better estimates. As previously mentioned, emission allowance sensitivities were increased by ESMA staff to match the energy commodity ones.

130. Additionally, the concentration risk estimates are not adjusted for the impact of the any market risk scenario.

131. In section 4.3.4.2, the model risk for securities is assessed using an alternative model.

3.5.3.3 Market depth

132. For securities, the primary source for ADVs is the systematic internaliser data[19] computed and published by ESMA.

133. In most other cases, the market depth was computed using the CCP's own submitted reference volumes, as they reflect the markets the CCP can readily access and for which it has in place the operational arrangements to readily execute transactions.

134. The submitted reference and aggregated position volumes could be affected by errors in the data provided or assumptions used by CCPs. The two levels of validations (by NCAs and ESMA

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[18] For example, see Credit Derivatives methodology in annex.
[19] The "systematic internaliser calculations" data files can be downloaded from ESMA Website: https://www.esma.europa.eu/data-systematic-internaliser-calculations.

staff) aimed at limiting the risk of wrong computations by CCPs, but this risk cannot be completely eliminated with ex-post desk-based verifications.

3.6 Methodology – Operational risk analysis

3.6.1 Overview

135. The objective of the operational risk analysis is to assess the level of operational resilience of EU and Tier-2 CCPs. In this first exercise, specific focus will be put on third-party risk, with a hypothetical scenario of an outage of a critical third-party service provider.

136. Operational resilience has been defined by the Basel Committee on Banking Supervision (BCBS) in its "Principles for Operational Resilience"[20] as the ability of a regulated entity to deliver critical operations through a disruption. The use of this definition has also been applied in the IOSCO consultation report of "Operational resilience of trading venues and market intermediaries during the COVID-19 pandemic"[21].

137. The concept of operational resilience is closely related to the broader concept of operational risk as defined in the glossary (annex H) of the Principles for Financial Market Infrastructures (PFMI) as: "The risk that deficiencies in information systems or internal processes, human errors, management failures, or disruptions from external events will result in the reduction, deterioration, or breakdown of services provided by an FMI."

138. The operational risk analysis is comprised of three parts:

1. Assessment of the general level of operational resilience of individual CCPs

   – Using data of past events, ESMA staff developed metrics to evaluate and compare the past operational performance of individual CCPs' internal critical systems and critical supporting functions and derive insights on their level of operational resilience.

2. Assessment of risk exposures of individual CCPs to critical third-party providers

   – Using data of critical providers, risks related to each critical provider and available protective tools ESMA staff developed metrics to evaluate and compare the exposure of individual CCPs to third-party risk and their resilience to a hypothetical unavailability scenario.

3. Assessment of concentration or systemic risks in the network of critical third-party providers

   – Using data of critical providers, risks related to each critical provider and available protective tools ESMA staff analysed the interconnections between individual third-

[20] BCBS Principles for Operational Resilience (2021) (https://www.bis.org/bcbs/publ/d516.pdf)
[21] Operational resilience of trading venues and market intermediaries during the COVID-19 pandemic (https://www.iosco.org/library/pubdocs/pdf/IOSCOPD694.pdf)

party providers and multiple CCPs that could lead to correlated operational risk events across entities.

139. For the operational risk analysis, only 14 out of the 15 CCPs that could be in scope are included, due to the absence of historical data of operational risk events for 1 CCP.

3.6.2 Assessment of the general level of operational resilience of individual CCP

3.6.2.1 Overview

140. Measuring operational resilience involves understanding the universe of risks an entity can face and how well it would be able to avoid disruption or minimize downtime; both elements represent a challenge, as the universe of risks cannot be easily determined ex-ante and the ability of the CCP to withstanding these may or may not be known depending on whether there is data available to reach meaningful conclusions.

141. The starting point for the analysis of operational resilience was to look at past historical events to gather evidence. Although there is no defined way to measure operational resilience, it is known that the deterioration or disruption of the CCP's ability to perform its services would have an effect on the performance indicators of the service an FMI provides, which is something for which the discipline of reliability engineering has mathematical tools that can be used to measure reliability and availability of CCP's services.

142. From a user perspective, the CCP provides a specific service that is expected to be available and perform in an expected manner, during agreed business hours. A disruption is a lack of availability or a degradation in the quality of the service.

143. Linking operational resilience and availability, it can be affirmed that the level of operational resilience of an entity will determine the availability of the service in the face of adversity and threats to disruption. Firms with a high level of resilience against specific risks or scenarios will be able to maintain higher levels of availability of the service when confronted with these risks than firms with lower levels of resilience against those risks or scenarios.

144. Understanding this relationship, ESMA staff can start the analysis by observing the historical incidents of EU and Tier-2 CCPs and develop reliability and availability indicators, as they will provide information of the level of operational resilience of CCPs against the events they have experienced during the selected historical timeframe.

3.6.2.2 Reliability measurement

145. From a reliability engineering perspective, a service is considered as a repairable system. This means that the system may experience outages, leading to downtime, but it is repairable, and after some time (repair time) the service will be restored.

146. The mathematical modelling of repairable systems is performed with probabilistic models and statistical methods. The reliability (the ability of a system to operate for a specific period of time) of a repairable system is described by the following elements:

- A stochastic process (usually Poisson, Renewal…) that describes the frequency of outages across time.

- A probability distribution of the time to repair of individual outages (usually Weibull, Exponential…).

147. The occurrence of outages and their associated time to repair generates downtime of the service or systems in scope.

148. Availability metrics describe relationships between downtime, uptime and total time of operation:

- Availability: The fraction of time that the service is in operating condition in relation the total time where it is expected to be operational.

- Unavailability: The fraction of time that the service is in downtime in relation the total time where it is expected to be operational.

3.6.2.3 Reliability and availability metrics used in the report

149. For this analysis ESMA staff used two approaches:

1. Metrics based on average times and expected unavailability:

    - Mean time between failures (MTBF): The average time between service breakdowns.

    - Mean time to repair (MTTR): The average time taken to recover from a failure.

    - Expected 1 year unavailability: The expected downtime in a one-year period using MTBF and MTTR.

2. Estimation of percentile metrics:

    a. Model based estimation of percentile metrics of unavailability.

150. As part of the results, a description of the model's methodology, its parameters, assumptions and results are provided.

151. Both approaches are used together to analyze the risk characteristics of individual CCPs.

3.6.2.4 Information collected from operational incidents experienced by CCPs

152. In order to calculate the reliability and availability metrics, information of past incidents provided by CCPs is used. Incidents were measured at an internal CCP level by using:

- Data of incidents of that have affected the clearing service or could have affected it had it occurred at a different time (incidents and near misses).

- Incident time is measured between the start of the incident until remediation.

153. The measurement with an internal approach is different from the measurement at customer experience level. ESMA staff adopted an internal approach measurement in order to develop indicators that allow us to detect issues in a preventive manner.

154. The internal approach implies that incidents included in the measurement may or may not be responsibility of the CCP, as they can include outages of other FMIs that would have a knock-

on effect on the CCP and are out of its control. It also implies that the measured incident remediation time will be equal or higher than the incident time experienced by customers.

155. The instructions given to CCPs were to report events where any of the following conditions were to report:

All operational risk events whether generated by an internal or external cause during the past five years since the reference date for the operational risk analysis (the most recent date from the two dates specified in the credit component) are in scope. Events shall be reported when any of the below conditions are met:

1. A CCP's critical clearing services or supporting functions are affected during business hours, with any of the levels of impact defined in the "Types of impact" considered.

2. The CCP experienced a direct financial loss greater than 50,000 €.

3. A third-party provider is unavailable during business hours (even if it doesn't create an outage in the CCP, due to not being needed in that specific moment) for a period greater or equal to 30 minutes.

156. Incidents in parts of the clearing process that would have a role before a trade is accepted by the CCP creating the legal obligation for the CCP would not be in scope of the exercise. For example, the failure of a trading venue in sending trade information would be considered previous to the start of the obligations of the CCP and would not be reported in this exercise.

157. It must be noted that for this exercise we only consider two types of states for systems / third-party providers:

   a. Available: The system / third-party is operating normally

   b. Non-available: The system / third-party is suffering an outage that leads to a lack of availability or a degraded state

3.6.2.5 Dimensions of operational risk considered

158. When considering operational risk events in the context of operational resilience, one needs to use time as the quantitative variable (as opposed to monetary quantities, which are the quantitative variable used when assessing the financial consequences of operational events) and take into account different aspects:

$$Operational\ risk_i\ = f(\ Probability\ of\ \ ocurrence, Type\ of\ \ impact,\ Exposure\ to\ \ risk_i)$$

159. The $Probability\ of\ ocurrence$ describes the probability of events and the probability distribution of the time duration of events.

160. $Type\ of\ impact$ is qualitative in nature; buckets are used in order to be able to aggregate information using three different $Type\ of\ impact$ representing different levels of severity describing the consequences for the CCP:

<u>1.Clearing / settlement unavailable</u>

161. Description: Immediate critical impact to the ability of the CCP to perform the clearing function for clients in any clearing service, product, or currency. Evidenced by:

- Inability to accept / receive trades.

- Inability to make necessary computations to calculate payments / settlements (due to any element involved being unavailable, including infrastructure or data unavailability / inaccuracy).

- Inability to complete full process of payment or settlement to final client (due to any element that forms part of the chain).

- Non-availability of cash or securities that are needed to fulfil payment or settlement under normal conditions (no default assumed).

- Non-availability of risk management function leading to the inability of the CCP to perform the clearing or fulfilment of payments / settlements.

- Non-availability of liquidity provider that is needed to perform operational functions under normal conditions (no default assumed) leading to the CCP's inability to perform the clearing function.

- Non-availability of operational infrastructure leading to inability to perform the clearing function.

- Interoperability link disrupted.

2.Critical supporting function unavailable

162. Description: Impacts a critical supporting function of the CCP without direct disruption of the clearing function for the clients meanwhile it is remediated. Evidenced by:

- Non-availability of Business Continuity, disaster recovery or cybersecurity capabilities.

- Non-availability of risk management functions limiting the ability of the CCP to monitor / manage risk (but allowing the CCP to clear and fulfill payments / settlements).

- Non-availability of default management capabilities.

- Non-availability of capabilities, infrastructure or data for monitoring or supervision purposes.

3.Other Service Level Agreement breach

163. Description: Any other impact that would have a lower level of severity than the two above-described categories and that would be different from no impact.

164. Lastly, $Exposure\ to\ risk_i$ is defined as the percentage of clearing activity that was affected by the incident. For this analysis, we build a proxy of activity impacted by using the margin that can be linked to the activity disrupted, in the following manner:

$$\%\ of\ activity\ impacted\ by\ event_i = \frac{Margin\ linked\ to\ activity\ affected\ by\ event_i}{Total\ CCP\ margin}$$

3.6.3 Assessment of risk exposures of individual CCPs to critical third-party providers

3.6.3.1 Objective

165. The aim of this exercise is to quantify the level of third-party risk for each individual CCP and understand how the CCPs would be able to cope with a hypothetical scenario involving the outage of a critical third-party provider.

3.6.3.2 Overview

166. ESMA staff used concepts and methods from the disciplines of reliability engineering and operational risk management to describe the logic behind the approach for CCP third-party risk indicators and the methodology used for the hypothetical scenario. The purpose in this section is to provide an intuition of the logic behind this methodology, not to build a complete model for computing results, so where relevant ESMA staff will use mathematical methods that describe probabilities of a single outage to simplify things.

3.6.3.3 Third-party risk from an individual entity

167. From the perspective of a CCP, the third-party risk to which it is exposed is related to the number of third-party entities that provide critical services needed for the CCP to perform its functions, their reliability ('probability of failure' and 'severity of failure' probability distributions), the potential impact on the CCP's processes from the non-performance of any of these entities ('type of impact'), the exposure of the CCP to each third-party entity ('exposure') and the operational risk management tools the CCP has in place to reduce risk ('tools').

168. The risk to the CCP from each individual third-party entity without taking into account any risk management tools can be linked to the following factors:

$$Third - party\ risk_{\ Entity\ (i)} = f(\ Reliability, Type\ of\ impact,\ Exposure\ to\ \ entity_i)$$

169. For the $Type\ of\ impact$ dimension, ESMA staff applied the same approach as in the section on measuring operational resilience at CCP level. ESMA staff separated the analysis for the two relevant categories of "Type of Impact" (Clearing / settlement unavailable and Critical supporting function unavailable) due to their different qualitative nature.

170. For the $Exposure\ to\ \ entity_i$ dimension, exposures to individual entities received a weight by adjusting for the percentage of CCP's clearing activity serviced by $entity_i$.

171. With respect to the $Reliability$ of individual entities, quantitative estimations were not produced due to the current limitations of available data; rather exposures were identified by the type of entity, using three broad categories linked to their regulatory status.

- FMI group: Financial Market Infrastructures, payment systems, settlement systems, central banks.
- Other financial: Regulated financial institutions excluding those in the first group (credit institutions, insurance undertakings or investment firms …).
- Non-financial: Entities outside of the financial regulatory perimeter (technology providers, data providers…).

3.6.3.4 Third-party risk from the aggregated exposure to the network of critical third-party providers

172. The starting point is the exposure towards a single entity, for which ESMA staff has identified the main factors of interest and described the approach in the previous section:

$$Third - party\ risk_{\ Entity\ (i)} = f(\ Reliability, Type\ of\ impact,\ Exposure\ to\ \ entity_i)$$

173. From a mathematical perspective, reliability is defined as the probability of non-failure across time. For one failure, the reliability of a simple component with respect to time ($R(t)$) is described as:

$$R(t) = 1 - \mathrm{F(t)}$$

174. with $\mathrm{F(t)}$ being the probability function of failure sometime up to time t.

175. Critical third-party service providers are entities that are all needed at different points of the operational process of a CCP in order for it to deliver its clearing services; in this sense if any of the critical providers has an outage, then the CCP would experience an outage with a specific $Type\ of\ impact$ for a percentage of its activity linked to the $Exposure\ to\ \ entity_i$ of the third-party provider experiencing the outage.

176. A system composed by a set of components that are all needed in order for the system to work can be described as a series system, and the reliability of a series system is described as:

$$R_s(t) = \ R_1(t)\ \times\ R_2(t)\ \ldots \times\ R_n(t) = \prod_{i=1}^{N} R_i(t)$$

177. In other words, the reliability of the CCP can be expressed as the product of the reliability of each of the component of the system: if one component suffers an outage, the entire system suffers an outage.

178. From the observation of this simple reliability model, one can come up with some initial observations:

- The probability of non-failure decreases as the number of components increases (assuming the components have a non-zero probability of experiencing outages), so third-party risk of an entity is an increasing function of the number of individual critical third-party providers. The longer and more complex the system, the higher the probability of a system outage for a given level of reliability of individual components.

- Third-party risk depends on the level of reliability of its individual components.

179. Taking into account these observations, ESMA staff set as general objective for CCP risk indicators to quantify the number of entities to which individual CCPs have exposure and the level of expected reliability of these entities.

3.6.3.5 The effect of operational risk management tools

180. From an operational risk management perspective, CCPs can act proactively to enhance their resilience with respect to failures from critical third-party providers by using preventive tools or mitigation/protective tools.

181. For the area of third-party risk, ESMA staff considered as preventive tools any Policies, Procedures or Controls that can reduce the probability of failure of individual third-party entities or that could help reduce the detection time contributing to a lower recovery time. The main tools in the area of third-party risk are the selection of highly reliable critical third-party service providers and the enforcement/monitoring of high operational standards in the selected third-party entities.

182. These tools affect the individual reliability of the components in the CCP's system of critical third-party providers. When a CCP chooses high quality providers, then the reliability of the individual components will be high leading to a reduced overall third-party risk.

183. The problem with respect to the quantification of the effect of preventive tools is that one can't easily measure their effect, as one doesn't know what the situation would be should the prevention tools be different or non-existent (one can only measure the reliability of an existing provider). Information about the quality of the third-party providers can be extracted using the analysis of historical information of events with the methodology of section 1 'Assessment of the general level of operational resilience of individual CCPs'.

184. With respect to <u>mitigation tools</u>, they are categorized into two groups:

- Building resilience by setting up a redundant external third-party provider that acts as a backup, e.g., receive critical data from two providers, have contractual arrangements with more than one financial entity for a specific critical service, have a redundant data centre, and duplicated telecommunications lines.

- Building resilience by developing a specific internal tool that can act as a substitute of the critical third-party service provider, e.g., being able to build data in house in case of emergency, having alternative communication means, a UPS system for electricity outages, and relevant and effective legal provisions.

185. The effect of mitigation tools can be directly measured as each of the elements is observable. Their effect is that building resilience through mitigation tools reduces the probability of failure of each specific component in the system of third-party dependencies. Each component in our series system model can be considered a unique service for which the CCP can have one or more providers operationally set-up; increasing the number of alternative providers (or internal tools) increases the reliability of an individual component ($R_n(t)$ in the model) due to the fact that a simultaneous failure of all redundant options is needed in order to produce an outage in the component and subsequently affect the reliability of the system.

186. Mitigation tools have been the focus of the analysis, as they are the most relevant for the hypothetical scenario of outage affecting a critical third-party provider. Once an outage is assumed, prevention tools cannot protect a CCP from the consequences, but mitigation tools can protect from one (or multiple) outages.

3.6.3.6 Modelling the behaviour of the risk management tools

187. CCPs were asked to report the impact from a hypothetical outage affecting each critical third-party provider without taking into account any mitigation risk management tools and also the residual impact after taking into account mitigation tools.

188. For the reporting of the residual impact, CCPs were allowed to report the impact after taking into account mitigation tools:

- There was not residual impact,
- The $Type\ of\ impact$ would change, and/or
- The $Exposure\ to\ entity_i$ would be reduced.

189. Critical third-party providers that perform similar functions and act as redundant options of each other were linked together, so that they are not considered independent entities where the failure of any of them leads to an impact to the CCP but rather groups of providers where all of them need to fail in order to cause an impact to the CCP (they are all considered as one exposure with multiple providers).

3.6.3.7 Hypothetical scenario

190. In the hypothetical scenario it was assumed that any critical third-party provider could suffer an outage independently of its level of perceived resilience, and that individual outages for each third-party provider were independent (the fact that third party ABC has an outage has no impact on the probability of third-party DEF suffering an outage at the same time). It was also assumed that all reported tools work as intended. The scenario simulated one single outage (so redundancy configurations of two providers are sufficient to absorb the shock).

191. The outcome of the scenario was the identification of the critical third-party providers to which the CCP would be exposed in case of this scenario materializing: they represent single points of failure tied to specific consequences ($Type\ of\ impact$).

192. For the risk indicators, the exposure to each third-party entity was weighed taking into account the percentage activity of the CCP they service. This weighted exposure metric was calculated as:

$$Weighted\ exposure_{third-party\ entity(i)} = 1 * (\%\ of\ activity\ serviced\ by\ third - party\ entity_i)$$

193. With $\%\ of\ activity\ serviced\ by\ third - party\ entity$ measured using relative margin quantities linked to the clearing activity that is serviced by the third-party entity:

$$\%\ of\ activity\ serviced\ by\ third - party\ entity_i = \frac{Margin\ linked\ to\ activity\ serviced\ by\ third - party\ entity_i}{Total\ CCP\ margin}$$

3.6.4 Assessment of concentration or systemic risks in the network of critical third-party providers

3.6.4.1 Overview

194. This section provides insights into the topology of the network of CCPs' third-party providers and performs a risk assessment of potential systemic implications from entities interconnected to more than one CCP.

195. This analysis is divided into three sections:

- Overview of the network: overall topology of the network and analysis of most interconnected entities.
- Analysis for specific types of services: analysis of interconnectedness segmented by types of services.
- Evidence of events affecting multiple CCPs: analysis of past events that have affected multiple CCPs.

3.6.4.2 Measuring interconnectedness per third party provider

196. Interconnectedness was measured by the number of CCPs connected to a third-party provider as a share of the total number of CCPs in the stress test for which there is incident data available (number of connected CCPs / Total number of CCPs (14)).

3.6.4.3 Assessing the risk of each interconnection

197. The risk of the interconnections was characterized using the information derived from the results of the hypothetical scenario (described in section 3.6.3.4). Different colours were used to represent the different levels of impact severity that the CCP would have experienced in case of an outage of a critical third-party provider (the categories are described in section 3.6.2.5). The colours follow a "traffic light" approach as described below:

- Risk level 0 (Grey colour): The CCP has a preventive/protective tool in place to prevent any risk in case of an outage of the third-party.
- Risk level 1 (Green colour): In case of an outage of the third-party, the CCP would experience an impact leading to a deterioration of its ability to achieve a specific Service Level Agreement (Type of impact: Other Service Level Agreement breach).
- Risk level 2 (Orange colour): In case of an outage of the third-party, the CCP would experience an impact of type: critical supporting function non available.
- Risk level 3 (Red colour): In case of an outage of the third-party, the CCP would experience an impact of type: clearing or settlement function non available.

198. The analysis used this information both in the graph charts and in the network charts. The interconnectedness indicators have been constructed such that:

- The percentage of interconnectedness is (number of connected CCPs / Total number of CCPs (14)).

- The size of each colour part of the interconnectedness bar is (number of connected CCPs to Risk level X / Total number of CCPs (14)).

3.6.4.4 Assessing the risk of each node

199. The risk characteristics of entities have not been calculated, three broad categories linked to their regulatory status were used.

- FMI group (Purple colour node): Financial market infrastructures, payment systems, settlement systems, central banks.

- Other financial (Blue colour node): Regulated financial institutions excluding those in the first group (such as credit institutions, insurance undertakings or investment firms).

- Non-financial (Black colour): Entities outside of the financial regulatory perimeter (such as providers of cloud, data or electricity).

200. In case of the hypothetical groups, all nodes are in grey colour as the groups encompass more categories than one.

3.6.4.5 Scope of operational outages and hypothetical groups of critical third-party providers

201. Operational outages can affect the whole entity (LEI level), part of the activity of the entity, or groups of third-party entities in the hypothetical cases of events involving interconnections between entities (leading to propagation of operational risks) or common points of failure (such as reliance on common systems or third-party providers).

202. The analysis focused on interconnections at LEI level, for which the results have been calculated. Additional results involving hypothetical scenarios of groups of entities are provided.

203. The hypothetical scenarios involving groups of entities have a connecting relationship as to test aggravated hypothetical scenarios of correlated outages within the whole group. These relationships are based on legal relationships between entities belonging to the same group, relationships found through their website, or possible reliance on shared infrastructure. These relationships are built using publicly available information and expert knowledge without detailed information on the operational aspects of the relevant entities. As such, they should be considered as hypothetical scenarios for analytical purposes without being necessarily plausible.

4 Results

4.1 Analysis and Breakdown of Resources

4.1.1 Overview, objective of this analysis and limitations

204. The CCPs included in the scope of the exercise reported data on the required and available financial resources used to run the credit stress test. The analysis of reported resources as presented in this section is used to set the scene for the core credit stress test, provide an

overview of the size of the industry, the breakdown of activity by individual CCPs or participants and identify significant changes or potential trends in the activity or risk management practices.

205. Although one can identify different practices and risk management techniques being implemented by different CCPs, the purpose of presenting this data is not to benchmark individual CCPs. Different CCPs clear different products with distinct characteristics. The size of resources alone cannot indicate the effectiveness of the CCP's risk mitigation arrangements. The resilience of CCPs to adverse market developments is assessed using the core stress results.

206. The data on financial resources was available for the two reference dates of the credit stress test exercise, i.e. 19th March and 21st April 2021. It should be noted that some of the financial resources available to CCPs, such as margin amounts, may vary significantly between different periods depending on the activity and volatility of underlying markets. Therefore, the analysis cannot be used to draw conclusions on the size and breakdown of resources held at other times.

207. Finally, the presented data is not always directly comparable with similar data reported in the context of previous stress tests because the underlying data has changed, and definitions have in many cases evolved to accommodate the scope of the present exercise. For example, the presented amounts now correspond to pre-stress values (as opposed to post-stress values reported in the previous exercise) and also include interoperability margin that is forwarded to the linked CCPs. Finally, the stress test exercise includes in its scope one CCP less (LME) compared to the previous exercise.

4.1.2 Default Waterfall

208. The amount of resources comprising the default waterfall of CCPs has overall increased compared to the previous stress exercises. The total amount (and % share) allocated to each tranche of the default waterfall across all CCPs in scope of this exercise and for each of the two reference dates can be seen in Figure 6.

209. The CCPs reported in total approximately 423bn EUR of required margin, default fund contributions and other committed prefunded resources for March and 409bn EUR for April. The required margin alone corresponded to more than 90% of these resources and the total amount was slightly higher in March (392bn EUR) compared to April (377bn EUR). Keeping in mind the limitations of comparing amounts reported for different stress test exercises, it can still be noted that the required margin has significantly increased since the previous exercise. In particular, the required margin amount has increased by close to 26%[22] over the two-year period from March 2019 to March 2021.

210. Moreover, the amount of mutualised resources contributed by clearing members to the Default Funds of all CCPs was 30.5bn EUR in March and 31.7bn EUR in April. The total amount of default fund contributions has also increased, but less so compared to margins, if compared to what was calculated in the previous stress test (+9% for March). Finally, the amounts of dedicated own resources (skin-in-the-game of 0.6bn EUR) and other committed prefunded resources (approximately 0.1bn EUR) have not materially changed since the previous exercise.

[22] This comparison corresponds to the margins of the CCPs included in the scope of the present exercise, i.e. ESMA staff has accounted for the fact that the present exercise includes one less CCP in its scope.

211. The data collected for the purpose of this exercise does not allow to identify the exact reasons behind the apparent increase of total resources. However, it can be reasonably assumed that the volatility experienced during the covid-19 crisis has played a role in this direction and which may be further accentuated by an overall increase of the clearing activity.

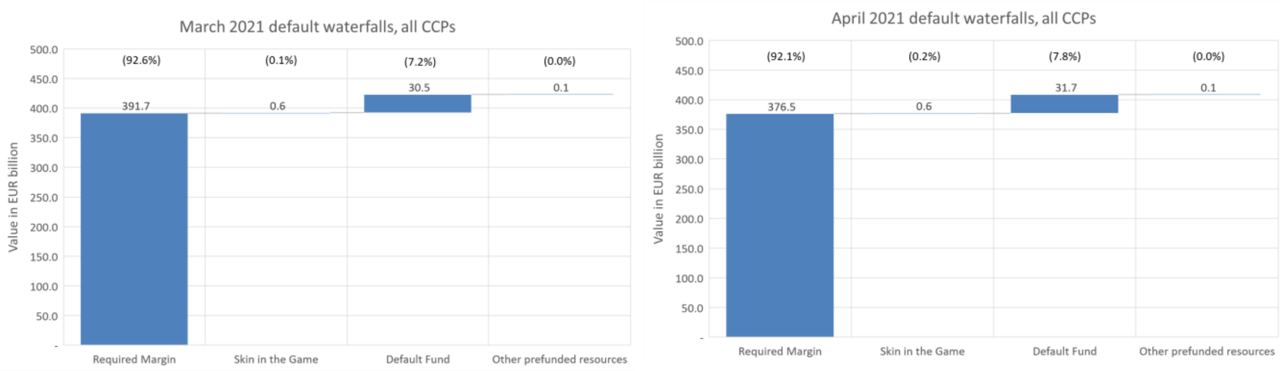
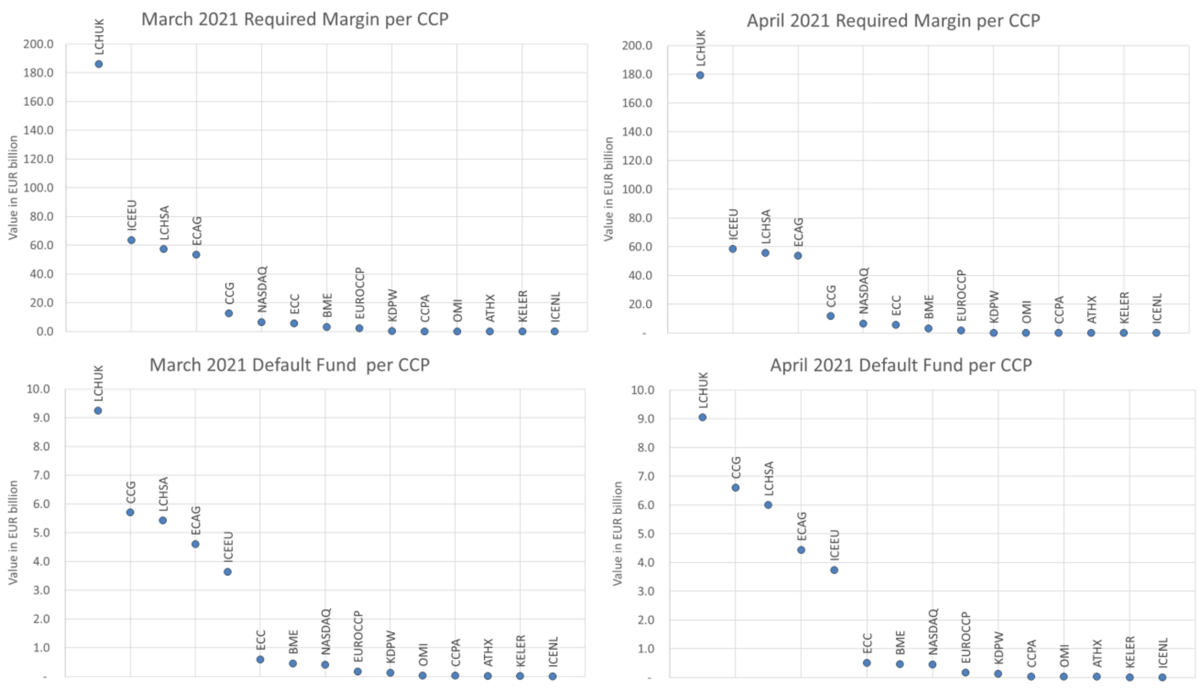


FIGURE 6: DEFAULT WATERFALL – ALL CCPS

212. ESMA staff has not identified any significant change in the relative allocation of prefunded resources between the different tranches of the default waterfall, i.e. margin, skin-in-the-game and mutualized resources.

213. The sizes of the two main tranches of the default waterfall (margin and default fund) are presented below for each CCP. As also noticed in the previous exercises, the top CCPs are significantly larger compared to the remaining CCPs and especially the top CCP (LCHUK) accounted for approximately 48% of the total required margin and for 30% of the total default fund collateral.



214. Finally, the data shows that the allocation of resources between margin and default fund contributions is not always proportional across different CCPs. This is also shown in the figure below (Figure 8) illustrating (in logarithmic scale) for each CCP the required margin against the default fund size.

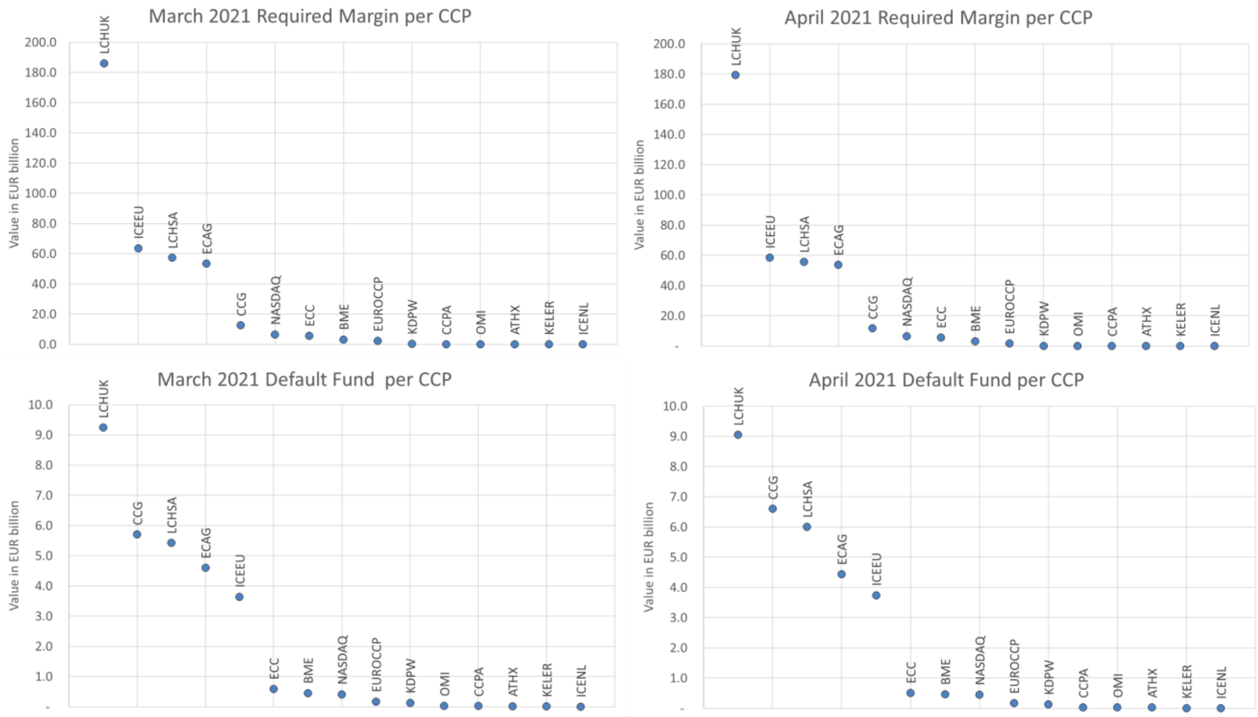


FIGURE 7: REQUIRED MARGIN AND DEFAULT FUND – PER CCP

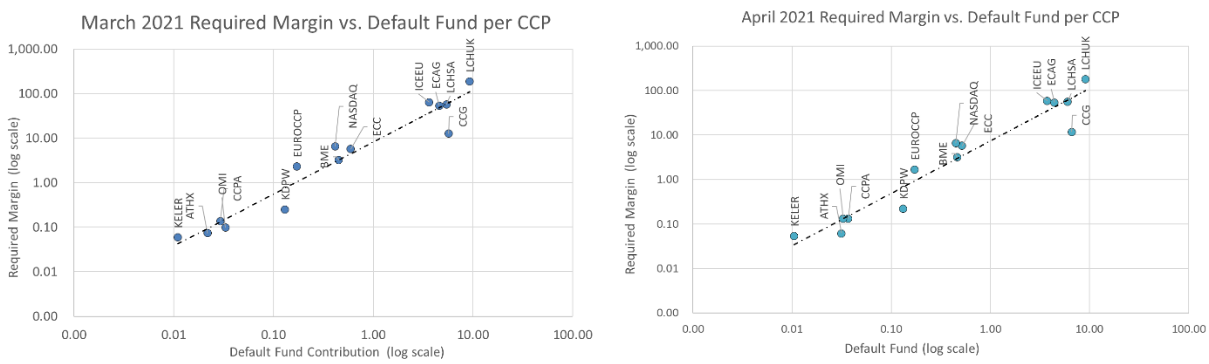


FIGURE 8: REQUIRED MARGIN VS DEFAULT FUND – ALL CCPS

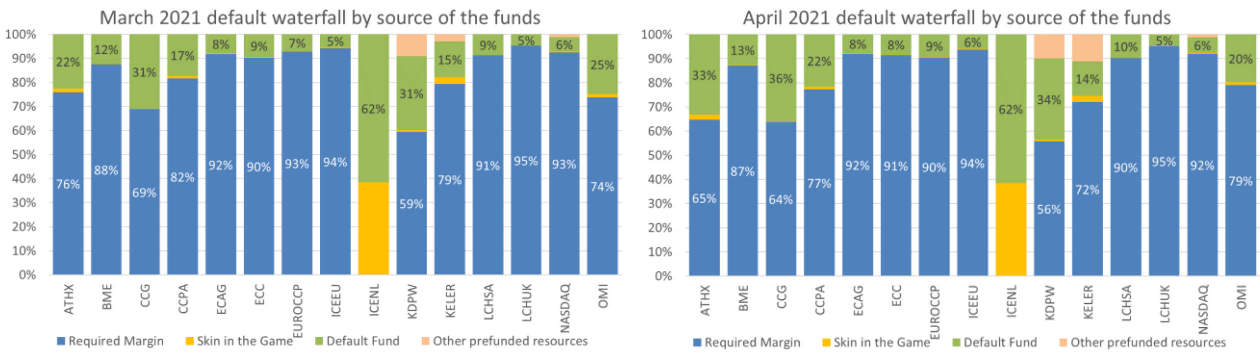
215. The composition of the default waterfall of individual CCPs is illustrated in Figure 9[23]. Different CCPs would rely more on margins or mutualised resources. As explained above, this alone cannot be used to draw any conclusions on the resilience of a CCP as it can be the result of a conservative calibration of any of the two tranches. If compared to the previous exercise, there

[23] One CCP (ICENL), reported zero margin requirements and zero exposures.

is no significant structural change. It seems that, overall and with only a few exceptions, the CCPs that were relying to a larger extent on mutualized resources, continue to do so.

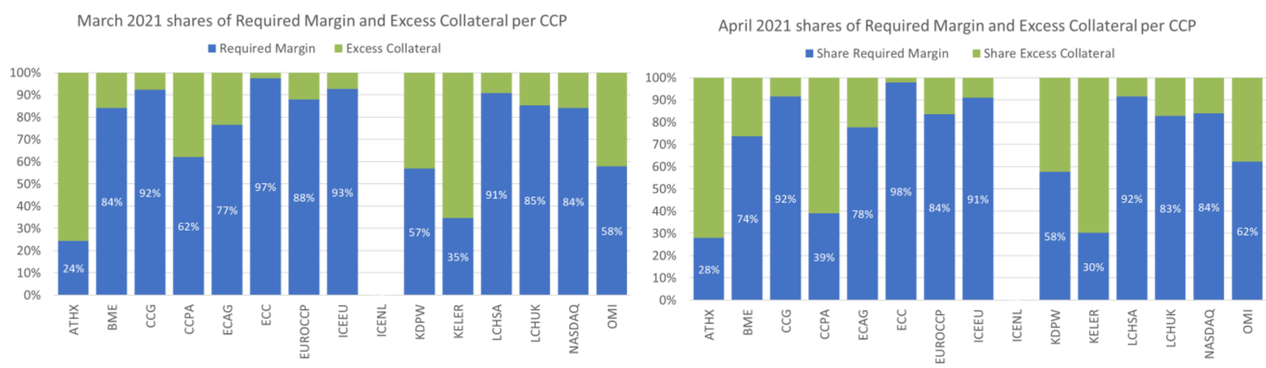
216. Overall, it is again confirmed that smaller CCPs tend to have a larger share of their coverage stemming from mutualized resources. This could be partly explained by the fact that since all CCPs have to meet as a minimum and independently of their size a cover-2 requirement, the risk-sharing (mutualised) part is expected to generally be smaller for CCPs that have a larger number of clearing members and smoother allocation of exposures across their top participants. Of course, other factors that are linked to the cleared products also play a significant role such as the comparison of the severity of adverse (to be covered by margins with a minimum of 99%/99.5% confidence level) versus stress market conditions (such as most extreme historical moves to be covered by mutualised resources).

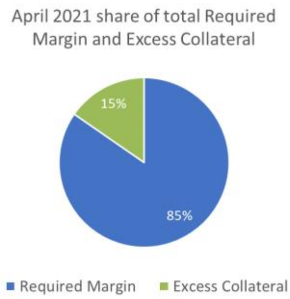
FIGURE 9: DEFAULT WATERFALL – PER CCP



217. In the context of the credit stress test, the assessment of the resilience of the CCPs will be based on the required margin collateral, as it can be assumed that a member in distress would not have posted any excess collateral, while excess margin of non-defaulting members can anyway not be used to cover losses. Nevertheless, for completeness the CCPs were asked to also report the (post-haircut) amount of collateral that was actually provided in order to give an indication of the actually available margin collateral on a particular date even where this is in excess of the minimum margin requirement. Figure 10 illustrates the required margin amount in comparison to the actually provided (post-haircut) collateral value, i.e. including excess margin amount.

FIGURE 10: REQUIRED VS EXCESS MARGIN





218. Overall, the excess margin collateral corresponds to a relatively small percentage (14%-15%) of the total provided margin collateral. If compared to the previous exercise, the share of excess collateral has not changed significantly (was 16%). Also, on a per CCP basis, overall, the CCPs that were collecting a large amount of excess collateral continue to do so with only a few exceptions. Although not always the case, it can again be noted that it is mostly the smaller CCPs and especially the ones that clear cash equities that have an exceptionally large share of excess collateral. This can be attributed to the fact that exposures can change significantly from one day to the other. Members prefer to over-collateralize their exposures, in order to avoid having to provide additional collateral on an intraday basis.

4.1.3 Clearing Members

219. ESMA staff has also analysed the distribution of required margins and default fund contributions across the clearing participants providing them in order to investigate if the increased financial resources were contributed by only a few top members, or if there was a general increase of provided resources by all participants. The analysis presented below indicates that while all clearing members have in general provided more financial resources, the top participants have done more so and have increased their relative share.

220. In this exercise ESMA staff identified approximately 750 clearing members (single entities) being a member in at least one CCP, which is smaller than the number of entities identified in the previous exercise[24]. However, there is no strong evidence of this being a general trend as for 6 out of the 15 CCPs the number of clearing members actually increased.

221. Of course, many of the reported entities are at the same time members at multiple CCPs. For example, 6 entities are at the same time clearing members at 10 CCPs or more. The number of clearing members and cumulative share (percentage), in terms of their aggregate contribution to the Default Fund of all CCPs and in terms of the aggregate margin required again from all CCPs (Figure 11) are presented below. For comparison, one can see in light grey the relevant share of resources under the previous (3rd) stress test exercise and in yellow the corresponding share under the 2nd stress test exercise[25].

222. First, it is observed that more members have very high margin requirements. In particular, the number of clearing members having each a total margin requirement (across all CCPs) greater than 10bn EUR has increased further, i.e. 7 members in this exercise compared to 5 in the 3rd exercise and none in the 2nd exercise. Similarly, more members have now a required margin amount greater than 5bn EUR[26] and these account in total for 57% of the margin provided to all

[24] Approximately 800 single entities were identified in the previous exercise. Please note that this includes members from one additional CCP (LME). After the removing the entities that were only members at this CCP, the total number of entities was close to 790.

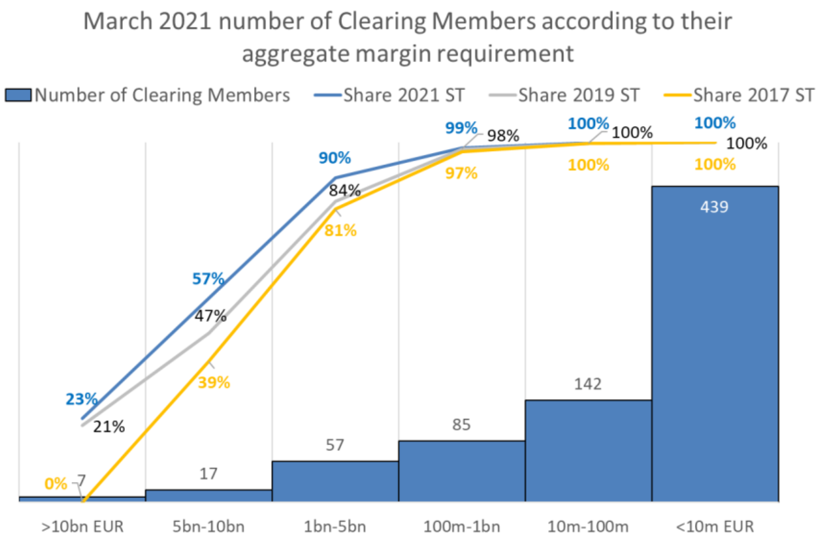
[25] It is noted that the shares reported here stemming from different exercises are not 100% comparable, including because the 2nd and 3rd exercises reference one additional CCP.

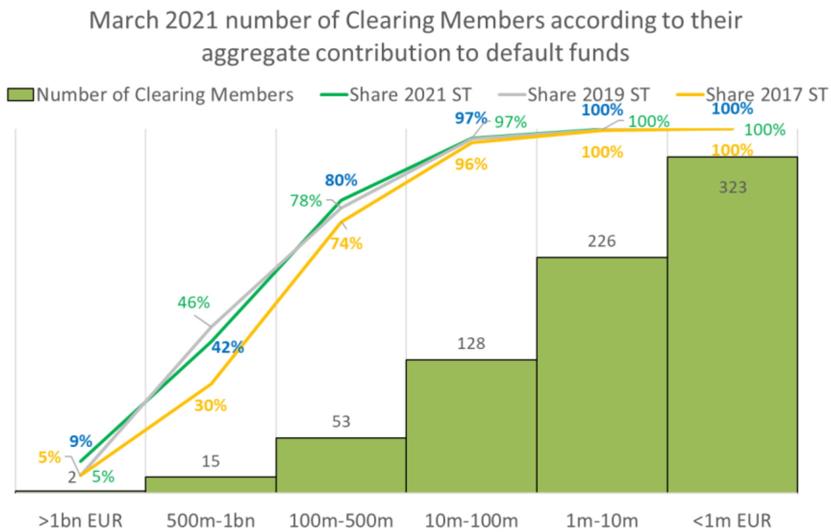
[26] 24 in the present exercise compared to 16 in the 3rd exercise and 14 in the 2nd.

CCPs compared to 47% in the previous exercise and 39% in the 2nd exercise. This observed increase could be driven by the general increase of required resources, i.e. members in general required to provide more resources due to the overall increase of CCP margin, as the comparison is done across constant buckets. However, this trend is further analysed below and it seems that while the general increase of resources has pushed the top participants to higher levels, at the same time, these participants have also increased their relative share. The clearing member (single entity) with the highest required margin amount across all CCPs had a total margin requirement of approximately 18bn EUR.

223. At the same time, no significant change is observed to the distribution of default fund contributions. Focusing on the highest contributors, e.g. members with an aggregate contribution across CCPs of more than 500m EUR, it can be seen that the number of members and their share have not changed significantly compared to the previous exercise[27].

FIGURE 11: CLEARING MEMBERS – ALL CCPS





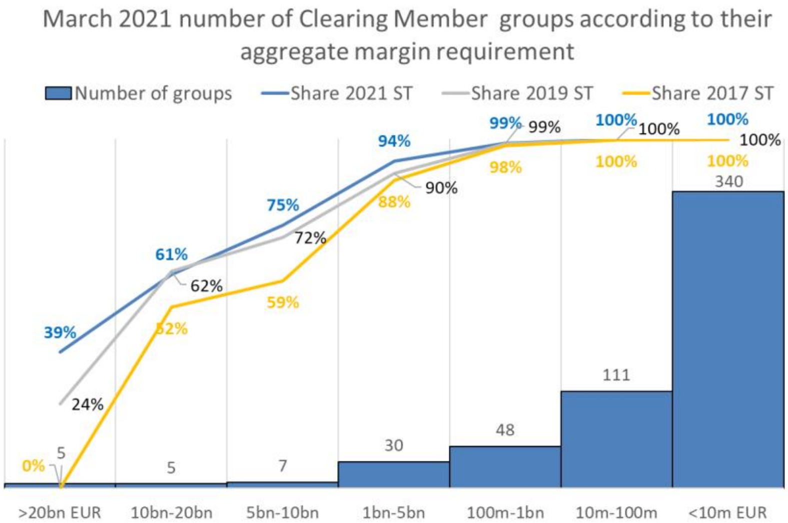
[27] 17 members with a contribution of 500m EUR or more in both exercises (2021 and 2019) accounting for 42% of the default funds in 2021 and 46% in the previous exercise.

224. This analysis was also run at the group level, after adding the resources provided by all affiliates within a single corporate group. As expected, the level of concentration increases further (Figure 12), while the amounts calculated for the top groups confirm the conclusions drawn above.

225. The top Clearing Member Groups have contributed more resources, both in absolute and in relative terms. In particular, 5 clearing member groups have each provided more than 20bn EUR in required margin across all CCPs, compared to 3 groups in 2019 (3rd exercise) and none in 2017 (2nd exercise). These groups account now for approximately 39% of total margin requirement, compared to 24% in the precious exercise. At the same time, there is no significant change in the number of groups than have a required margin that is higher than 10bn EUR[28]. Hence, it seems that the members belonging to the top groups increased their share of margin compared to the remaining members, thus meaning that clearing activity becomes more concentrated between main players. This is confirmed in Figure 13 where it is shown that the top-5 groups provided 39% of the total required margin in 2021 vs 36% in 2019 (3rd exercise). The group with the maximum margin requirement across CCPs had a total margin requirement of approximately 36 billion EUR.

226. Furthermore, no significant change was observed in the distribution of default fund contributions, similarly to what was observed at single entity level. The group with the largest aggregate contribution to default funds had a total default fund contribution across CCPs of 2.5 billion EUR.

FIGURE 12: CLEARING MEMBER GROUPS – ALL CCPS



[28] 10 groups (61% of margin) in 2021 compared to 11 groups (62% of margin) in 2019.

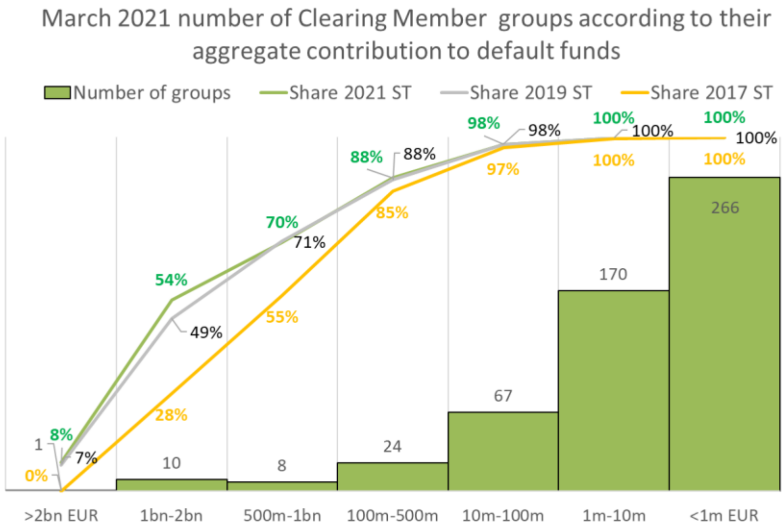
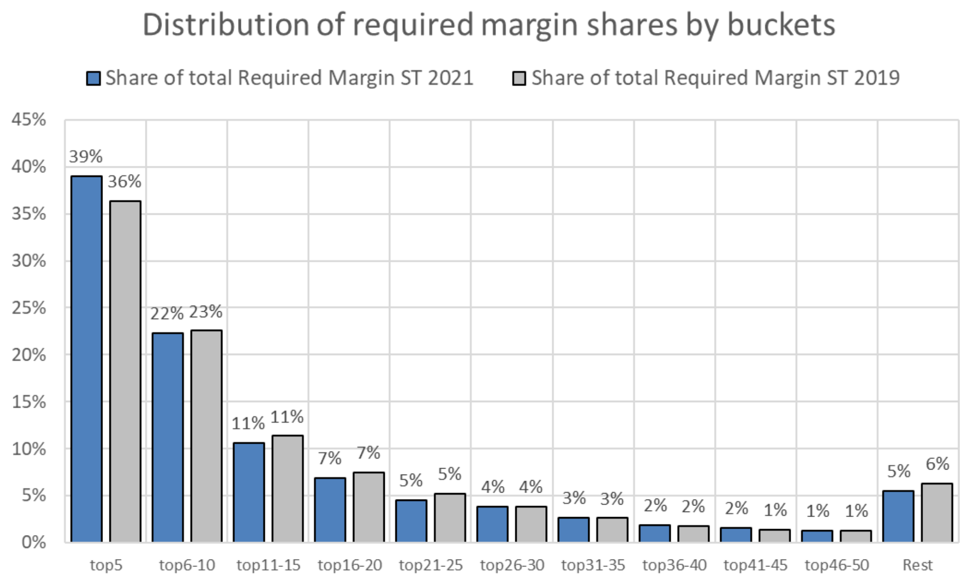


FIGURE 13:
CLEARING MEMBER GROUPS - DISTRIBUTION OF REQUIRED MARGIN SHARES



4.2 Credit Stress Test Results

227. This section presents the full range of credit stress test results assessing the sufficiency of CCPs' resources to absorb losses under a combination of market shocks and member default scenarios. From a credit risk perspective, a combination of clearing member defaults and simultaneous severe shifts of risk factor prices, including those due to high concentration or specific wrong-way risk, is needed to put a CCP at risk. If clearing members continue to post margin and meet their obligations, periods of extreme market volatility in isolation will not pose a specific market risk to a CCP. Similarly, defaults of clearing members without simultaneous adverse price shocks should not put a CCP at risk[29]. Under normal market conditions, the CCPs will have the resources to withstand multiple defaults. Hence, from a credit risk perspective and with the exception of investment risks, only simultaneous defaults and extreme, adverse shifts of market prices could pose potential risks to a CCP.

228. First, "cover-2 per CCP" results are presented (4.2.1) where two clearing member groups are assumed to be in default separately at each CCP and then "All CCPs cover-2" results are discussed (4.2.2), where the default of two groups across all CCPs is assumed, i.e. the same two groups for all CCPs. All these results are separately presented for the two dates that are covered in this exercise[30]. The methodology used in the credit stress test, including the design and assumptions of the market and member default scenarios, is detailed in Section 3.4. Where needed to provide additional insight, results are discussed using alternative defaulters' selection conditions and also the estimated impact from increased shocks is explored in the form of a sensitivity analysis.

229. One of the innovations of this stress test exercise is that for one of the dates ESMA staff has included in the calculations the impact due to concentration and specific wrong-way risk stemming from cleared positions. In order to be able to include those additional potential costs, results have been recalculated starting from the data reported at individual account-level and P&L calculations have been propagated through the account structure and default waterfall of each CCP. So, for the March date and the baseline market shocks results are also reported after adding the concentration and wrong-way risk impact.

4.2.1 Cover-2 per CCP Credit Stress Test Results

230. The "Cover-2 groups per CCP" member default scenario is designed to independently assess the resilience of each CCP to the Market Stress Scenario, focusing on the worst outcome for each CCP.

231. In accordance with the methodology, ESMA staff selects for each CCP individually two (2) corporate groups and assume that all the clearing members belonging to those 2 groups would default in the same CCP. The selected clearing member groups and defaulting entities will be different for each CCP and are not considered to be in default in other CCPs. The results for each CCP come from an independent selection of defaulting groups that don't propagate to other CCPs, therefore the interpretation should be limited to the assessment of the resilience of individual CCPs under a common market stress scenario.

[29] Clearing members post margins and default fund contributions scaled to a very high confidence level. This should make sure that CCPs have sufficient resources to manage a default of a clearing member in normal market conditions, and close out the resulting open positions in a stable market before suffering a loss.
[30] 19 March and 21 April 2021.

BOX 3: DESCRIPTION OF THE CREDIT STRESS TEST CHART

The credit stress test results are always presented in the form of a panel, showing for each CCP the following (from bottom to top):

Amounts of default waterfall consumption (in mil. EUR)

Loss covered with DF, SITG and other DF-level Resources: Amount of stress loss (in million EUR) covered with the Default Fund (including defaulting and non-defaulting members' contributions), dedicated CCP resources ("skin-in-the-game") and other prefunded and committed Default-Fund-level Resources that the CCP may have. Where the CCP has more than one Default Fund, this amount is the sum of amounts calculated per Default Fund. It is illustrated in green in the chart.

Loss covered with other CCP-level Resources: Amount of stress loss (in million EUR) covered with other prefunded and committed CCP-level resources, where applicable. The CCP-level resources are resources that can be used across default funds where the CCP has more than one default funds. It is illustrated in yellow in the chart.

Loss covered with PoA: Amount of stress loss (in million EUR) that would need to be covered with non-prefunded resources (powers of assessment). Where the CCP has more than one Default Fund, this amount is the sum of amounts calculated per Default Fund. Only the non-defaulting members are assumed to provide additional non-prefunded resources. It is illustrated in red in the chart.

Loss after PoA: Amount of stress loss (in million EUR) left uncovered after using prefunded and non-prefunded resources. This amount is again the sum of all uncovered amounts where the CCP has more than one Default Funds. It is illustrated in black in the chart.

% Consumption of Resources

% Consumption of the Default Fund (including the defaulters' contributions), the skin-in-the-game and other prefunded and committed Default-Fund-level Resources that the CCP may have. For CCPs that have more than one default funds, the maximum % consumption is presented.

% Consumption of Powers of Assessments (called only from non-defaulting members). For CCPs that have more than one default funds, the maximum % consumption is presented

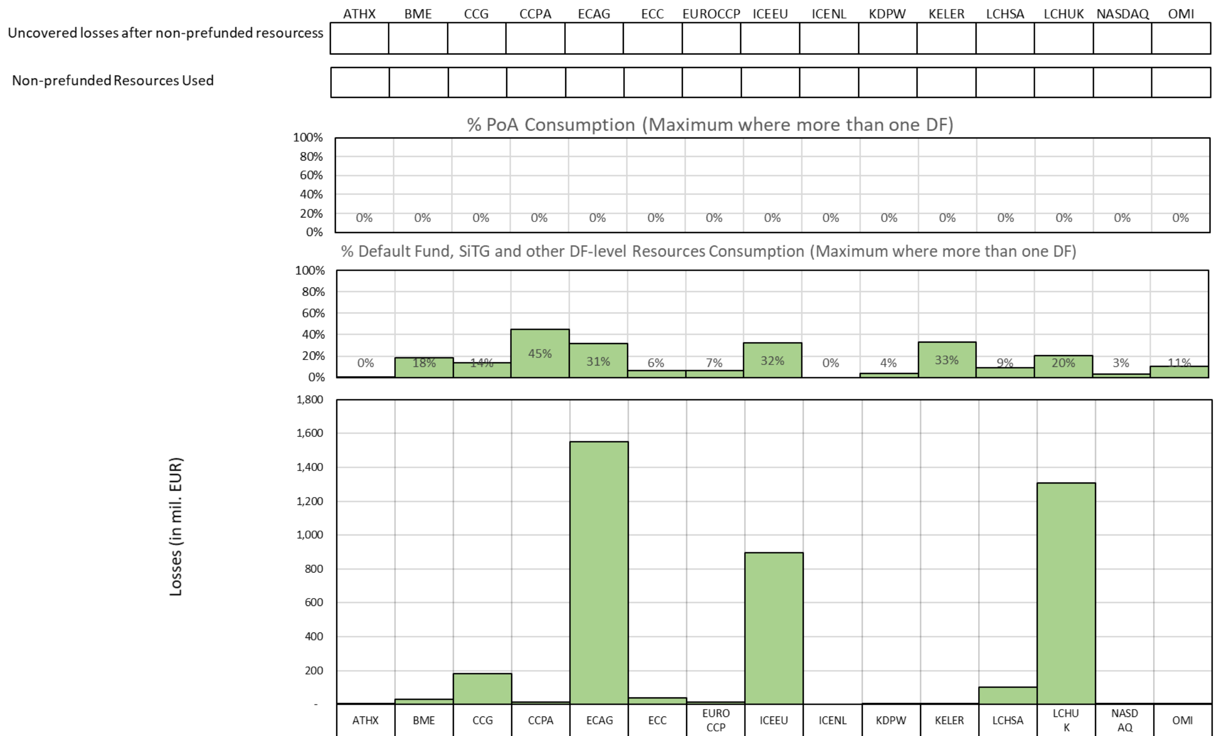
Two flags

A flag indicating (in red) whether non-prefunded resources would have to be used.

A flag (top of the panel) indicating (in black) whether there would be uncovered losses after using also non-prefunded resources.

4.2.1.1 Cover-2 per CCP Results for March 2021

Cover-2 Groups per CCP (no cross defaulting)
Date: March 2021 – Without Excess Margin



	ATHX	BME	CCG	CCPA	ECAG	ECC	EURO CCP	ICEEU	ICENL	KDPW	KELER	LCHSA	LCHUK	NASDAQ	OMI
Stress Loss after PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with other CCP-level Resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss above Margin covered with DF, SITG and other DF-level Resources	0	31	180	14	1,549	38	12	895	-	2	2	102	1,309	6	4

Figure 14: Cover-2 Groups per CCP – Date: March 2021 – Without Excess Margin

232. The core credit stress test results for March do not indicate a shortfall of prefunded resources for any of the CCPs in scope of the exercise. The maximum stress loss above margin is approximately 1.5bn EUR (ECAG) and the maximum % consumption of financial Default Fund-level resources available to cover losses beyond margin was 45% (CCPA). In terms of losses in monetary (EUR) amounts, the largest losses are naturally calculated at the bigger CCPs with the three largest amounts found at ECAG with 1,549 million EUR, LCHUK with 1,309 million EUR and ICEEU with 895 million EUR. Yet all three CCPs had sufficient prefunded resources to cover such losses, with relatively low % consumptions of available resources.

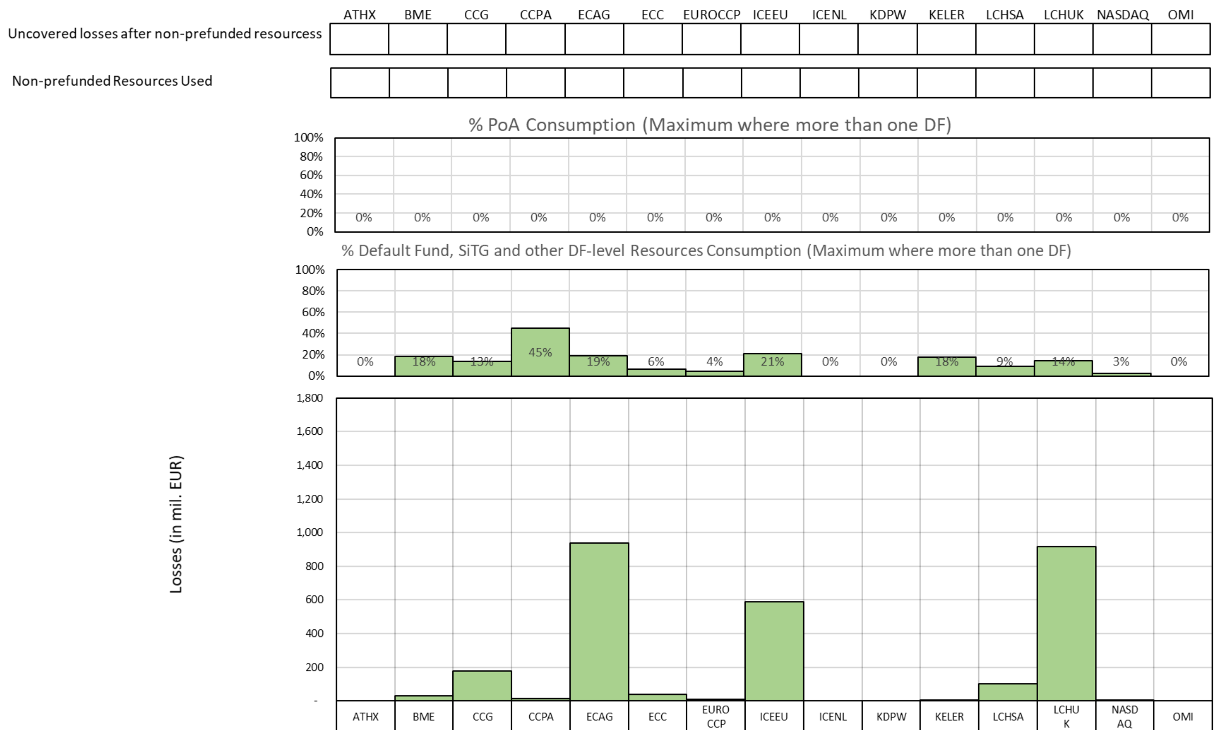
233. Since there was no shortfall of prefunded resources, the defaulters' selection algorithm focused on the pair of groups that would maximise the stress losses above margin. When ESMA staff instead selected the pair of defaulters to maximise the % consumption of financial resources, with the objective to identify cases where the scenario could put significant pressure to smaller default funds without necessarily maximising the total amount of losses, ESMA staff did not find any such cases and the results changed materially only for one CCP (Nasdaq) with the % consumption increasing but only to moderate levels, i.e. from 3% to 30%.

234. Hence, the implemented market stress scenario, before accounting for any additional losses due to concentration and wrong-way risk, has not put for the March date any of the in-scope CCPs to significant stress and all CCPs had sufficient prefunded resources to cover such losses.

235. Overall, aggregating the independent cover-2 results of the different CCPs there is a volume of approximately 4.1 billion EUR of losses after required margin and 3.3 billion EUR of losses after required margin and defaulters' default fund contributions. These amounts give an indication of how impactful the scenario is, but it should be noted that this is not a scenario that could be realised at the same time across all CCPs. It aggregates the worst results that were produced per CCP and assumes the default of different groups at different CCP.

236. For completeness, results using excess margin are also presented. The excess margin consists of collateral that was actually available at the CCPs on these particular dates. It was provided by the clearing members in excess of the required margin amounts. The rationale of not including excess collateral in the base scenarios is that it would not be prudent to assume that a member in default would have actually provided on the previous day any collateral in excess of the minimum requirement. The cover-2 per CCP results for the March date using excess margin are reported in Figure 15. It is noted that the selection of top defaulting entities is always performed using only the required margin collateral. The same defaulting entities are considered when reporting the results with total (i.e. including excess) collateral.

Cover-2 Groups per CCP (no cross defaulting)
Date: March 2021 – With Excess Margin



	ATHX	BME	CCG	CCPA	ECAG	ECC	EURO CCP	ICEEU	ICENL	KDPW	KELER	LCHSA	LCHUK	NASDAQ	OMI
Stress Loss after PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with other CCP-level Resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss above Margin covered with DF, SiTG and other DF-level Resources	-	31	177	14	937	38	8	591	-	-	1	102	915	5	-

FIGURE 15: COVER-2 GROUPS PER CCP – DATE: MARCH 2021 – WITH EXCESS MARGIN

237. After considering the excess margin, the losses would be smaller for many but not all CCPs. The maximum loss above total margin is significantly reduced to 937 million EUR while the maximum % consumption of Default-Fund-level mutualised resources is the same (45%) indicating that the assumed defaulters had not provided excess margin for this CCP. Overall, aggregating the independent cover-2 results of the different CCPs the volume of resources above margin that would be consumed decreased to approximately 2.8 billion EUR, compared to the 4.1 billion EUR calculated using only the required margin.

238. As with any exercise of this type, the magnitude of the market stress shocks that would be needed to adequately reflect extreme but also plausible conditions in a forward-looking basis is subject to uncertainties. Therefore, ESMA staff has also explored the impact of small or moderate changes to the assumed shocks. The CCPs were asked to report the results not only for the common market scenario shocks, but also after applying a number of multipliers on the shocks[31]. For each value of the multiplier, the CCPs ran a full repricing of the portfolios, as opposed to applying a multiplier to the result (P&L) of the scenario. All shocks are simultaneously scaled for all risk factors. For the purpose of this analysis, the results were calculated after considering all shocks increased by 20% and by 50%. Acknowledging the severity of the shocks and the fact that it goes beyond what was considered as extreme but plausible in the context of this exercise, it should be noted that the rationale of this analysis is not to put the focus on specific CCPs but rather investigate if relatively small increases of the shocks could lead to systemically relevant changes on the results of individual CCPs. A similar analysis is performed under the reverse stress test component that is expanded in two dimensions, being the severity of the shocks and the number of defaulting groups. The key difference is that the reverse stress analysis focuses on the internally consistent “All CCPs member default” scenarios, i.e. select the same groups as defaulting across all CCPs. Here ESMA staff selects the worst two groups per CCP and thus tries to identify any systemically relevant impact at individual CCPs. For March, when moves that are 20% or even 50% more severe than the baseline stress shocks were assumed, there would still be no shortfall at any CCP. The 20% increase of the shocks led to a maximum loss above required margin of approximately 2.9bn EUR, which is compared to the 1.5bn EUR of the baseline scenario. The % consumption also remains moderate with a maximum % consumption of default funds and other mutualised resources equal to 62%. This indicates that the conclusions seem robust to small changes in the baseline shocks. When even more severe shocks were assumed, i.e. increase of baseline shocks by 50%, the CCPs were subject to significant pressure. There would still be no shortfall of prefunded resources, however, one CCP would have had exhausted the resources dedicated to one smaller default fund and would have had to use a very small amount (<1m EUR) of other CCP-level prefunded resources. For three other CCPs the consumption of default fund, skin-in-the-game and other prefunded resources would be greater than 80%. The maximum loss over required margin at a single CCP would be close to 5.6bn EUR (double compared to the +20% scenario). As explained, considering the fact that it goes well beyond what was considered as an internally consistent, extreme but plausible scenario in the context of this exercise, these results raise no additional concerns.

239. The following figure (Figure 16) illustrates the baseline cover-2 per CCP results after also adding the impact from the liquidation of concentrated positions, as this is calculated according to the concentration component. The methodology used to incorporate the concentration cost and select the top default parties is detailed in Section 3.4.3.3.

[31] The multipliers used are x0.7, x 1.2, x1.5 and x2.0, implying an increase of the baseline shocks by 20% to 100%.

Cover-2 Groups per CCP (no cross defaulting)
Date: March 2021 – with Concentration impact

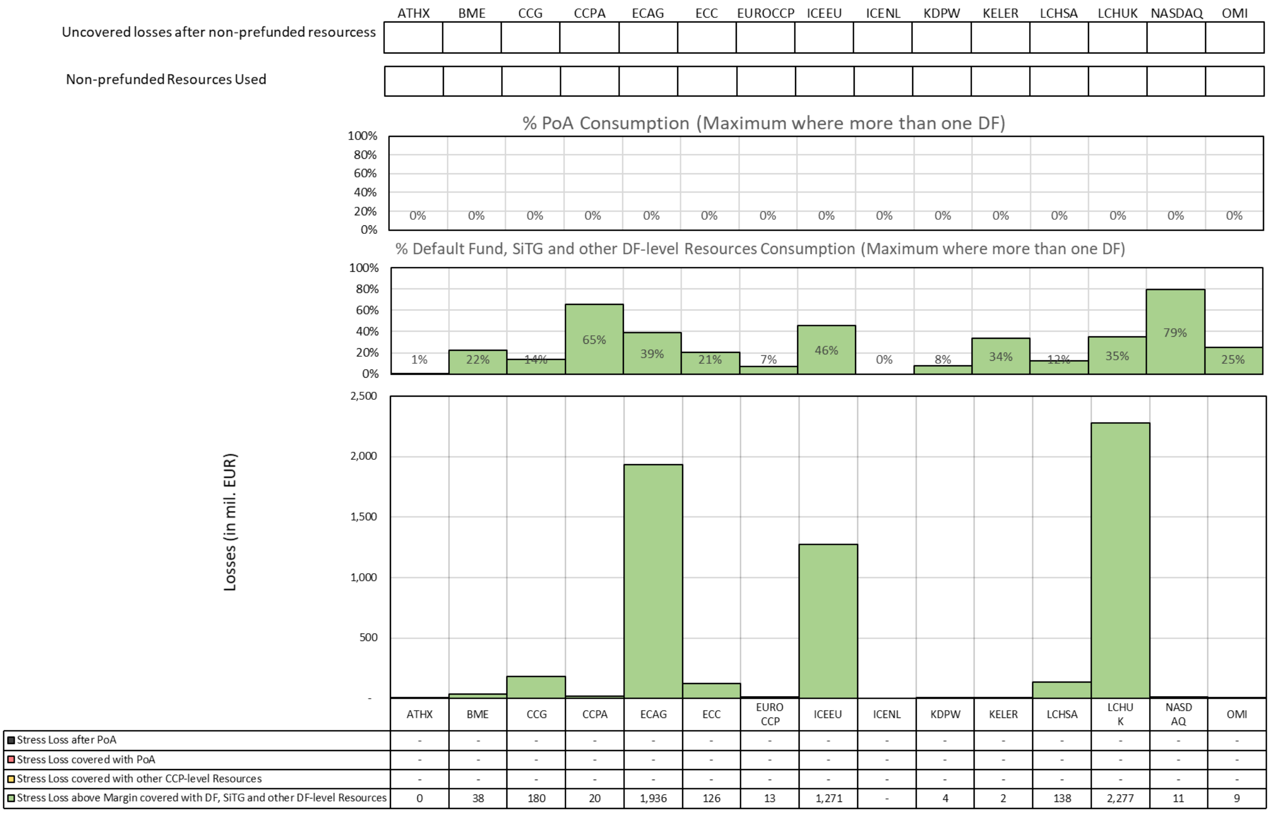
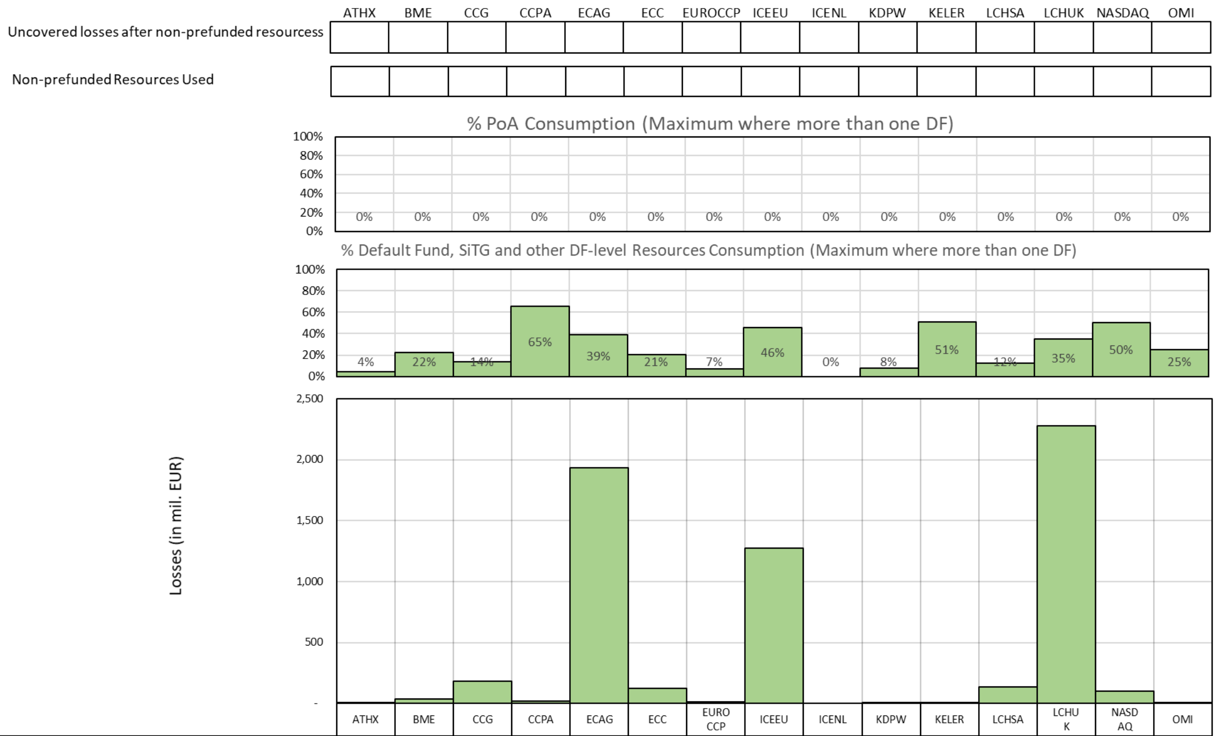


FIGURE 16: COVER-2 GROUPS PER CCP – DATE: MARCH 2021 – WITH CONCENTRATION IMPACT

240. As expected, the addition of the concentration impact leads to higher losses and consumption for almost all CCPs. However, there is still no shortfall of prefunded resources with the % consumption of default-fund level mutualised resources reaching 79% (Nasdaq). Of course, the maximum amount of losses above required margin is increased from 1.5bn EUR (under the baseline scenario without the concentration impact) to 2.3bn EUR. The aggregate (across all CCPs) amount of losses above margin add to approximately 6bn EUR, compared to 4.1bn EUR under the baseline – without concentration impact - scenario. Hence, the addition of the concentration impact increases significantly the losses, but under the considered market scenario, these are contained within the default waterfalls of the CCPs. This impact is further discussed below after also adding the enhanced wrong-way risk cost.

241. The baseline “Cover-2 per CCP” results after also adding the wrong-way risk adjustment for cleared positions are presented in the following figure (Figure 17). The methodology used to calculate the wrong-way risk and relevant assumptions are detailed in paragraph 3.4.3.4.

Cover-2 Groups per CCP (no cross defaulting)
Date: March 2021 – with Concentration and Wrong-way risk impact



	ATHX	BME	CCG	CCPA	ECAG	ECC	EURO CCP	ICEEU	ICENL	KDPW	KELER	LCHSA	LCHUK	NASDAQ	OMI
Stress Loss after PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with other CCP-level Resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss above Margin covered with DF, SiTG and other DF-level Resources	1	38	180	20	1,936	126	13	1,271	-	4	4	138	2,277	101	9

FIGURE 17: COVER-2 GROUPS PER CCP – DATE: MARCH 2021 – WITH CONCENTRATION AND WWR IMPACT

242. When also considering the wrong-way risk on top of the concentration impact for the March date, the losses above required margin increased for 3 CCPs without leading to a shortfall of prefunded resources at any CCP. The impact from wrong-way risk is significant under the considered scenario only for one CCP (Nasdaq), as it clears covered bonds. The maximum loss above margin (2.3bn EUR) did not change as the CCP (LCHUK) showing this loss did not experience any wrong-way risk losses under the considered member default scenario. The maximum % consumption is now 65%, i.e. lower, and also for a different CCP compared to the concentration-only run, which seems counter-intuitive. This is because the defaulters' selection algorithm now focuses on a different pair of members that maximises the total amount of losses above margin for a different (larger) default funds leading to lower % consumption.

243. When instead selecting groups maximising the % consumption, there would be 100% consumption of the default fund-level resources at a smaller default fund of one CCP (Nasdaq) with very small residual losses (<2m EUR) still covered fully by the additional available prefunded CCP-level resources. This impact was driven by additional concentration costs. Furthermore, under this selection, there would be increased % consumption for two other CCPs, i.e. Keler (90%) for a smaller default fund due to concentration and ATHX (6%) due to concentration and wrong-way risk, but in both cases the loss above margin was again very small (<1m EUR).

244. Hence, the addition of the concentration and wrong-way risk impact in the considered scenarios did not raise any systemically relevant concerns. However, it should be noted that this impact was added to the P&L calculated from the baseline market stress scenarios. Therefore, there may be cases where this additional cost, though significant, would be added to accounts that would experience profits from the given market scenario, muting the impact from these additional risks. Hence, these results cannot be used to draw conclusions on what the impact would be under all possible extreme but plausible market scenarios. The CCPs should have dedicated risk management measures to prudently mitigate these risks. Finally, the potential impact from increased concentration, independently from the market scenario, is assessed in the concentration component (4.3).

4.2.1.2 Cover-2 per CCP Results for April 2021

Cover-2 Groups per CCP (no cross defaulting)
Date: April 2021 – Without Excess Margin

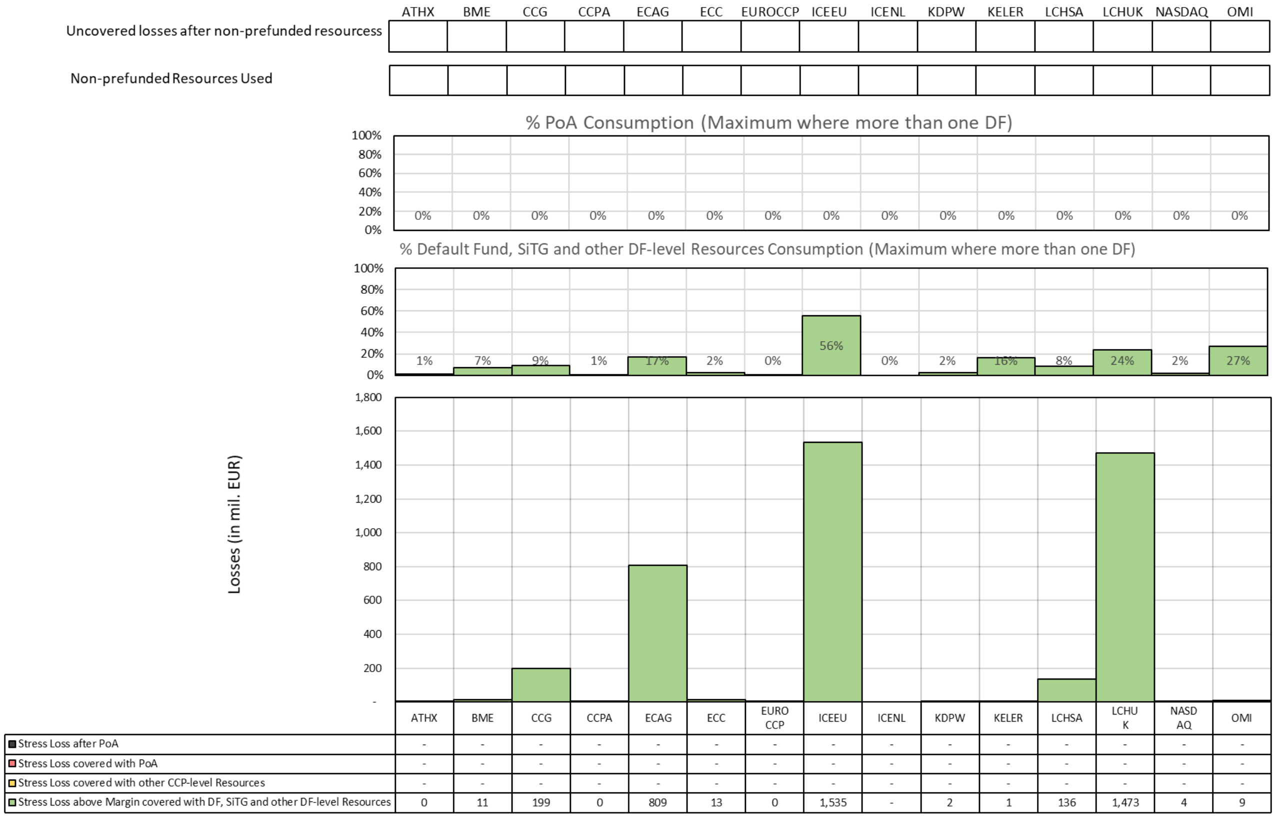


FIGURE 18: COVER-2 GROUPS PER CCP – DATE: APRIL 2021 – WITHOUT EXCESS MARGIN

245. For the April date, the cover-2 per CCP scenario does not generate a shortfall of prefunded Resources at any CCP. The maximum loss above required margin is 1.5bn EUR, very close to what was calculated for the March date, but for a different CCP (ICEEU). The maximum % consumption of default fund-level mutualised resources is 56% (ICEEU).

246. In general, if compared to March the impact is mixed across CCPs. For 8 CCPs the losses over required margin are lower with the largest positive difference being +0.6bn EUR (ICEEU) and the largest negative difference equal to -0.7bn EUR (ECAG). However, in aggregate across all CCPs, the scenario generated similar losses over required margin, i.e. 4.2bn EUR compared to 4.1bn EUR calculated for the March date. Also, the impact on non-defaulting members is similar, since the losses after exhausting the defaulters' resources are 3.4bn EUR compared to 3.3bn EUR for March.

247. Some CCPs present higher losses, but overall, it seems that the intraday default assumption as implemented for the April reference date did not put significant additional stress on the resilience of the system of CCPs. Having said that, it is important to note that the results are based on the data reported by CCPs implementing the intraday default assumptions. Sourcing positions and resources from intraday data has added significant complexity both on CCPs and authorities

validating the data, which means that, also as with any newly tested stress assumption, some uncertainties may remain with regard to their consistent implementation.

248. Finally similar to March, ESMA staff has calculated the results with increased shocks for April in an effort to explore whether small changes could dramatically impact the conclusions; this does not seem to be the case. When shocks were increased by 20%, the maximum loss above required margin increased from 1.5bn EUR (baseline scenario) to 3.2bn EUR. Increased pressure would be noted especially for one CCP with a % consumption of prefunded resources that was close to 81%. However, there was no shortfall of prefunded resources at any CCP, and the conclusions seem again robust to small changes in the underlying shocks. On the other hand, where shocks were increased significantly by 50%, multiple CCPs would be subject to significant pressure with 4 CCPs showing consumption of prefunded resources higher than 80%. Moreover, there would be a shortfall of prefunded resources at one CCP for approximately 0.5bn EUR that could still be covered with additional non-prefunded resources that the CCP has the right to call from non-defaulting members. As explained before, the purpose of this analysis is to explore the impact of small changes and considering the fact a 50% increase would go well beyond what was considered as an internally consistent, extreme but plausible scenario in the context of this exercise, these results raise no additional systemic concerns.

4.2.2 All CCPs Cover-2 Credit Stress Test Results

249. The “All CCPs Cover-2” credit stress test is designed to assess the resilience of CCPs collectively to the Market Stress Scenario, focusing on the worst outcome for the whole system of CCPs.

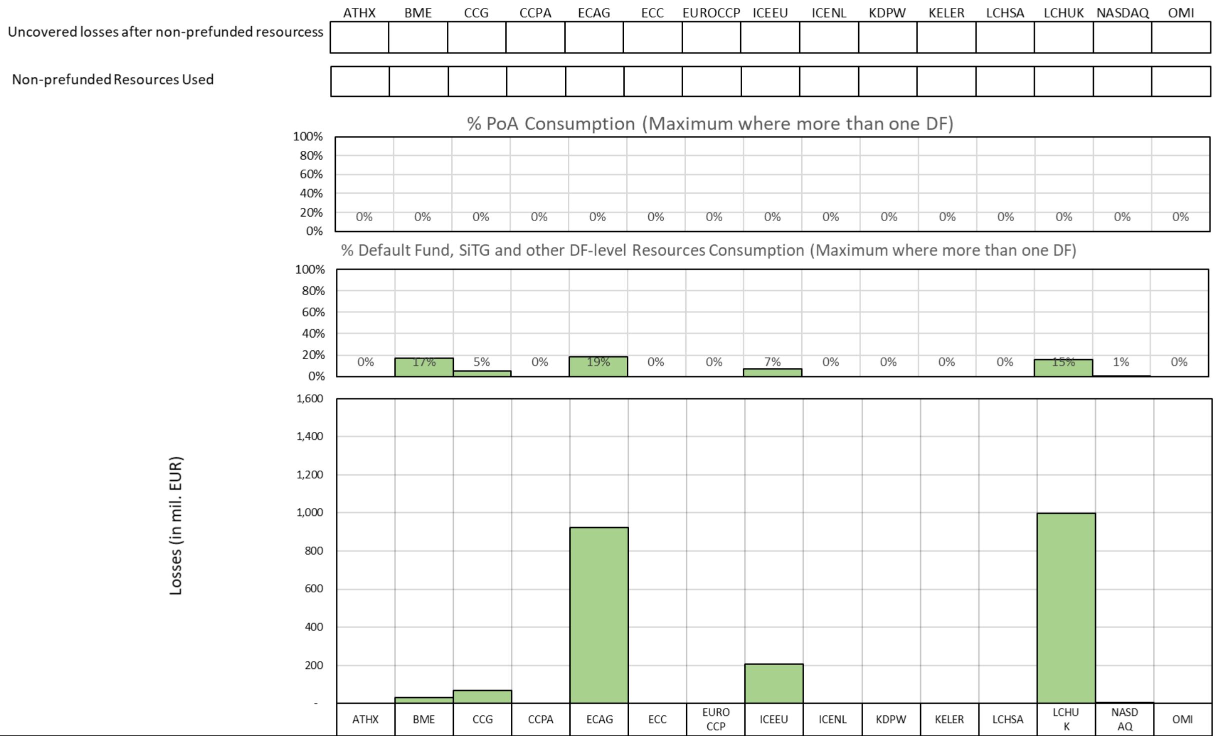
250. In this scenario, all members belonging to the same two clearing member groups are assumed to be in default at all CCPs in scope of the exercise. The selection of the top-2 defaulting groups is based on the aggregate impact to prefunded resources, considering all CCPs. Given that the selection of defaulters is the same for all CCPs, the results illustrate what would be the systemic effect of the most impactful default of two clearing member groups and how it would affect each CCP.

251. The “All CCPs Cover-2” results are reported separately for the two dates, based on the same format that was used for the “Cover-2 per CCP” results. For the March date results after considering the impact from concentration and wrong-way risk are also presented.

4.2.2.1 All CCPs Cover-2 Results for March 2021

252. The “All CCP cover-2” results for March after selecting the two groups that would maximize the overall impact on prefunded resources are reported in the figure below (Figure 19).

All CCPs Cover-2 (top-2 groups CCP-wide, defaulting at all CCPs) Date: March 2021 - Without Excess Margin



	ATHX	BME	CCG	CCPA	ECAG	ECC	EURO CCP	ICEEU	ICENL	KDPW	KELER	LCHSA	LCHUK	NASDAQ	OMI
Stress Loss after PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with other CCP-level Resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss above Margin covered with DF, SiTG and other DF-level Resources	-	29	69	-	922	-	-	205	-	-	-	-	1,000	1	-

Figure 19: All CCPs Cover-2 – Date: March 2021 – Without Excess Margin

253. As expected, there is no common pair of defaulting groups that would lead to a shortfall of prefunded resources at any of the CCPs. The individual results of each CCP are by design equally or less severe than the results calculated under the "cover-2 per CCP" assumption. The reason is that here ESMA staff selects the same two clearing member groups as defaulting across all CCPs.

254. The two defaulting groups were selected to maximise the aggregate, across all CCPs, loss above required margin in order to assess the impact on the system of CCPs. In this case, the selected pair of defaulting groups is none of the pairs that would maximise the losses at any individual CCP. The algorithm focuses on a pair that maximises the aggregate impact across all CCPs. We note that by prioritizing maximization of losses above required margin in absolute terms, the Cover 2 selection naturally leans towards combinations that are most impactful for the largest CCPs.

255. The total loss above required margin is close to 2.2bn EUR with 1bn EUR being the maximum loss at a single CCP. This scenario does not put significant stress to any CCP with the % consumption of default fund-level prefunded resources being less than 20% in all cases. However, 10 of the CCPs would have experienced at least one member default with 5 CCPs having to use prefunded resources beyond collateral (margin or default fund contribution) of the

defaulter(s)[32]. While this confirms on the one hand that CCPs are highly interconnected through common clearing participants, the exercise did not highlight any pairs of groups that are at the same time and under the common tested scenario highly impactful at multiple CCPs.

256. Similar to the "cover-2 per CCP" scenario, ESMA staff also presents here (Figure 20) the "All CCPs cover-2" results after considering the impact from concentration and wrong-way risk.

All CCPs Cover-2 (top-2 groups CCP-wide, defaulting at all CCPs) Date: March 2021 - Without Excess Margin – With Concentration and wrong-way risk Impact

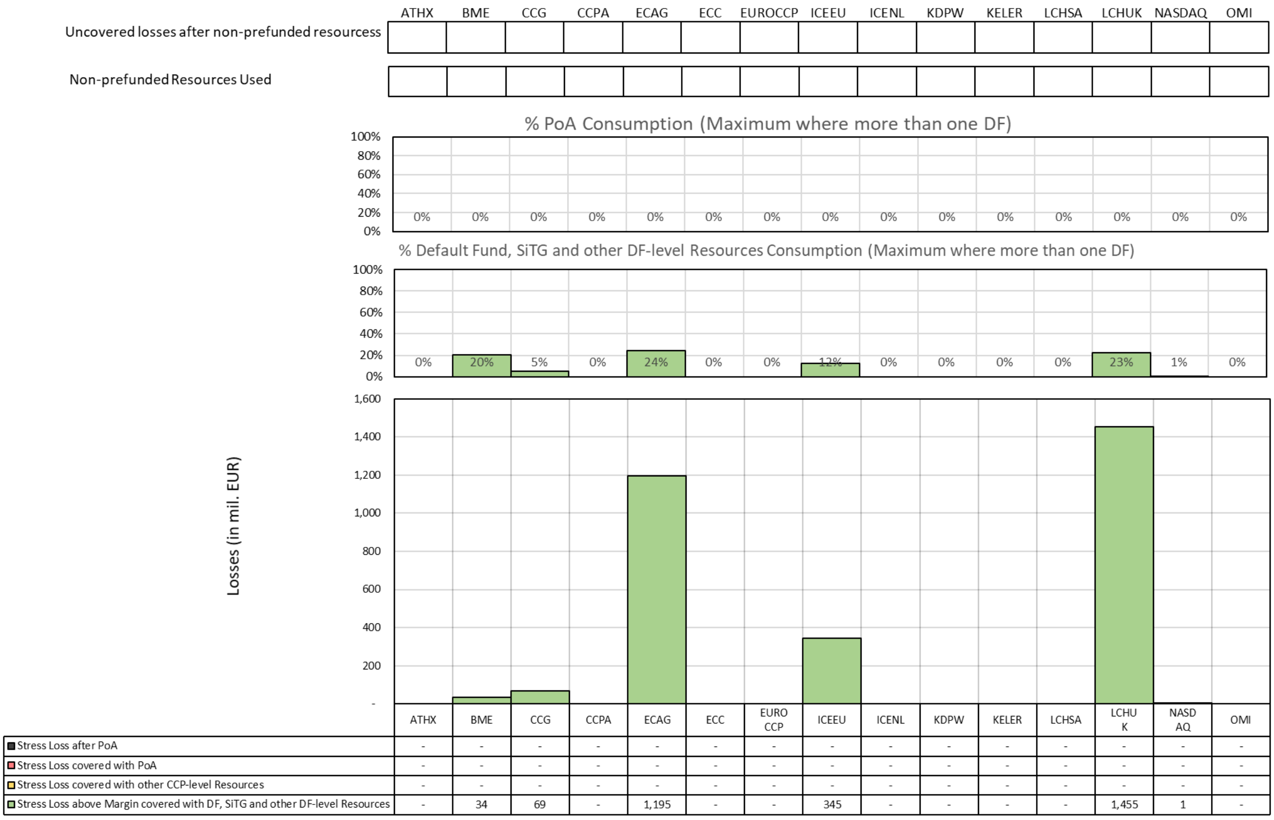


FIGURE 20: ALL CCPS COVER-2 – MARCH 2021 – WITHOUT EXCESS MARGIN – WITH CONCENTRATION AND WRONG-WAY RISK IMPACT

257. After adding the concentration and wrong-way risk impacts, the algorithm used to select the top defaulting groups focuses on the same defaulting pair that maximises again losses across CCPs.

258. The total loss above required margin increases by approximately 0.9bn EUR to 3.1bn EUR. This increase is only due to the addition of concentration cost, as there is no wrong-way risk impact stemming from the default of the selected pair. There is no shortfall of prefunded resources. In fact, the impact on the default waterfall of CCPs is still limited with the % consumption of default fund, skin-in-the-game and other prefunded default fund-level resources being lower than 25%.

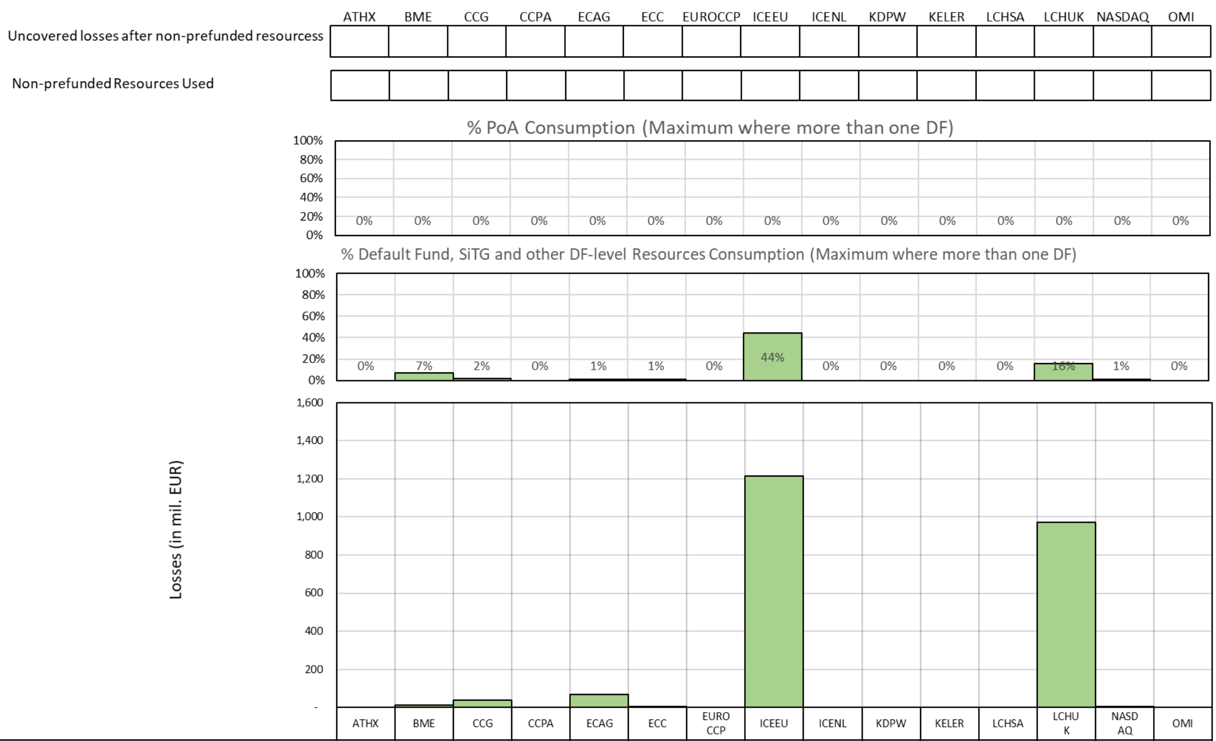
[32] And 6 CCPs having losses beyond required margin of the defaulter(s) as shown in the figure.

259. Hence, even after adding the concentration cost, the exercise did not highlight any pairs of groups that would at the same time and under the common tested scenario cause a significant impact at multiple CCPs. The limitations explained before still hold. The results may be sensitive to the underlying market scenario, should be used with caution when drawing general conclusions and CCPs should have dedicated risk management measures to prudently mitigate these risks. The potential impact from increased concentration, independently from the underlying market scenario, is assessed in the concentration component (4.3).

4.2.2.2 All CCPs Cover-2 Results for April 2021

260. The All CCPs cover-2 results for the April date after selecting for the groups that would maximize the overall impact, are presented in the figure below (Figure 21).

All CCPs Cover-2 (top-2 groups CCP-wide, defaulting at all CCPs) Date: April 2021 - Without Excess Margin



	ATHX	BME	CCG	CCPA	ECAG	ECC	EURO CCP	ICEEU	ICENL	KDPW	KELER	LCHSA	LCHUK	NASDAQ	OMI
Stress Loss after PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with PoA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss covered with other CCP-level Resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress Loss above Margin covered with DF, SiTG and other DF-level Resources	-	11	39	-	69	5	-	1,216	-	-	-	-	971	2	-

FIGURE 21: ALL CCPS COVER-2 – APRIL 2021 – WITHOUT EXCESS MARGIN

261. The pair maximising the losses across CCPs is again none of the pairs that would maximise the losses at any individual CCP. The calculated total loss above margin is 2.3bn EUR, very close to what was observed for the March date before adding the concentration cost. The maximum loss above margin is slightly higher, i.e. 1.2bn EUR, and for a different CCP (ICEEU), also leading to a higher % consumption of 44%.

262. Under the selected scenario, 10 CCPs would experience a default of at least one of their clearing members. However, the majority of losses would stem from two of the bigger CCPs and although there would be losses above required margin of the defaulters for 7 CCPs, only 3 CCPs would experience losses above the collateral (required margin default fund contribution) provided by the defaulting parties. Hence, the exercise did not identify any pairs of groups whose default would at the same time have a significant impact at multiple CCPs under the common tested scenario.

263. For the April date, the concentration and wrong-way risk costs were not considered as the data was not provided at account level. The sensitivity of the “All CCPs cover-2” results to changes in the market shocks and number of defaulting entities is analysed in the following section as part of the reverse stress test.

4.2.3 Reverse Credit Stress Test Results

264. The reverse stress test in the 4th stress test exercise has similar characteristics with the analysis performed in previous exercises. For the reverse stress tests, ESMA staff performs a two-dimensional analysis of the absorption capacity of the system of CCPs by stepwise increasing the number of defaulting groups and the severity of the market shocks in order to identify at which point resources are exhausted.

265. While exploring the different combinations, ESMA staff goes intentionally beyond what is considered as plausible for the purpose of this exercise. The idea is to capture the sensitivity of the results to the considered stress scenarios and understand how the results are affected by changing the underlying assumptions. After all, although the baseline stress scenario is carefully modelled to simulate extreme market conditions, it is still subject to uncertainties and limitations, as is the case with all modelling procedures. A steep increase of the uncovered losses following a relatively small change in the shocks could indicate a high sensitivity and raise concerns on the robustness, considering the limitations and uncertainties.

266. With respect to the number of defaulting groups, ESMA staff considers the default of the top-n clearing member groups, where n ranges from one (1) to five (5) groups. All entities belonging to these groups are considered to be in default across all CCPs. The selection of defaulting groups for each combination of severity level and number of defaulting groups is done by an algorithm that selects the groups that maximize the losses over prefunded resources. The selection is done independently for every combination of severity level and number of defaulting groups. The selection of groups is performed without considering excess margin and is looking for the greatest loss over prefunded resources. The same selected groups are then used for the analysis of losses over non-prefunded resources.

267. The different severity levels are the result of adjusting the base scenario shocks using a number of multipliers[33]. At each severity level, the shocks of all risk factors are adjusted simultaneously. The five severity levels are the following:

x0.7: A decrease in the stress test shocks of 30%.

Base: The base scenario shocks as used for the credit stress test.

x1.2, x1.5, x2: An increase in the stress test shocks of 20%, 50% and 100% respectively.

[33] For each value of the multiplier, the CCPs ran a full repricing of the portfolios, as opposed to applying a multiplier to the result (P&L) of the scenario

268. The following two tables of results are presented both using only required margin:

The "Loss above Required Prefunded resources" table (Table 1) presents the aggregate (across all CCPs) amount of losses (in billion EUR) beyond prefunded resources, as applicable. These include required margin collateral, "skin-in-the-game", default funds and other Default-Fund-level resources[34].

The "Loss above Required & non-Prefunded resources" table (Table 2) presents the aggregate (across all CCPs) amount of losses (in billion EUR) beyond prefunded and non-prefunded resources (Powers of Assessment).

Loss above Required Prefunded Resources (bil. EUR)							
			Market Shock				
			x0.7	Base	x1.2	x1.5	x2
Number of Groups Defaulting	1	March 2021	-	-	-	-	0.0
	2	March 2021	-	-	-	-	5.4
	3	March 2021	-	-	-	1.9	10.6
	4	March 2021	-	-	-	3.8	15.3
	5	March 2021	-	-	-	5.4	20.3
	1	April 2021	-	-	-	-	0.1
	2	April 2021	-	-	-	0.5	5.2
	3	April 2021	-	-	0.1	1.9	10.7
	4	April 2021	-	-	0.5	3.9	16.9
	5	April 2021	-	-	0.8	6.0	21.8

[35]

TABLE 1: REVERSE STRESS TEST – LOSS ABOVE REQUIRED PREFUNDED RESOURCES (NO EXCESS)

269. The amounts shown in the table are the losses beyond prefunded resources in billion EUR assuming the default of the same groups across all CCPs. So, this is an extension of the "All-CCPs cover-2" member default scenario.

270. When the severity of the shocks is only increased by 20% and without increasing the number of defaulting clearing member groups, i.e. stay at the regulatory requirement of **cover-2 defaulting groups**, there is no shortfall of prefunded resources for any of the two dates. A further increase of the severity of the shocks, i.e. by 50%, would lead to a shortfall of 0.5bn EUR at one CCP for April which was already discussed in the context of the sensitivity of the "Cover-2 per CCP" results in 4.2.1.2. When the shocks are increased by 100%, the maximum shortfall of prefunded resources that would be inflicted by the default of a pair of clearing member groups would be 5.4bn EUR for March and 5.2bn for April, and in both cases caused by one CCP.

271. In case of the default of one clearing member group (**cover-1 defaulting group**), a very small shortfall can be noted when the underlying shocks are increased by 100% (doubled). For the April date, this is a shortfall of approximately 50m EUR at one CCP. For March, the shortfall observed in the table is simply because of not including other CCP-level resources in this reverse

[34] The other CCP-level resources have not been considered in the reverse stress test in order to simplify the calculation, but the impact from this assumption is assessed as immaterial in the context of the reverse stress test.
[35] The cell is highlighted in red where there is a non-zero loss. There are cells where the loss is small (<0.1), but still greater than 0 and is thus highlighted.

stress test analysis. In practice, this shortfall would be covered by the available prefunded resources.

272. Following a small increase of the shocks, i.e. by 20%, there is no shortfall for March even when the number of defaulting clearing member groups is increased to 5. On the other hand, for April there is a small shortfall of 60m EUR at cover-3 (three defaulting clearing member groups).

273. Finally, without increasing the shocks (baseline common market stress scenario), there is no shortfall of prefunded resources at any CCP for any of the dates even when 5 clearing member groups default simultaneously.

274. In the following table (Table 2) one sees the shortfalls after accounting also for the non-prefunded resources that the CCPs have the right to call. Of course, one should note that each CCP uses different definitions, assumptions and conditions, when setting the maximum amounts that can be called. These may include for example specific cool-off periods, distinction between simultaneous and sequential defaults, limited scope of use for resources and different priorities amongst clearing members depending on the source of the default event. Therefore, any effort to use a harmonised modelling approach in order to analyse such a severe impact across CCPs can only serve as a rough approximation.

			Loss above Required & Non-Prefunded Resources (bil. EUR)				
			Market Shock				
			x0.7	Base	x1.2	x1.5	x2
Number of Groups Defaulting	1	March 2021	-	-	-	-	-
	2		-	-	-	-	-
	3		-	-	-	-	-
	4		-	-	-	-	-
	5		-	-	-	-	2.1
	1	April 2021	-	-	-	-	-
	2		-	-	-	-	-
	3		-	-	-	-	-
	4		-	-	-	-	-
	5		-	-	-	-	2.6

TABLE 2: REVERSE STRESS TEST – LOSS ABOVE REQUIRED & NON-PREFUNDED RESOURCES (NO EXCESS)

275. It can be seen that significantly more extreme assumptions would be needed in order to create a shortfall of non-prefunded resources. Under the considered scenarios, a cover-5 assumption (five defaulting clearing member groups) in combination to a 100% increase (x2) of the market shocks was necessary in order to have a shortfall of non-prefunded resources. However, it should be noted that this scenario would already involve a very large amount of non-prefunded resources (up to 19bn EUR) being called from non-defaulting clearing members and used to cover losses.

276. From the analysis of the reverse stress test results ESMA staff has not found any systemically relevant adverse impact following small changes in the underlying stress assumptions. It is also confirmed that incremental changes in the severity of the market shocks are generally more harmful than increases in the number of defaulting groups. For very large increases of the severity of the market shocks, going well beyond what was considered extreme but plausible in the context of this exercise, the observed maximum shortfalls of prefunded resources following

the default of two clearing member groups would not be spread across CCPs implying that there are different pairs of defaulting groups that would maximise the shortfalls at different CCPs for these particular dates.

277. One of the key limitations of this analysis is that second round effects are increasingly relevant as scenarios become more extreme, beyond what can be reasonably considered as plausible. However, as in the core credit stress test, second round effects are not accounted for. It should be highlighted that in practice the wide-spread effects from such catastrophic events in the financial system cannot be analysed fully only considering the CCPs and the cleared exposures. Therefore, due to its limited scope, this analysis cannot predict the impact from such events. Its purpose is to assess the sensitivity of the CCP stress results to relatively small changes in the scenarios and underlying assumptions.

4.2.4 Conclusions of Credit Stress Test Results

278. In the credit stress test, ESMA staff analysed the sufficiency of CCPs' resources to withstand the losses resulting from hypothetical multiple clearing member defaults combined with simultaneous extreme price changes. The core "Cover-2 per CCP" credit stress test results for the two dates did not indicate a shortfall of prefunded resources at any of the CCPs in scope of the exercise.

279. The implemented market stress scenario, especially before accounting for any additional losses due to concentration and wrong-way risk, has not put any of the in-scope CCPs to significant stress and all CCPs had sufficient prefunded resources to cover such losses. The CCPs could have covered losses generated by the common market stress scenario with relatively low or moderate % consumptions of available resources. For the April date ESMA staff tested using an intraday default assumption. Some CCPs presented higher losses, but overall, it seems that this modelled assumption did not put significant additional stress on the resilience of the system of CCPs. Having said that, sourcing positions and resources from intraday data has added significant complexity both on CCPs and authorities validating the data, which means that, as with any newly tested stress assumption, some uncertainties may remain with regard to their consistent implementation.

280. ESMA staff also performed a sensitivity analysis to explore the impact of small or moderate changes to the assumed shocks. When assuming moves that are 20% higher than the baseline stress shocks, there would still be no shortfall at any CCP. This indicates that the conclusions seem robust to small changes in the baseline shocks. When the shocks were increased further (+50% from baseline), ESMA staff noted increased pressure to CCPs including a shortfall of prefunded resources for one CCP for one of the dates. However, considering the fact that such assumed shocks would go well beyond what was considered as an internally consistent, extreme but plausible scenario in the context of this exercise, these results raise no additional systemic concerns.

281. For one of the dates, ESMA staff included in the baseline scenario calculations the impact due to concentration and specific wrong-way risk stemming from cleared positions. This led to higher losses and consumption for almost all CCPs but under the considered market scenario these were contained within the default waterfalls of the CCPs and there was no shortfall of prefunded resources. Hence, the addition of the concentration and wrong-way risk impact in the considered scenarios did not raise any systemically relevant concerns. However, it should be noted that this impact was added to the P&L calculated from the baseline market stress scenarios. Hence, these results cannot be used to draw conclusions on what the impact would be under all possible extreme but plausible market scenarios. The CCPs should have dedicated risk management measures to prudently mitigate these risks under all scenarios.

282. Under the "All CCP cover-2" scenario ESMA staff assumed the default of the members that belong to the same two top clearing member groups across CCPs that would maximize the overall impact on prefunded resources. The individual results of each CCP are by design equally or less severe than the results calculated when assuming the default of the top-2 groups selected for each CCP. The majority of CCPs would experience a default of at least one of their clearing members. However, these consistent scenarios did not put significant stress to any CCP with the % consumption of default fund-level prefunded resources being relatively low in all cases. This indicates that while CCPs are highly interconnected through common clearing participants, the exercise did not highlight any pairs of groups that are at the same time and under the common tested scenario highly impactful at multiple CCPs.

283. Finally, in the reverse stress test analysis, ESMA staff intentionally went beyond what was considered as plausible for the purpose of this exercise by stepwise increasing the number of defaulting entities and the severity of the market shocks. The results have not indicated any

systemically relevant adverse impact following small changes in the underlying stress assumptions. It is also confirmed that incremental changes in the severity of the market shocks are generally more harmful than increases in the number of defaulting groups. For large increases of the severity of the market shocks, going well beyond what was considered extreme but plausible in the context of this exercise, the observed maximum shortfalls of prefunded resources following the default of two clearing member groups would not be spread across CCPs implying that there are different pairs of defaulting groups that would maximise the shortfalls at different CCPs for these particular dates.

4.3 Concentration Stress Test Results

284. The objective of this analysis is to assess the adequacy of CCPs' resources in covering the cost of liquidating concentrated positions. To do so, the exercise computed the market impact of concentration risk in different asset classes (according to the methodology detailed in Section 3.5) and compared it with the concentration add-ons reported by the CCPs.

285. The sum of the market impacts of all clearing members does not represent the actual concentration risk faced by the CCPs, as CMs would not all default simultaneously, and because the final impact may be lowered by offsetting positions between defaulting CMs. However, the aggregated market impact approximates what would need to be charged by CCPs to cover the concentration risk, generally through dedicated add-ons (or other duly computed resources included in the initial margin).

286. The market impact computation heavily relies on the system-wide baseline sensitivity tables that ESMA staff computed for each asset class starting from the sensitivity parameters that each CCP submitted. To increase transparency, ESMA staff reported in the Appendix 6.2.3 a selection of the most important system-wide sensitivity tables, together with the market impact on typical concentrated positions.

4.3.1 Overview

287. The analysis starts with an overview at system-wide level of the concentration risk, in terms of market impact (EUR), for each asset class. In addition, details are provided about exposure of individual CCPs to concentration risk for each asset class.

288. The analysis continues by showing the concentration add-ons (EUR) provided for each asset class at system-wide level.

289. The market impact is then compared to corresponding concentration add-ons. First, a comparison is performed at CCP level. Subsequently, the comparison between concentration risk and concentration add-ons is performed at CCP level but separately for each asset class.

290. Finally, the importance of accurately estimating the concentration risk at clearing member level in order to prevent the consumption of mutualised resources is discussed.

4.3.2 System-wide impact

4.3.2.1 System-wide market impact per asset class

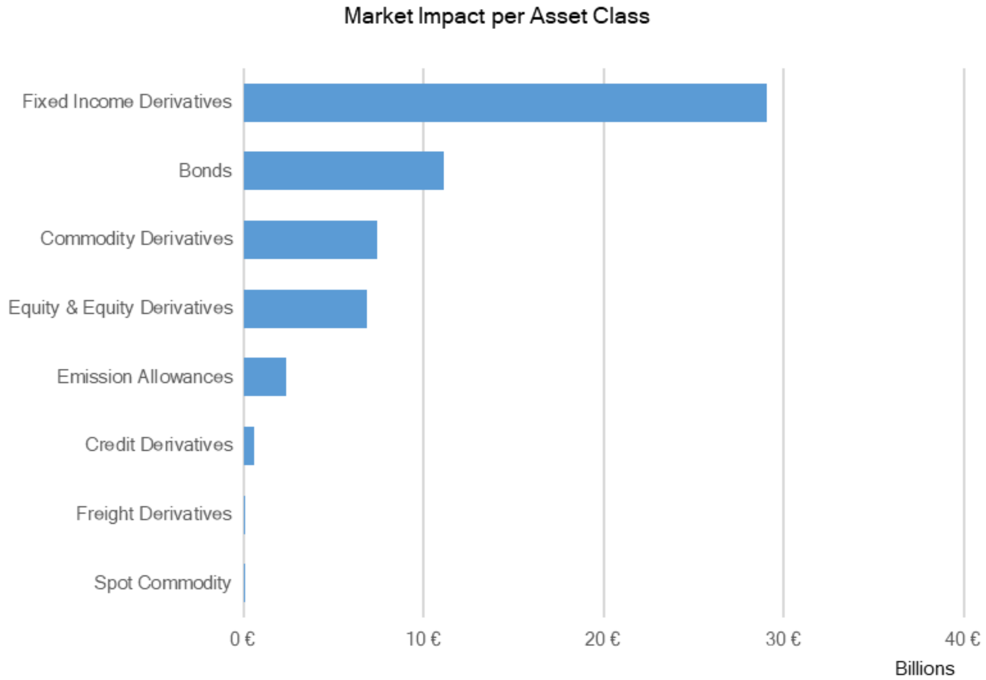
291. Figure 22 shows the aggregated system-wide market impact for each asset class, across all CCPs of the exercise.

292. ESMA calculation shows that fixed income derivatives positions contain most concentration risk, with a total over 29bn EUR. Bonds (including bonds from Repo clearing services) come next with a total modelled concentration risk of around 11 bn EUR.

293. Concentration in commodity derivatives and in the equity segment (securities and derivatives) is very significant as well, with around 7bn EUR of concentration risk calculated for each asset class.

294. The concentration risk modelled for Emission Allowances stands also out at 2.5bn EUR.

295. The low market impact for credit derivatives is most likely driven by methodological limitations of the framework[36].



Sources: ESMA

FIGURE 22: SYSTEM-WIDE MARKET IMPACT PER ASSET CLASS

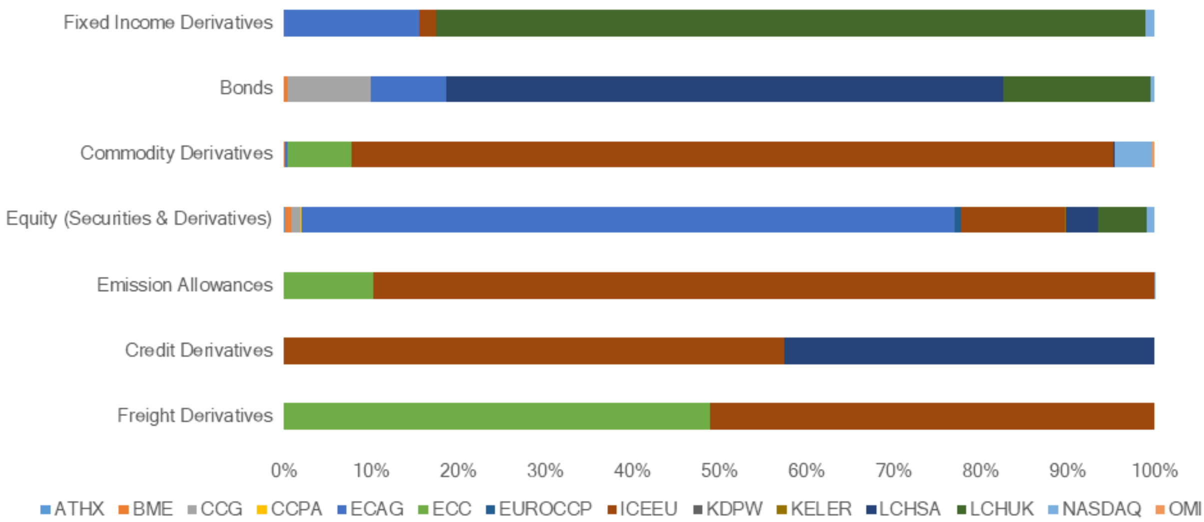
296. For asset classes only cleared by two CCPs, concentration risk is balanced between them as in Credit Derivatives (LCH SA & ICEEU) and Freight Derivatives (ECC & ICEEU).

297. For other classes, one CCP carries most of the risk and a second one most of the remainder. This is the case for Fixed Income Derivatives (LCHUK 81%, ECAG 16%), Commodity Derivatives (ICEEU 87%, ECC 7%), Equity (ECAG 75%, ICEEU 11%), Emission Allowances (ICEEU 90%, ECC 10%).

298. Only concentrated positions in bonds are spread over many CCPs (LCHSA 64%, LCHUK 17%, CCG 10%, ECAG 9%).

299. As illustrated, for most asset classes concentrated positions are clustered in only a few CCPs.

[36] For both CCPs clearing Credit Derivatives, the market impact is much lower than the add-ons they charge.

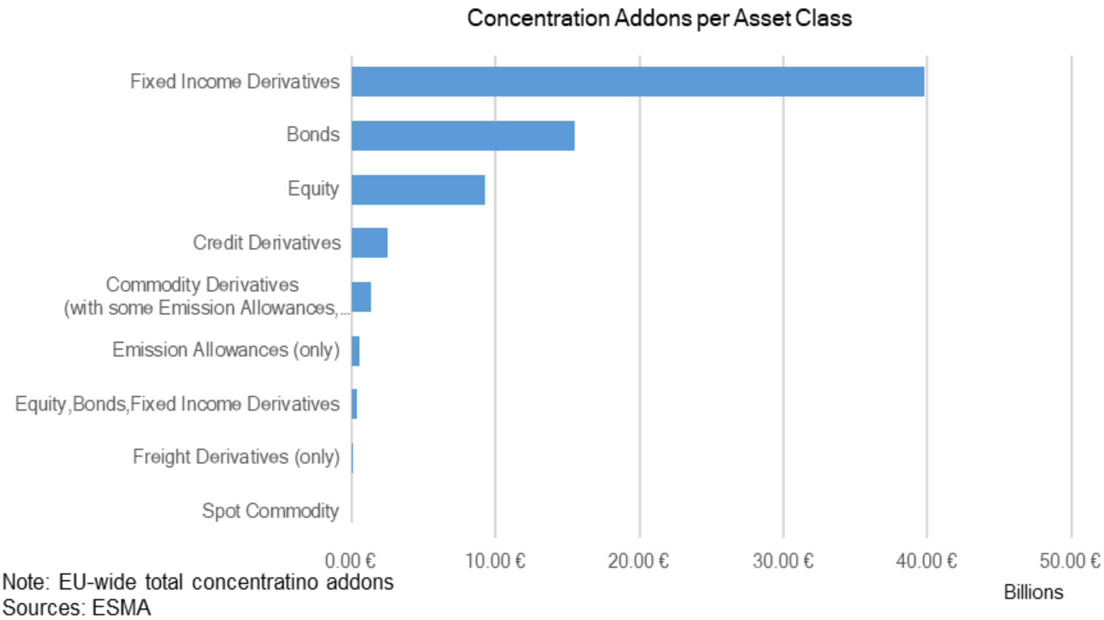


Sources:ESMA

FIGURE 23: BREAKDOWN OF CONCENTRATION RISK PER ASSET CLASS

4.3.2.2 System-wide concentration add-ons

300. CCPs generally charge concentration add-ons to cover concentration risk. Such add-ons are reported in Figure 24, aggregated on a system-wide basis, by asset classes. The analysis shows that, in absolute terms, such add-ons are largest for fixed income derivatives, bonds and equity (securities and derivatives). Commodity derivatives and emission allowances show overall lower concentration addons.



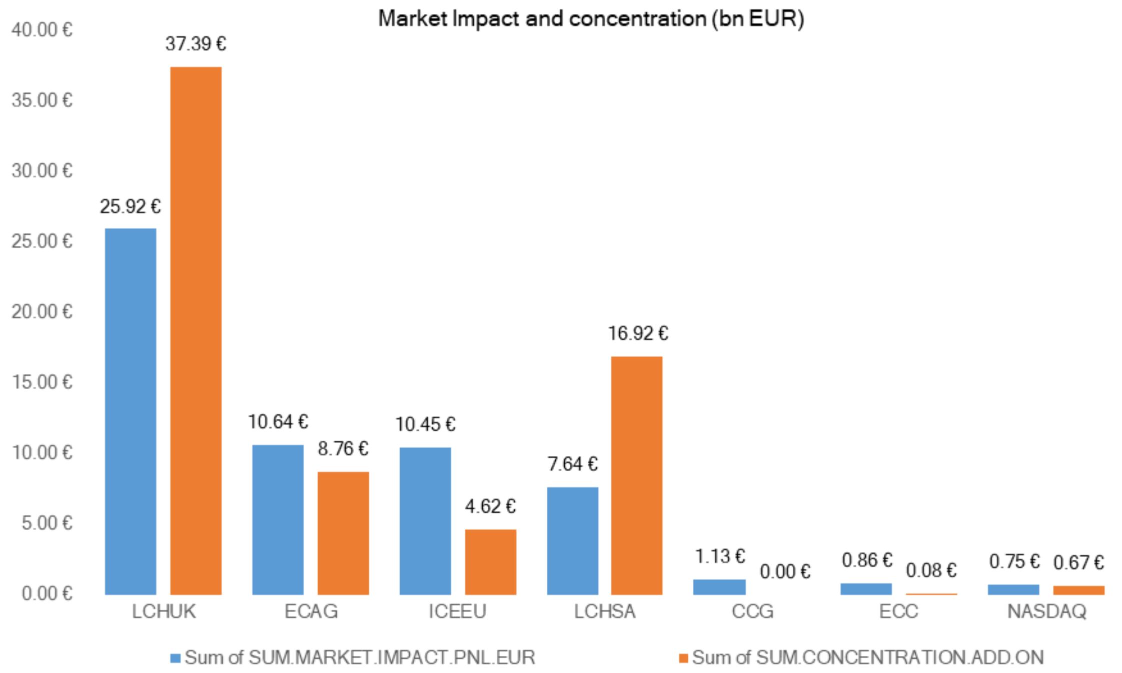
Note: EU-wide total concentratino addons
Sources: ESMA

FIGURE 24: SYSTEM-WIDE REPORTED CONCENTRATION ADD-ONS, PER ASSET CLASS

4.3.3 Comparison of concentration add-ons and market impact

4.3.3.1 CCP level coverage

301. When aggregating concentration add-ons across all asset classes, some CCPs charge more concentration add-ons than implied by the chosen baseline model (notably LCHUK and LCHSA). On the other hand, four CCPs charge concentration add-ons which are lower than the modelled market impact by more than 750m EUR (ICEEU 5.8bn, ECAG 1.8bn, CCG 1.1bn, ECC 800m).



Note: Market Impact and Concentration addons.
Sources: ESMA

FIGURE 25: CONCENTRATION RISK COVERAGE BY ADDONS FOR INDIVIDUAL CCPS

4.3.3.2 Asset class level coverage

302. The analysis shows that the calculated market impact materially exceeds the concentration add ons for commodity derivatives and emission allowances. In some cases, this observation also applies to Bonds, Equity Derivatives and Fixed Income Derivatives.

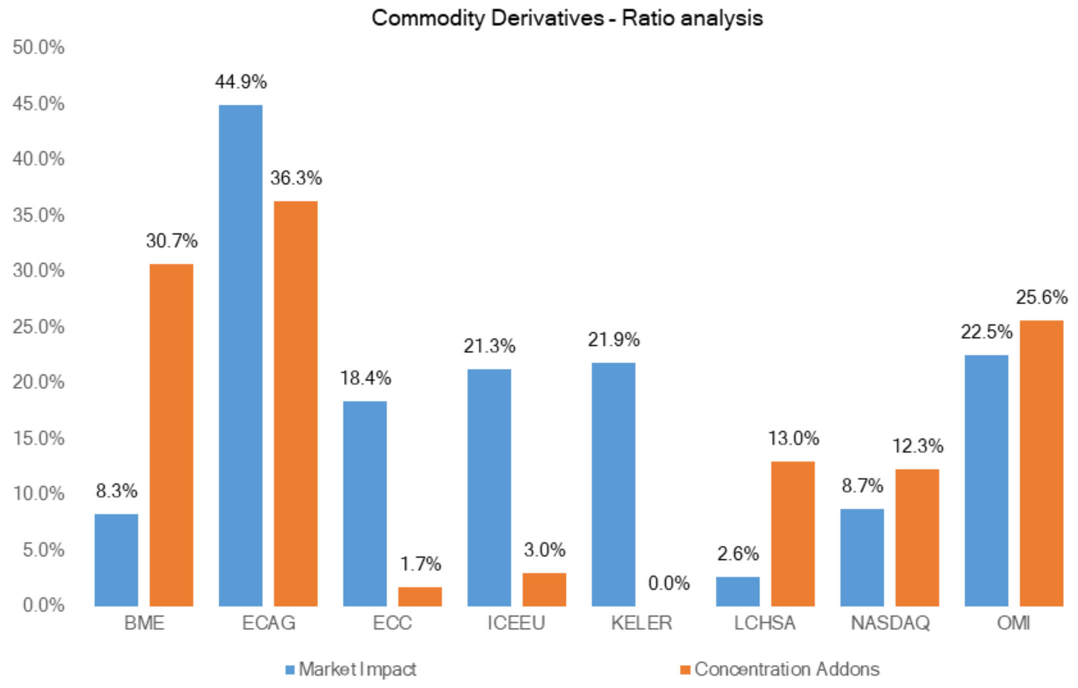
303. Within asset classes, the coverage of modelled market impact risk with concentration add-ons differs across CCPs. By normalising the market impact and the add-ons by the total required margin, both the importance of concentration and the different treatment by the CCPs can be visualized. This allows to draw conclusions, even for CCPs that did not report dedicated concentration add-ons.

304. For example, add-ons exceed the market impact in commodity derivatives only for some CCPs. The market impact would also use a very large part of the required margin the CCPs currently

charge in some cases. Keeping in mind the limitations of the exercise, this could indicate an insufficient coverage of concentration risk.

305. For the two main CCPs clearing commodities, ICEEU and ECC, the baseline model concentration risk is 7 to 10 times greater than their concentration addons. The gaps representing around 17% of required margin are 778m EUR for ECC and 5.6 bn EUR for ICEEU. The overall concentration risk for KELER is much smaller at 66k EUR.

306. Further, for emission allowances, ICEEU charges 573m EUR for a baseline model risk of 2.16 bn EUR (a gap of 1.59 bn EUR of 20% of the required margin for those products).



Note: Market Impact and Concentration addons normaiized by required margin.
Sources: ESMA

FIGURE 26: COMPARISON OF MARKET IMPACT AND CONCENTRATION ADD-ONS, COMMODITY DERIVATIVES

307. For fixed income derivatives, the add-ons and modelled market impacts are more in line. However, for ICEEU and KDPW modelled market impacts exceed add-ons by 442m EUR and KDPW of 8m EUR respectively.

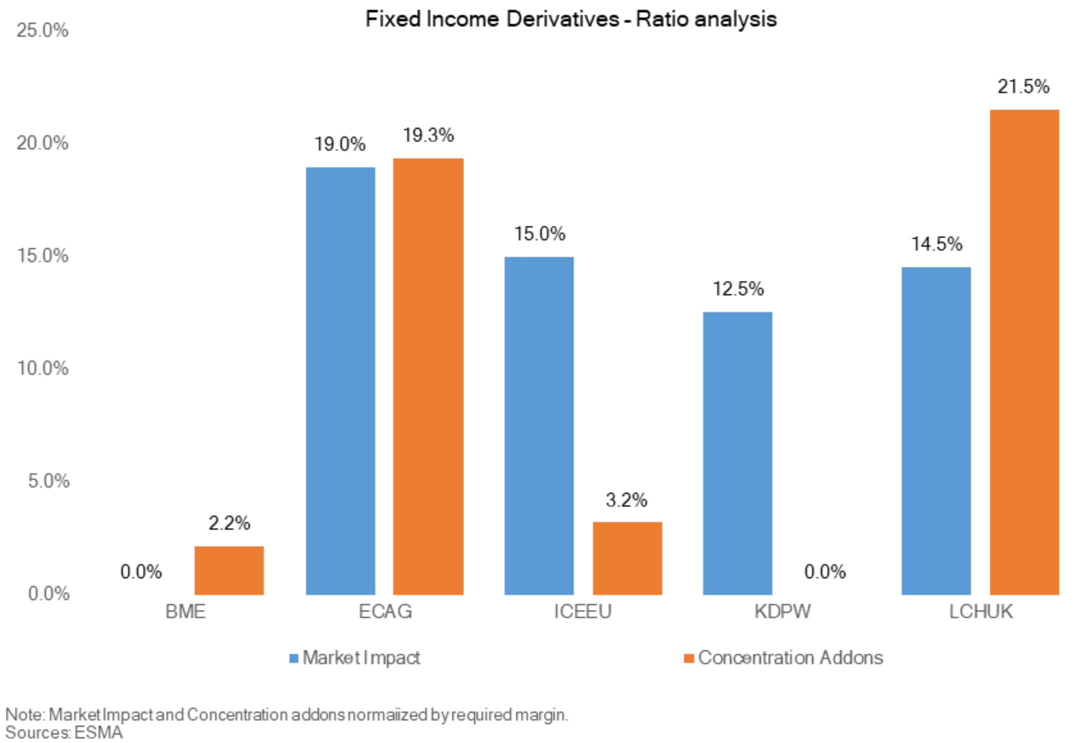
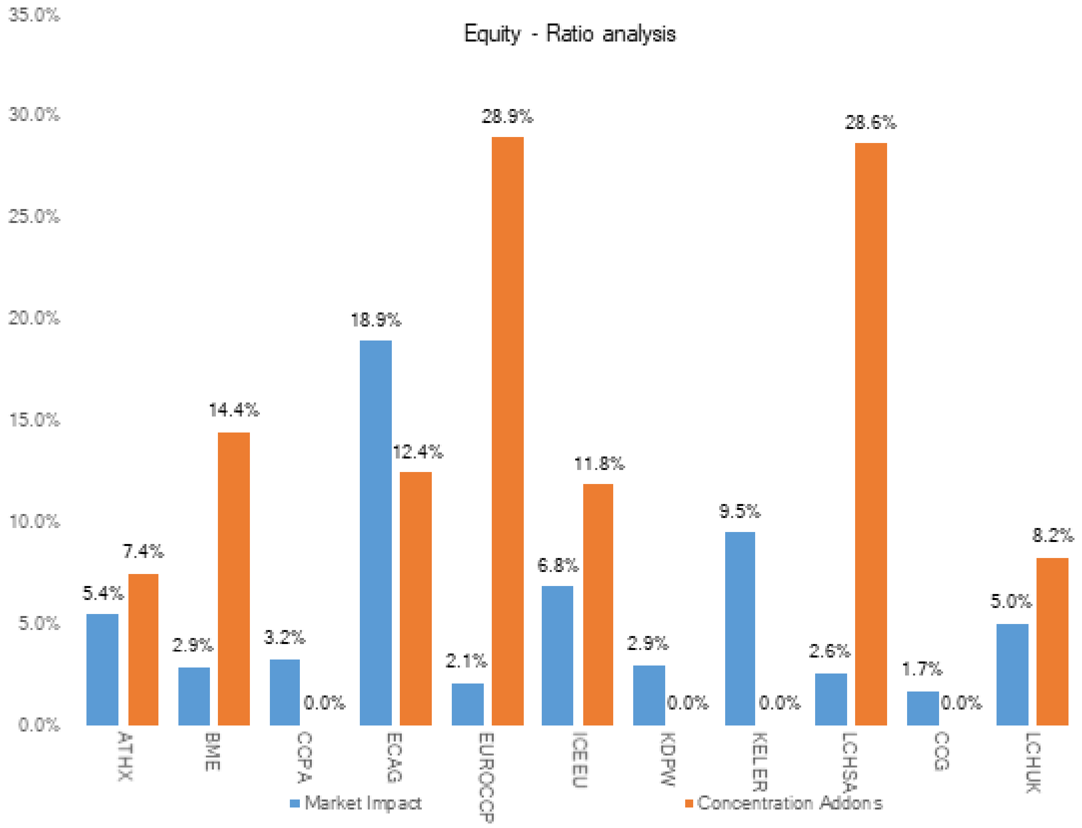


FIGURE 27: COMPARISON OF MARKET IMPACT AND CONCENTRATION ADD-ONS, FIXED INCOME DERIVATIVES

308. For equity and equity derivatives, concentration risk and add-ons seem overall to be balanced. However, it should be noted that ECAG, the CCP with the most concentrated positions, has a gap of 1.8 bn EUR (or 6.5% of the required margin). KDPW and KELER have gaps of 5m and 760k respectively.



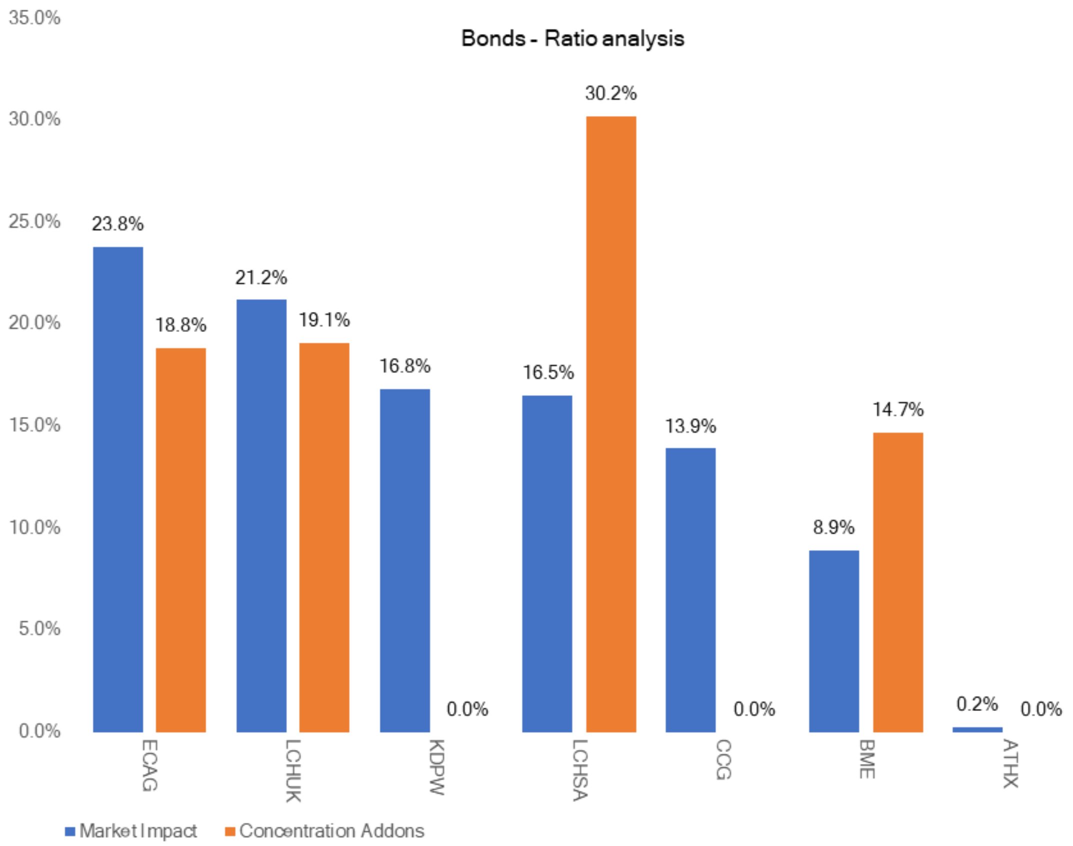
Note: Market Impact and Concentration addons normalized by required margin. Includes both Equity and Equity Derivaitves.
Sources: ESMA

FIGURE 28: COMPARISON OF MARKET IMPACT AND CONCENTRATION ADD-ONS, EQUITY

309. For bonds, CCG and KDPW did not report concentration addons for the stress testing date, leading to gaps of 1.06 Bn EUR and 840k EUR respectively.

310. KDPW implemented concentration addons for securities, but after the stress testing date. Hence, this change is not reflected in the results.

311. For CCG, over half of the total concentration risk is caused by the interoperable CCP and public or public owned entities. The results also do not assess a relevant model change proposed to introduce concentration add-ons.



Note: Market Impact and Concentration addons normaiized by required margin for bonds.
Sources: ESMA

FIGURE 29: COMPARISON OF MARKET IMPACT AND CONCENTRATION ADD-ONS, BONDS

312. Although all CCPs have market impact risk according to the framework, four CCPs (KDPW, CCPA, KELER, CCG) did not report any specific concentration add-ons.

313. Notwithstanding this limitation, ESMA looked at the overall margins and compared them with the market impact.

4.3.3.3 Accuracy of the coverage at clearing member level

314. As illustrated in the previous section, overall add-ons collected at CCP level cover the computed concentration risk. However, a large total amount of add-ons at default fund level does not correctly protect the mutualised resources if there is a mismatch at clearing member level between add-ons and concentration risk. Indeed, the market impact costs stemming from a defaulting clearing member's concentrated positions is only covered by the individual resources of this clearing member. Therefore, if the concentration risk is not covered properly at CM level, mutualised resources may still be consumed.

315. As previously shown, the level of add-ons charged at asset class / CCP level can differ widely from the market impact, but this could be explained mostly by the choice of sensitivity parameters.

316. It is also interesting to identify outliers where the market impact uses a large proportion of the required margin, putting the mutualised resources at risk.

317. Across CCPs, the baseline concentration risk accounts for more than 25% of required margin for 9.5% of clearing members, and more than 50% of required margin for 2.3% of them.

318. For those clearing members, before any prior market move, a large share of the required margin would be at risk in case of default.

319. It is therefore important for margin models to be not only conservative overall but also accurate.

320. A model that would build in some conservativeness (i.e. by using a longer margin period of risk) would be conservative most of time for most positions. However, in case a CM builds up some very large positions, the model may not be sufficient to cover the real concentration risk. In such a model, the adequate coverage of the market concentration risk at one point in time may not always demonstrate the robustness of the model to varying portfolios. This is in particular the case for securities, as the cleared portfolios can change a lot on a daily basis.

4.3.4 Additional risks

4.3.4.1 Vega risk

321. Products such as equity derivative options are sensitive to implied volatility. During the default management of a clearing member, this implied volatility sensitivity risk (vega) needs to be closed off or hedged before being auctioned off. For large optional positions, hedging vega or liquidation incurs further costs.

322. As with outright directional positions, such costs could arise from the bid ask spread or for the endogenous market impact.

323. Vega sensitivity was reported for equity derivatives and most commodity positions. ESMA staff computes the sensitivity of the market impact P&L for each 1 volatility point move. This sensitivity is then compared to the baseline (directional) market impact on all clearing member positions.

324. For equity instruments, a 1 volatility point impact when hedging the vega exposure represents 10% of the baseline model market impact from the delta exposure arising from both equity securities and derivatives. For commodities, the vega market impact is much smaller than the concentration risk from directional positions.

	1% VOL MARKET IMPACT	DELTA MARKET IMPACT
Commodity Derivatives	102,213,180 €	7,391,083,142 €
Equity (Securities & Derivatives)	677,053,411 €	6,865,975,310 €

325. The concentration risk stemming from implied volatility appears only significant for equity derivatives. Although smaller on aggregate than the market impact stemming from directional hedging, this is not the case for all portfolios even under only the 1% volatility assumption.

326. It should be noted that the further costs incurred from the vega liquidation are not part of the chosen baseline.

4.3.4.2 Model risk

327. It is notoriously difficult to estimate the price impact as a function of the sold volume for hypothetical sales under stressed market conditions. Moreover, the market impact parameters are derived from the CCPs' own estimates, with only few contributions for some asset classes.

328. The order of magnitude of the chosen estimates has been reported for transparency.

329. To assess model risk for securities, it was decided to model the price impact of fire sales based on the exponential specification in line with Cont and Schanning (2017)[37], with a market impact on securities calculated according to the formula:

$$\Psi_\phi(S_\phi) = B_\phi(1 - e^{-S_\phi \lambda_\phi / B_\phi}),$$

330. where $\lambda_\phi$is the impact parameter, B_ϕ the corresponding boundary parameter and S_ϕ the total amount sold.

331. Fukker et al. (2022)[38] extend the exponential specification with an approach that is similar to the CoVaR methodology of Adrian and Brunnermeier (2011)[39] with the exception that the qth quantile of the security-level price impact is estimated as a function of volumes sold and the system-level return. This is the basis for our benchmarking exercise.

$$\hat{R}^q_{\phi,t} = \hat{\beta}^q_0 (1 - \exp(-s_\phi V_{\phi,t})) + \hat{\beta}^q_1 R_{sys,t},$$

332. ISIN-level parameters are available for 1403 equity securities and 3244 bonds with calibration at quantile levels q in {0.05;0.10;0.15;0.20;0.25}. Those securities are responsible for around 75% of baseline market impact.

333. In this exercise, the tail returns at q = 0.05 is selected, given that they reflect best stressed market conditions. It is also assumed that one can apply the same parameters when closing short positions.

	Baseline model (bn EUR)	**Alternative model (bn EUR)**	**Difference**
Bonds	5.18	8.7	67.82%
Equity (with derivatives)	1.29	2.16	67.73%

TABLE 3: COMPARISON BETWEEN BASELINE AND ALTERNATIVE MODELS

334. The baseline model relies on the average daily volume as the only ISIN specific parameter. The alternative model uses a full functional form with 3 ISIN specific parameters. It does not rely on

[37] Cont, Rama and Eric Schaanning (2017). "Fire sales, indirect contagion and systemic stress testing".
[38] Fukker and al (2022). Contagion from market price impact: a price-at-risk perspective.
[39] Adrian, Tobias and Markus K Brunnermeier (2011). CoVaR. Tech. rep. National Bureau of Economic Research.

extrapolation beyond a cut-off (2 average daily volumes) and provides a cost even for the smallest positions.

335. The impact varies across CCPs, with a large CCP having a concentration risk 250% greater with the alternative model.

336. Although the alternative model only covers a subset of cleared securities, it evidences the importance of model risk for concentration risk.

4.3.5 Conclusions of Concentration Stress Test Results

337. The analysis shows that concentrated positions represent a significant risk for CCPs. Moreover, the overall risk is clustered in one or two CCPs for most asset classes.

338. ESMA calculation shows that fixed income derivatives have the most concentration risk, with a total over 29bn EUR. Bonds (including bonds from Repo clearing services) come next with a total modelled concentration risk of around 11 bn EUR.

339. Concentration modelled for commodity derivatives and the equity segment (securities and derivatives) is very significant as well, with around 7bn EUR of concentration risk calculated for each asset class. There is a very large coverage gap between the system-wide estimated market impact and margin add-ons, for commodity derivatives and to a lesser extent for equity products.

340. For the two main CCPs clearing commodities (ICEEU and ECC),the baseline model concentration risk is 7 to 10 times greater than the concentration addons. The gaps representing around 17% of required margin are 778m EUR for ECC and 5.6 bn EUR for ICEEU.

341. The modelled concentration risk for Emission Allowances stands also out at 2.5bn EUR and is not adequately covered per the ESMA methodology.

342. The concentration risk is factored in explicitly in a majority of CCPs through dedicated margin add-ons. Although all CCPs have market impact risk, four CCPs (KDPW, CCP.A, KELER, CCG) did not report any concentration add-ons. Since the data request date, KDPW and CCG have implemented or are in the process of introducing concentration addons. KELER relies on a monitoring system to require additional collateral in case of elevated concentration.

343. Margin models need to be not only conservative but also accurate. This is especially the case for liquid markets where large positions can build up very quickly.

4.4 Operational risk analysis

4.4.1 Results of the assessment of the general level of operational resilience of individual CCPs

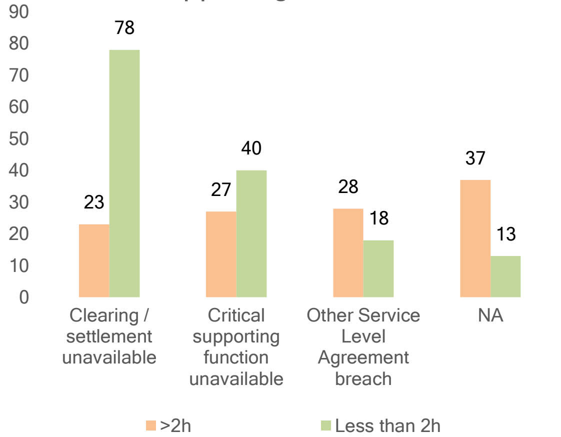
4.4.1.1 Descriptive analysis of operational risk events

Overview

344. A total of 14 CCPs (out of 15 in-scope CCP, cf. 3.6.1) reported a total of 330 operational risk events that occurred during the reporting period, implying on average around 4 events per CCP and per year. The number of events reported by CCPs ranged between 7 (1.2 per year) to 68 (12 events per year). In terms of impact, most operational risk events relate to the operational risk dimensions 'clearing/settlement unavailable' and 'critical supporting function unavailable' (Chart 1). Over time, the number of operational events has been rising to reach 91 events in 2020 (Chart 2). It is challenging to know whether this increase relates to better reporting by CCPs for more recent periods, or a genuine increase in the frequency of events. More than half of the reported events lasted more than the 2-hour target recovery time used with respect to clients, and 83 events lasted more than 10 hours (Chart 3), although the latter did not impact the core functions of CCPs[40]. Around half of the 'clearing/settlement unavailable' events lasted more than two hours and for the 'critical supporting function unavailable' or 'service level agreement breaches', the share of events lasting more than two hours amounted to more than 60% of the cases (Chart 4). This shows that events affecting the core services of CCPs had a shorter duration. On average, events affecting clearing or settlement had a duration of 6.5 hours compared with around 17 hours for events affecting critical supporting functions or resulting in SLA breaches.

Operational risk chart 1

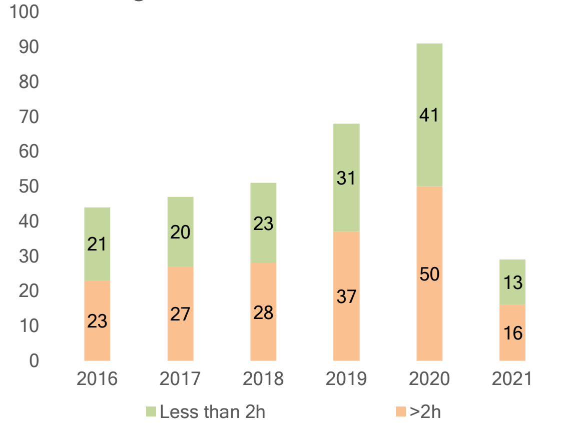
Operational risk events by type
Most events related to clearing/settlement and critical supporting function unavailable



Note: Number of operational events per type of impact
Sources: CCP, ESMA.

Operational risk chart 2

Number of events per year
The frequency of operational events has been rising

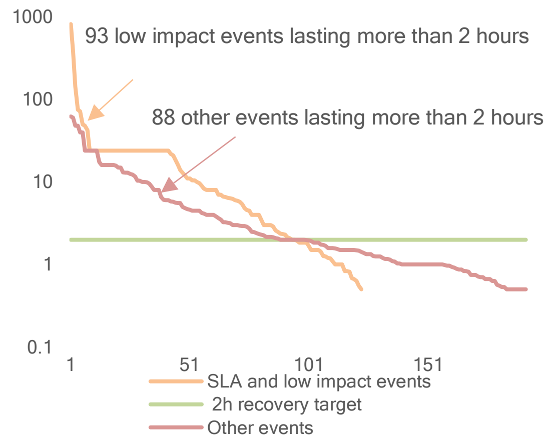


Note: Number of operational events per year.
Sources: CCP, ESMA.

[40] Around 65% (53 cases) of these very long cases resulted either in a breach of 'other service level agreement', and only affected a few clients or had an impact that affected less than 10% of the CCP's activity.

Operational risk chart 3

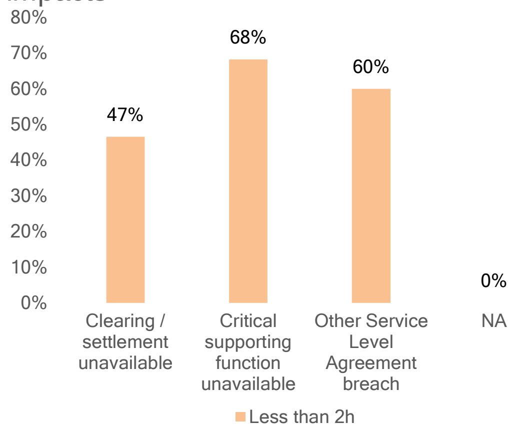
Distribution of duration of operational risk events
More than half of the events lasted more than the 2-hour target recovery time



Note: Duration time of operational risk events, in hours.
Sources: CCP, ESMA.

Operational risk chart 4

Risk events longer than 2 hours
Most long events related to the same impacts



Note: Share of long events (>2h) per type of impact
Sources: CCP, ESMA.

TABLE 4: OPERATIONAL RISK EVENTS BY TYPE, NUMBER OF EVENTS PER YEAR, DURATION OF EVENTS AND EVENTS LONGER THAN 2 HOURS

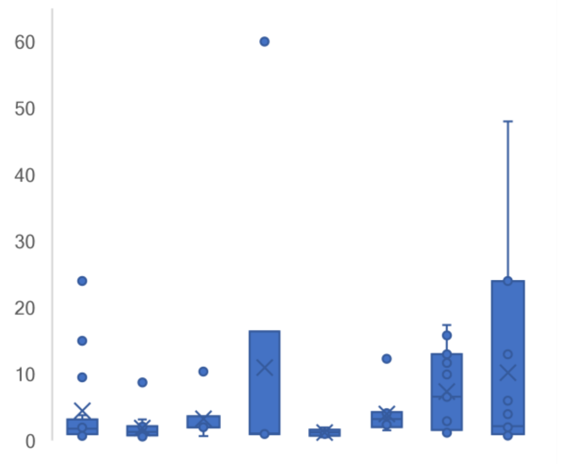
345. In the subsequent analysis ESMA staff focuses on events related to ‘clearing/settlement unavailable’ and ‘critical supporting functions unavailable’ because they are more critical to the functioning of CCPs and are less likely to be affected by reporting errors. Events with a minor impact (less than 10% of the CCP’s activity affected) are also excluded.

Events resulting in clearing or settlement unavailable

346. The sample covering events on the unavailability of clearing and settlement services (or core functions) includes 113 events across 14 CCPs. Most operational risks events are concentrated in a limited number of CCPs, with the number of events per CCP ranging from 1 to 26, with 6 CCPs reporting less than 5 events. Most events lasting more than two hours are related to payments or trade transactions and are mainly caused by third party issues. In terms of duration, Chart 5 shows a large dispersion among CCPs. Such operational events impact foremost at CCP level (the whole CCP activity is affected) or at clearing service level (Here, by clearing service we refer to the clearing activity linked to a segregated default fund, for CCPs that have different clearing services with separated default funds). This impact implies a lower severity than the whole CCP) rather than clients or products (Chart 6), which imply a lower level of severity. For each datapoint, additional information on the risk event type is reported, detailing whether the event is related to a third-party issue, a technology issue or issues around transaction processing and execution. Overall, most of the events are related to issues with third parties especially for events lasting more than 2 hours (87% of the 'long event' cases against 61% for the events lasting less than 2h). Technology accounts for 19% of the events (Chart 7), mainly concentrated in short events (30% of the cases) rather than long events (4% of the cases). Transaction processing and execution-related events accounted for 8% of the events reported, equally across short and long events. The impact of these events was mainly on payment and cash management (50% of cases) and to a lesser extent on trade acceptance (24%).

Operational risk chart 5

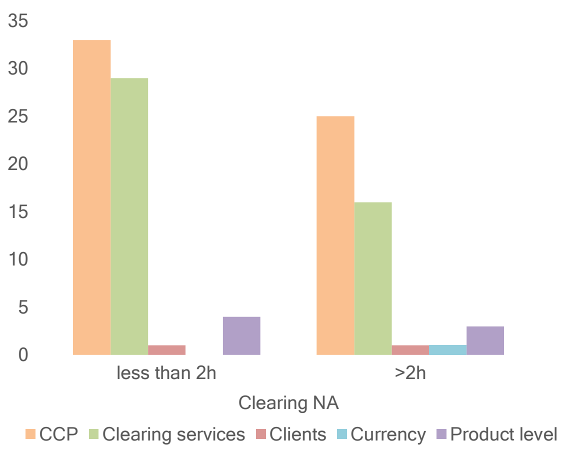
Distribution of events
High dispersion across CCPs



Note: The box plot shows the interquartile range (Q1-Q3) in the rectangular area, the median is indicated by a cross and the mean by an horizontal bar. Outlier points as shown by dots. Distribution of events duration by CCP, in hours. Only events leading to clearing/settlement unavailable. CCP with less than 5 events not shown.
Sources: CCP, ESMA.

Operational risk chart 6

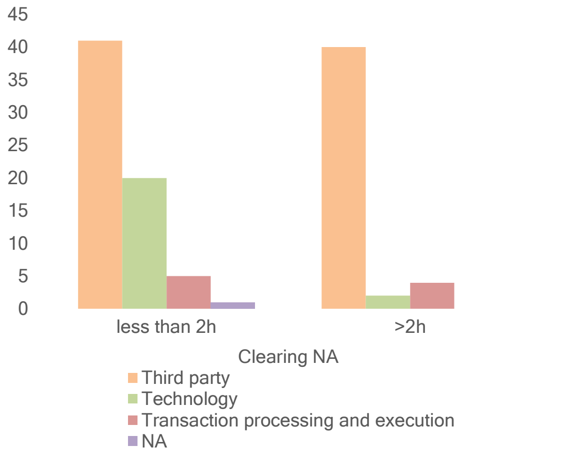
Scope
Clearing services and CCP most impacted



Note: Number of events by scope for clearing/settlement unavailable.
Sources: CCP, ESMA.

Operational risk chart 7

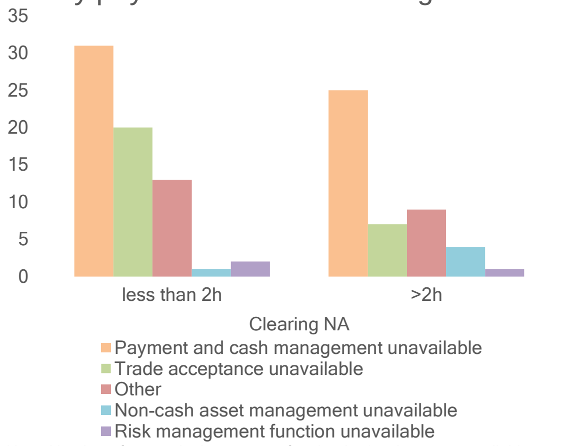
Risk event type
Most events related to third party issues



Note: Number of events by risk event type for clearing/settlement unavailable.
Sources: CCP, ESMA.

Operational risk chart 8

Type of impact
Mainly payment and cash management



Note: Number of events by impact type for clearing/settlement unavailable.
Sources: CCP, ESMA.

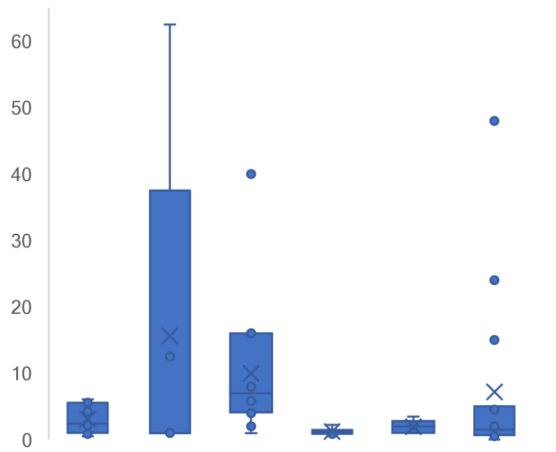
TABLE 5: EVENTS RESULTING IN CLEARING OR SETTLEMENT UNAVAILABLE – DISTRIBUTION OF EVENTS, SCOPE, EVENT TYPE AND IMPACT TYPE

Events resulting in critical functions unavailable

347. The sample covering events resulting in the unavailability of critical functions includes 80 events across 12 CCPs, with the number of events per CCP ranging from 1 to 20 and 6 CCPs reporting less than 5 events. In terms of duration, Chart 9 shows a large dispersion among CCPs. Such operational events impact foremost the CCP and clearing services rather than clients or products (Chart 10). Most of the events — as for clearing or settlement unavailable — are related to issues with third parties (58% of the cases). Events related to technology account for 26% of the cases, with similar patterns irrespective of the duration of the events. The impact of these events was mainly on the risk management function of CCPs (45% overall, 56% for long events) and on 'other' critical supporting functions (28%). Events related to 'other' include delay issues with pricing data and connectivity issues.

Operational risk chart 9

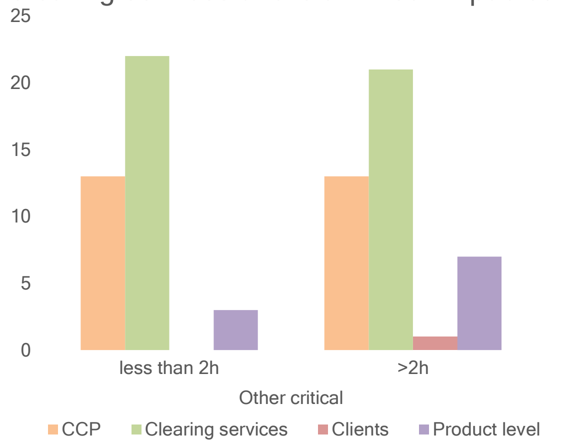
Distribution of events
High dispersion across CCPs



Note: The box plot shows the interquartile range (Q1-Q3) in the rectangular area, the median is indicated by a cross and the mean by an horizontal bar. Outlier points as shown by dots. Distribution of events duration by CCP, in hours. Only events leading to critical functions unavailable. CCP with less than 5 events not shown.
Sources: CCP, ESMA.

Operational risk chart 10

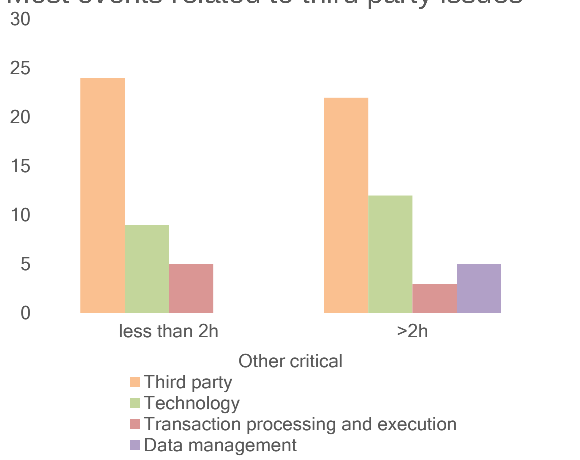
Scope
Clearing services and CCP most impacted



Note: Number of events by scope crticial supporting function unavailable.
Sources: CCP, ESMA.

Operational risk chart 11

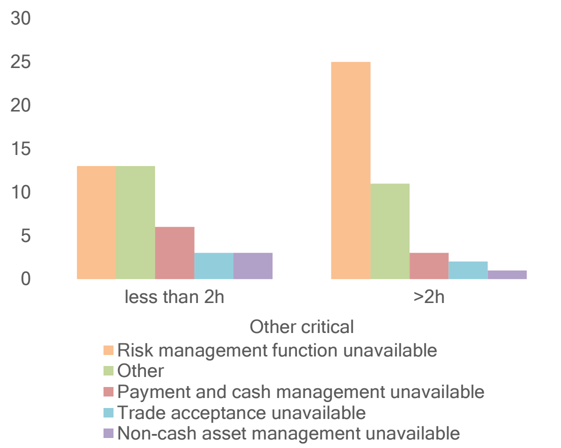
Risk event type
Most events related to third party issues



Note: Number of events by risk event type critical supporting functions unavailable.
Sources: CCP, ESMA.

Operational risk chart 12

Type of impact
Mainly risk management



Note: Number of events by impact type for critical supporting function unavailable.
Sources: CCP, ESMA.

TABLE 6: EVENTS RESULTING IN CRITICAL FUNCTIONS UNAVAILABLE – DISTRIBUTION OF EVENTS, SCOPE, EVENT TYPE AND IMPACT TYPE

4.4.1.2 Operational reliability metrics: Results

348. Using the reliability metrics described in the methodology ESMA staff computed results for both the $Type\ of\ impact$ "Clearing / settlement unavailable" and the $Type\ of\ impact$ "Critical supporting function unavailable" (see section 3.6.2.5).

349. The results are evaluated in conjunction with the percentile metrics in section 4.4.1.4.

Operational risk chart 13

Reliability metrics

Type of impact: Clearing / settlement unavailable

Critical functions				
CCP	MTBF_days	MTTR_hours	Expected_1y_downtime_hours	Average activity affected
CCP14	416.7	1.0	0.6	38%
CCP06	312.5	0.8	0.7	100%
CCP02	416.7	1.3	0.8	75%
CCP08	1250.0	4.0	0.8	11%
CCP13	250.0	1.2	1.2	67%
CCP01	250.0	1.2	1.2	60%
CCP12	416.7	2.4	1.4	99%
CCP11	178.6	3.3	4.6	100%
CCP09	89.3	1.9	5.3	99%
CCP03	138.9	4.0	7.2	61%
CCP10	625.0	21.0	8.4	100%
CCP04	83.3	7.4	22.2	95%
CCP07	48.1	4.5	23.4	74%
CCP05	69.4	8.4	30.1	56%

FIGURE 30: CLEARING / SETTLEMENT UNAVAILABLE: RELIABILITY METRICS

350. Overall, we observe high levels or reliability across CCPs; the list of CCPs is ordered using the expected aggregated amount of downtime (or unavailability) per year, the top half of entities exhibit very low expected downtime values, meanwhile the bottom three entities exhibit figures that signal a higher level or risk.

351. While expected downtime is an important figure, for FMIs it is particularly important to minimize the Mean Time to Repair, in order to achieve availability of the clearing services with a Recovery Time Objective of two hours. In this sense we pay particular attention to CCPs with high values of MTTR that don't have Mean Time Between Failures values of a very high magnitude (which would imply that events are very rare, and our conclusions may not be significant), Using these criteria we observe high MTTR values for CCP10, although for CCP10 the high value of MTBF indicates that the figures may be driven a very small number of events.

Operational risk chart 14

Reliability metrics
Type of impact: Critical supporting function unavailable

Critical supporting functions				
CCP	MTBF_days	MTTR_hours	Expected_1y_downtime_hours	Average activity affected
CCP11	1250.0	1.5	0.3	25%
CCP13	625.0	1.3	0.5	100%
CCP02	416.7	1.0	0.6	53%
CCP14	312.5	1.5	1.2	85%
CCP03	625.0	4.0	1.6	78%
CCP12	250.0	1.9	1.9	100%
CCP09	156.3	1.2	2.0	100%
CCP01	1250.0	10.0	2.0	68%
CCP07	89.3	3.1	8.6	41%
CCP08	250.0	15.6	15.6	51%
CCP05	250.0	17.4	17.4	87%
CCP10	62.5	10.0	39.9	75%

FIGURE 31: CRITICAL SUPPORTING FUNCTIONS UNAVAILABLE: RELIABILITY METRICS

352. For critical supporting functions we observe slightly higher levels or resilience, with some CCPs reporting not incidents.

353. Only the bottom four entities exhibit metrics that suggest that further supervisory analysis should be performed, with CCP07 being a different case than the other three, as rather than exhibiting incidents with long duration, the low MTBF and MTTR indicate recurrent frequent problems with short remediation times.

4.4.1.3 Estimation of percentile metrics: methodology and results

354. The data on operational risk events can be used to assess the likelihood and impact of disruptions using the loss distribution approach commonly used to estimate operational risks for banks. The underlying idea is that observed events are 'draws' from a specific frequency distribution (which describes the average number of events over a given time horizon) and from a specific severity distribution (which describes the duration of the disruption time). By calibrating the parameters of the frequency and severity distributions and running a large number of numerical simulations, one is then able to estimate the distribution of operational events[41].

355. The objective of these metrics is to produce measurements that reflect stressed conditions and complement the operational metrics based on mean measurements.

356. The model methodology, its assumptions, calibration and model risk analysis are provided in Annex 6.3.

[41] See Shevchenko (2010) for details on the loss distribution approach. Shevchenko, P. (2010), "Calculation of aggregate loss distributions", Journal of Operational Risk Vol.5 (2).

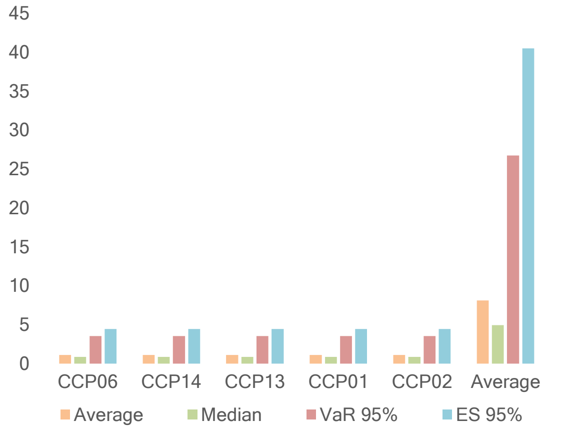
Results for clearing or settlement unavailable

357. For each CCP, ESMA staff obtained results which are driven by two factors: the average frequency of operational events and the severity distribution which depends on the bucket the CCP belongs to[42]. The charts below show that for CCPs in the lowest severity group, the total disruption time in a given year would be below 2 hours on average and would remain below 10 hours in the most extreme cases (VaR and expected shortfall at 95% level). For CCPs in the second group (low severity), total disruption time would be below 6 hours but in the most extreme cases could range up to 21 hours. CCPs in group 3 (high severity) exhibit some variation because some of the CCPs had more frequent disruptions than others, resulting in a higher frequency of events and relatedly more total disruption time on average. Overall, average disruption time would be below 10 hours for two CCPs but above that mark for one other CCP with more frequent events. In extreme cases, total disruption time could be higher than 50 hours for at least one CCP. Finally, two CCPs in the highest severity bucket have median disruption time above 25 hours per year, while the other CCP would have a median disruption time around 9 hours, and all the CCPs in this bucket would have total disruption times above 50 hours in extreme cases.

Operational risk chart 15

Risk indicators for group 1 (lowest severity)

Total median disruption time below 2h

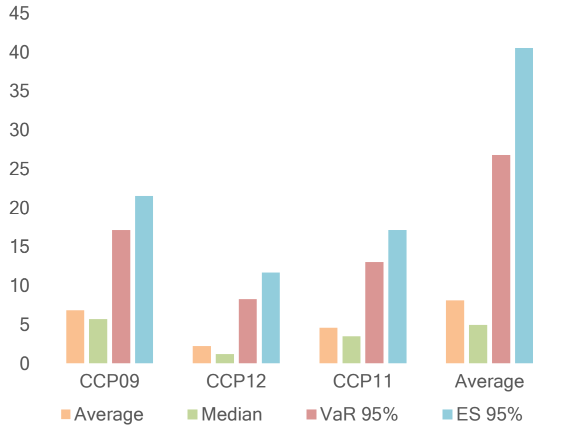


Note: Sum of disruption time over one-year for clearing or settlement unavailable, in hours
Sources: CCPs, ESMA

Operational risk chart 16

Risk indicators for group 2 (low severity)

Total median disruption time below 6h

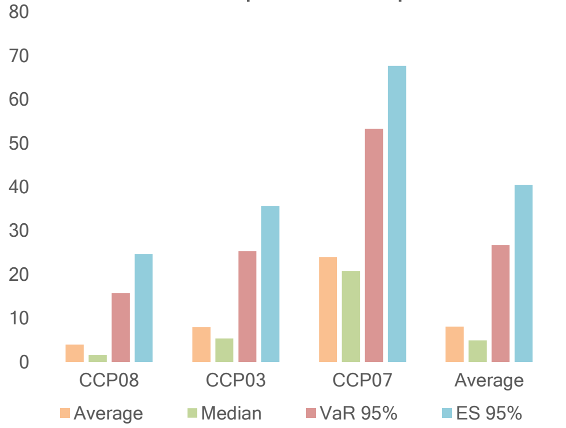


Note: Sum of disruption time over one-year for clearing or settlement unavailable, in hours
Sources: CCPs, ESMA

[42] In a few cases, some CCPs had a low number of events (low frequency) but these events lasted for long. Therefore, for some CCPs in group 4 the total median disruption time in one year might be lower than CCPs in group 3 (which had a higher frequency of events.

Operational risk chart 17

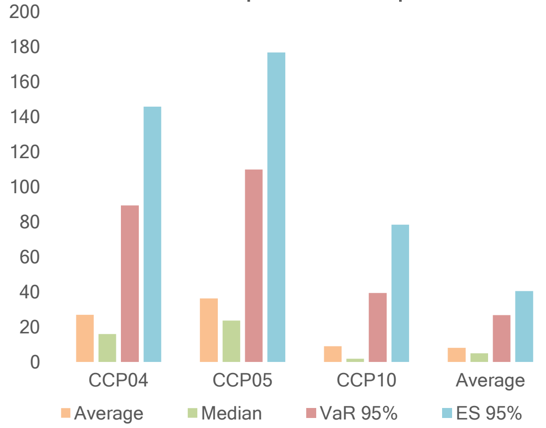
Risk indicators for group 3 (high severity)
Total median disruption time up to 20h



Note: Sum of disruption time over one-year for clearing or settlement unavailable, in hours
Sources: CCPs, ESMA

Operational risk chart 18

Risk indicators for group 4 (highest severity)
Total median disruption time up to 24h



Note: Sum of disruption time over one-year for clearing or settlement unavailable, in hours
Sources: CCPs, ESMA

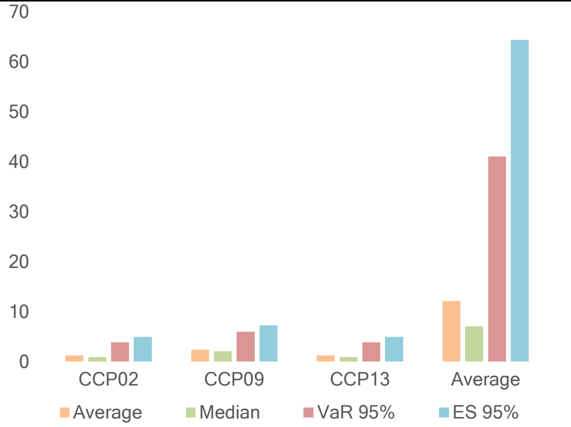
FIGURE 32: RISK INDICATORS BY SEVERITY GROUPS- CLEARING OR SETTLEMENT UNAVAILABLE

Results for critical supporting functions unavailable

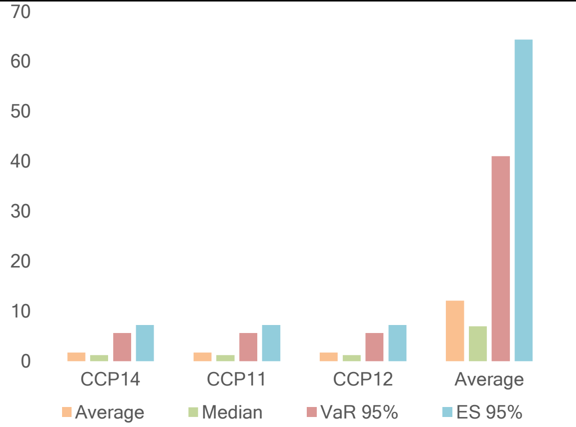
358. For each CCP, ESMA staff obtained results which are driven by two factors: the average frequency of operational events and the severity distribution which depends on the bucket the CCP belongs to[43]. Qualitatively, the results are similar to those described in the previous section. First, CCPs in the lowest severity group have an average total disruption time below or close to 2 hours and even in the extreme cases disruption time remains below 10 hours. Second, CCPs in the low severity group have slightly longer disruption time but are quite close to the first group. Third, one of the CCPs in the high severity group would have disruption time higher than 10 hours on average and more than 30 hours in extreme cases. Finally, CCPs in the highest severity group could experience long disruption time on average (more than 12 hours) and more than 80 hours for all those CCPs in extreme circumstances.

Operational risk chart 19	Operational risk chart 20
Risk indicators for group 1 (lowest severity) Total median disruption time below 2h	Risk indicators for group 2 (low severity) Total median disruption time below 2h

[43] In a few cases, some CCPs had a low number of events (low frequency) but these events lasted for long. Therefore, for some CCPs in group 4 the total median disruption time in one year might be lower than CCPs in group 3 (which had a higher frequency of events.



Note: Sum of disruption time over one-year for critical supporting function unavailable, in hours
Sources: CCPs, ESMA

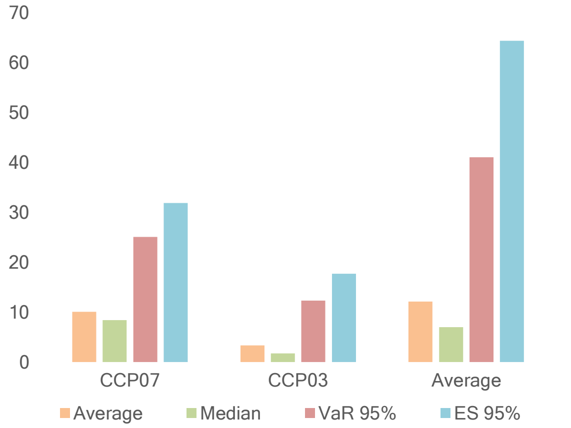


Note: Sum of disruption time over one-year for critical supporting function unavailable, in hours
Sources: CCPs, ESMA

Operational risk chart 21

Risk indicators for group 3 (high severity)

Total median disruption time up to 8h

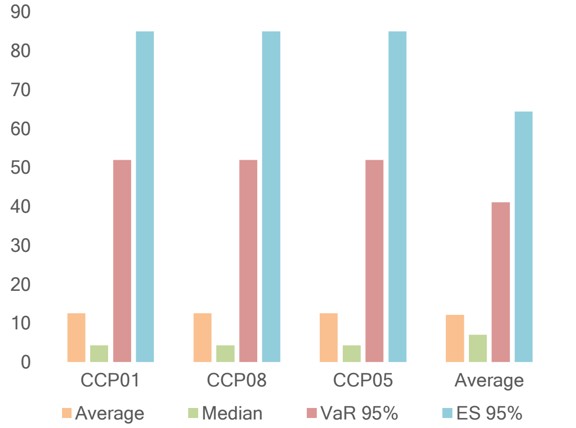


Note: Sum of disruption time over one-year for critical supporting function unavailable, in hours
Sources: CCPs, ESMA

Operational risk chart 22

Risk indicators for group 4 (highest severity)

Disruption time higher than 80h in extreme cases



Note: Sum of disruption time over one-year for critical supporting function unavailable, in hours
Sources: CCPs, ESMA

FIGURE 33: RISK INDICATORS BY SEVERITY GROUPS- CRITICAL SUPPORTING FUNCTIONS UNAVAILABLE

4.4.1.4 Identification of entities with higher measured risk

359. In order to perform a final evaluation, ESMA staff compared the combined results from two of the risk indicators developed: the expected 1yr downtime and the estimated 95th percentile 1yr downtime, in order to identify CCPs that are performing worse than average in both for the sample of CCPs.

Operational risk chart 23

Scatterplot: Expected 1y downtime and estimated 95th percentile downtime
Type of impact: Clearing or settlement unavailable

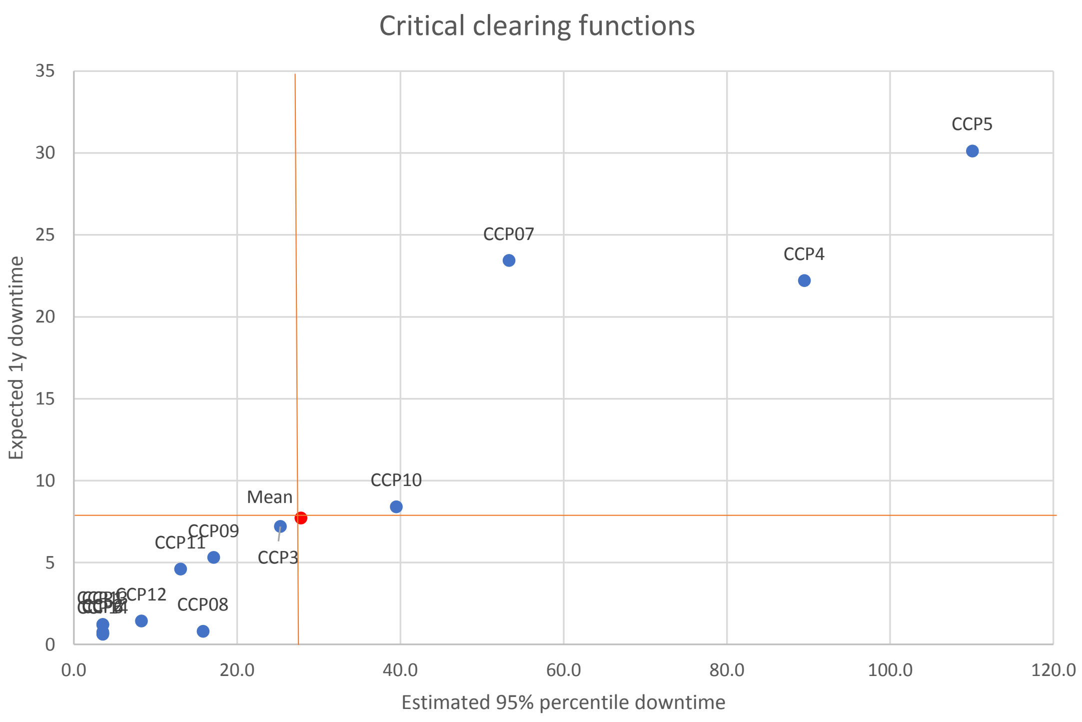


FIGURE 34: EXPECTED 1Y DOWNTIME AND ESTIMATED 95TH PERCENTILE DOWNTIME - CLEARING OR SETTLEMENT UNAVAILABLE

360. Using Chart 23, for the category of critical clearing functions ESMA staff identifies three CCPs where risk indicators signal higher risk: CCP04, CCP07 and CCP05. This implies that in terms of availability, operational risk for clearing or settlement (‘critical clearing functions) might be higher for those CCPs. Therefore, further scrutiny of prevention and recovery tools for those CCPs is key.

Operational risk chart 24

Scatterplot: Expected 1y downtime and estimated 95th percentile downtime
Type of impact: Critical supporting function unavailable

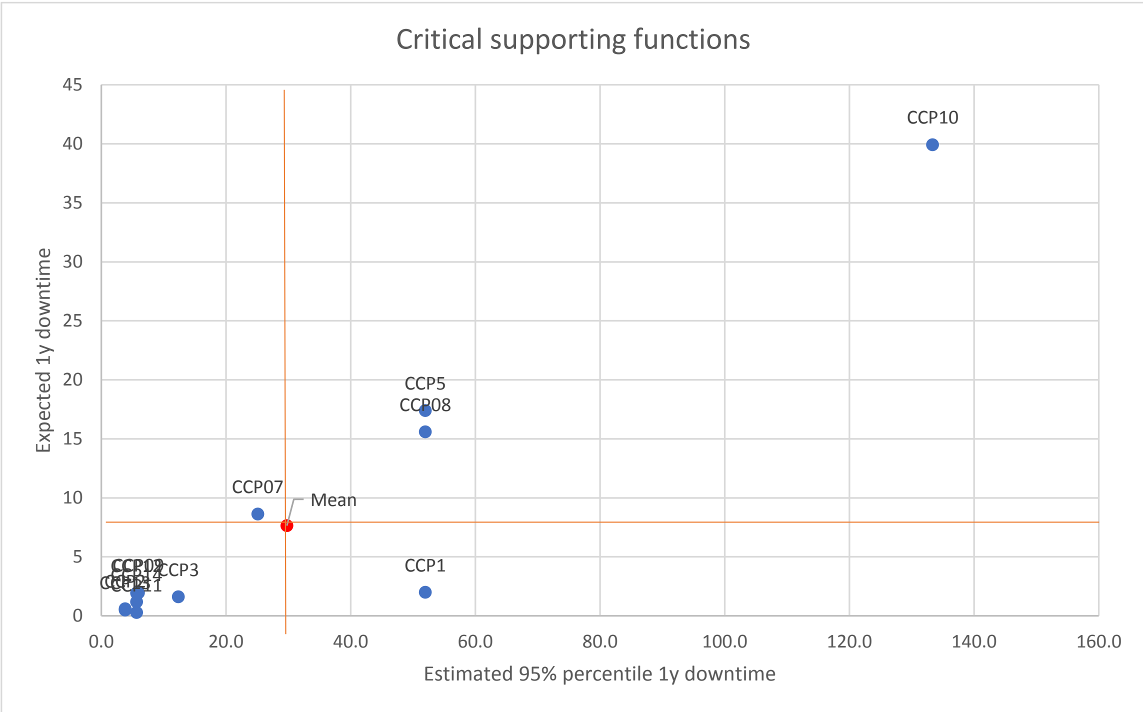


FIGURE 35: EXPECTED 1Y DOWNTIME AND ESTIMATED 95TH PERCENTILE DOWNTIME – CRITICAL SUPPORTING FUNCTIONS UNAVAILABLE

361. Using Chart 24, for the category of critical supporting functions ESMA staff identified three CCPs where risk indicators signal higher risk than their peers: CCP08, CCP05 and CCP10.

362. It must be noted that due to the construction of the category "Critical supporting function", there is a higher degree of heterogeneity in the events included and the impact for the CCPs is of lower importance than the events of the category with impact "Clearing or settlement non-available", as they do not ultimately affect the ability of customers to access clearing (e.g: incidents affecting accuracy of internal risk management systems are relevant from a supervisory monitoring perspective but they would typically have limited operational impact to customers). The heterogeneity of this category suggests that further detailed analysis of individual events should be performed in order to reach definitive conclusions about the underlying risk signaled by the indicators.

4.4.1.5 Conclusions

363. The analysis confirms that operational risk is a substantial risk for CCPs that may impact their resilience. During the reporting period, CCPs experienced a range of operational risk events affecting their clearing and settlement activity or some of their critical supporting functions. The reported data suggests that the number of events is increasing, although caution is needed in interpreting the data. The current level of data quality and early development of methodologies suggest caution in drawing preliminary conclusions and their use should be focused on

identifying areas of risk to direct supervisory efforts. A key finding is that most of the operational events stem from issues in the provision of third-party services. This is subject to further analysis in the following sections.

364. Overall, CCPs exhibit high levels of reliability, as it is expected for this type of entity. However, there is variation across CCPs both with regards to the general level of operational risk measured and to the presence of incidents with long remediation timeframes or recurrence.

365. Using the information about internal incidents of CCPs systems and third-party providers ESMA staff developed two methodologies to measure operational risk from historical events for individual CCPs. With the computed results ESMA staff identified specific CCPs for which, based on the expected 1yr downtime and the estimated 95th percentile 1yr downtime, further specific work is warranted to understand the drivers of these differences, the root causes of the events and the remediation actions taken.

366. Looking forward, further work on a consistent reporting of operational risk events might be warranted. While CCPs already disclose publicly information on availability through the CPMI-IOSCO disclosures, a more consistent framework for collecting and reporting operational risks events to NCAs and ESMA would improve the quality of the analysis and support the monitoring of risks for CCPs.

4.4.2 Results of the assessment of risk exposures of individual CCPs to critical third-party service providers

4.4.2.1 Exposures of individual CCPs to critical third-party service providers without taking into account risk management tools

367. In line with the methodology, CCPs reported the critical third-party service providers on which they rely in order to provide their clearing services. The total number of third-party entities and the type of entity is shown in Chart 25.

368. From the data reported, significant variations are observed, with the minimum being around ten providers and the maximum nearly sixty providers. All CCPs use FMI services, which are mainly CSDs, trading Venues, settlement systems and payment systems; Also, all CCPs use non-financial services, such as technology providers, telecommunications and utility providers or specialized data providers; All but one CCPs use intragroup services, which directly relates to governance and the structure or the organisation of the CCP. Most CCPs also rely on different financial services for payments, custody, data, default management, settlement, investment and liquidity needs.

Operational risk chart 25

Number of critical third-party service providers per CCP by entity type

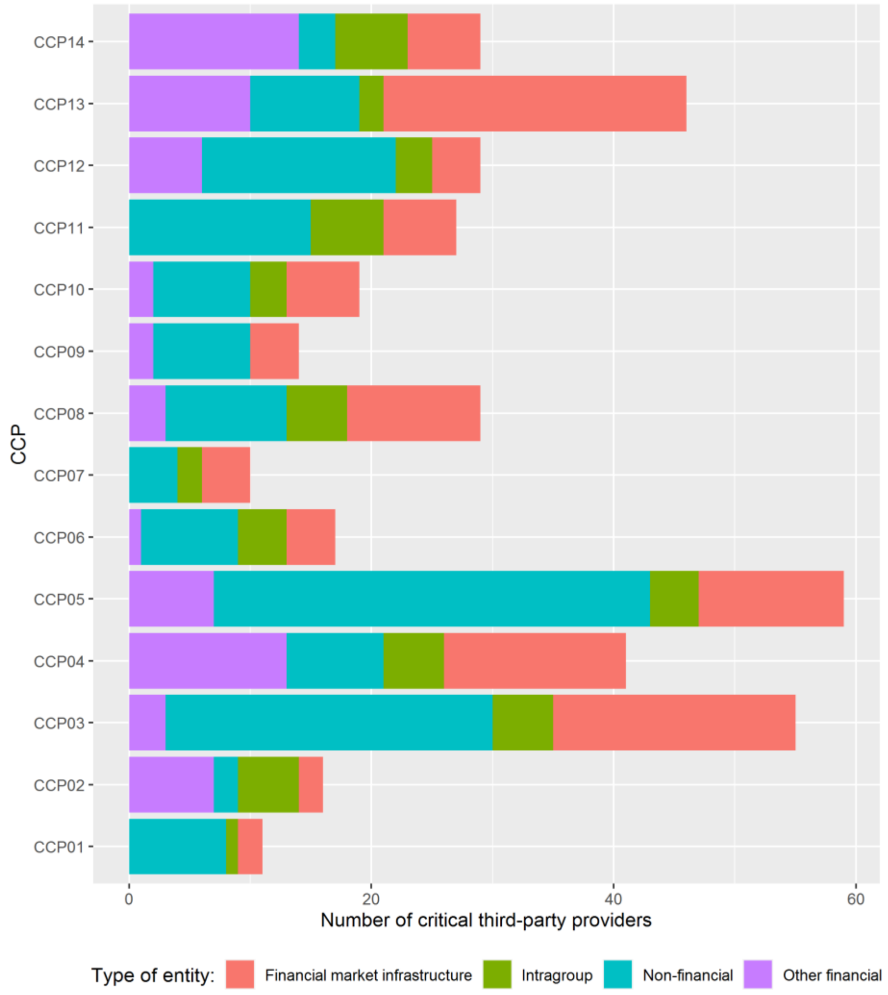


FIGURE 36: NUMBER OF CRITICAL THIRD-PARTY SERVICE PROVIDERS PER CCP BY ENTITY TYPE

369. The variation in these numbers across CCPs may be driven by various factors:

- Size and complexity of the CCP: Higher operational complexity may require the reliance on more critical third-party service providers.

- Exposure to each individual provider: When counting the number of providers, a value of one is assigned to each of them, however some entities may have a higher number of providers with each serving only segments of the activity, while others may rely on a more reduced number of providers that serve the whole CCP. This will be adjusted when using Weighted Exposure indicators later in this section in order to determine the relative exposure towards each third-party service provider.

- Risk management strategy: Building redundancy increases the number of third-party entities with relationship to a CCP, but its risk reducing (e.g.: A CCP may rely on one third-party service providers for a specific function, while another CCP may decide to have two providers for the same function, so that in case one is not available, they have another provider operationally set-up). This will be taken into account through the hypothetical scenario and modelling of risk management tools.

370. In the below figure, one can observe the weighted exposure per CCP and the difference with respect to just counting the number of linked third-party service providers. The number of third-party service providers is adjusted by weighting each service with the percentage of CCP clearing activity that they support (in line with the methodology described in section 3.6.3.7). The weighted metric adjusts for the exposure to each individual critical third-party provider and allows for a better comparability across CCPs that may have different operational structures. Furthermore, the reduction in exposure for the CCPs with a higher number of linked third-party service providers is higher than for those with lower number of linked third-party service providers. This is aligned with expectations, as entities with higher levels of operational complexity will tend to have more third-party service providers that serve only specific segments of the CCP.

Operational risk chart 26

Adjusting the number of critical third-party service providers weighting each of them with the percentage of CCP clearing activity they service

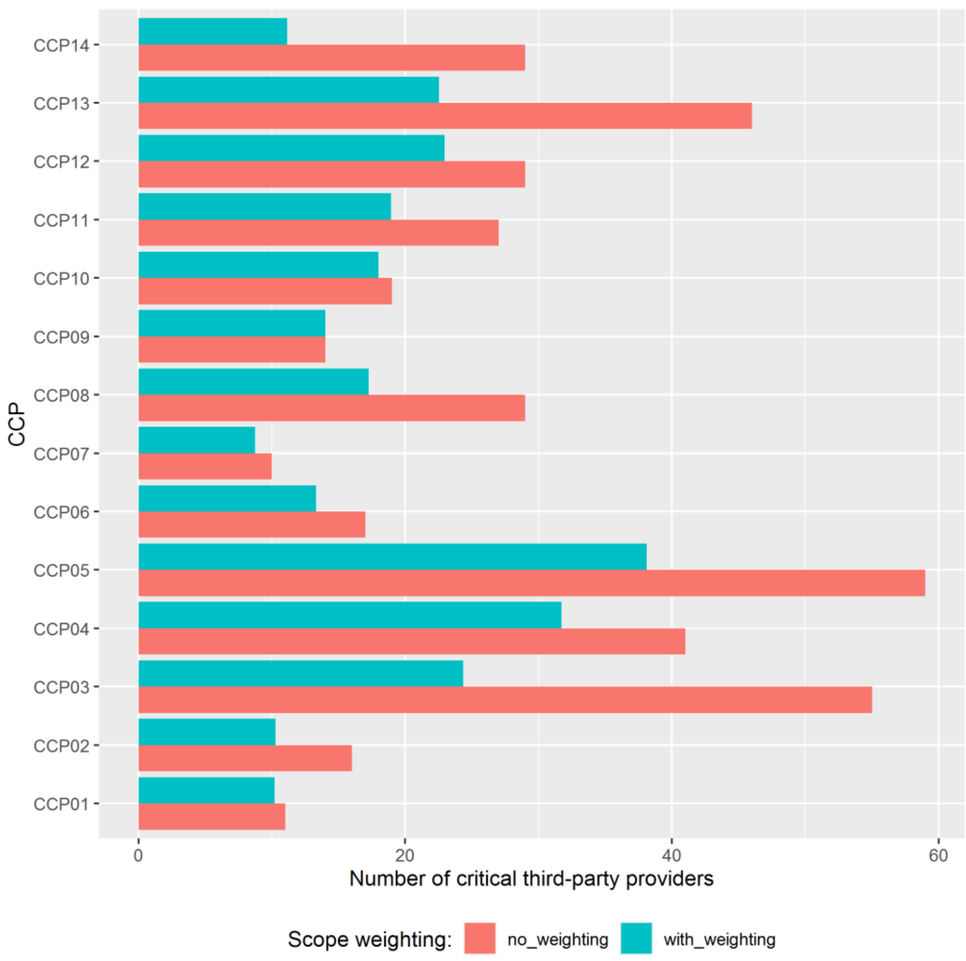


FIGURE 37: COMPARISON BETWEEN WEIGHTED AND NOT-WEIGHTED NUMBER OF CRITICAL THIRD-PARTY SERVICE PROVIDERS PER CCP

4.4.2.2 Reducing CCP exposures to third-party service providers through risk mitigation tools for a hypothetical scenario of an outage affecting a critical third-party provider

371. For our analysis of exposures, we follow a similar approach with respect to "Type of Impact" as in section 4.4.1., we analyse separately exposures with a severity in case of failure such that critical clearing or settlement functions would be affected from those in which a critical supporting function would be affected.

372. First, we look at the overall level of exposure of all CCPs before and after considering operational risk management tools in order to draw general conclusions and then we provide the exposures after considering risk management tools per CCP.

Overall risk reduction for exposures to entities that would have an impact to critical clearing or settlement functions

Operational risk chart 27

Aggregated exposures of CCPs towards third-party service providers before and after taking into account operational risk management tools. Exposure with impact to critical clearing or settlement functions.

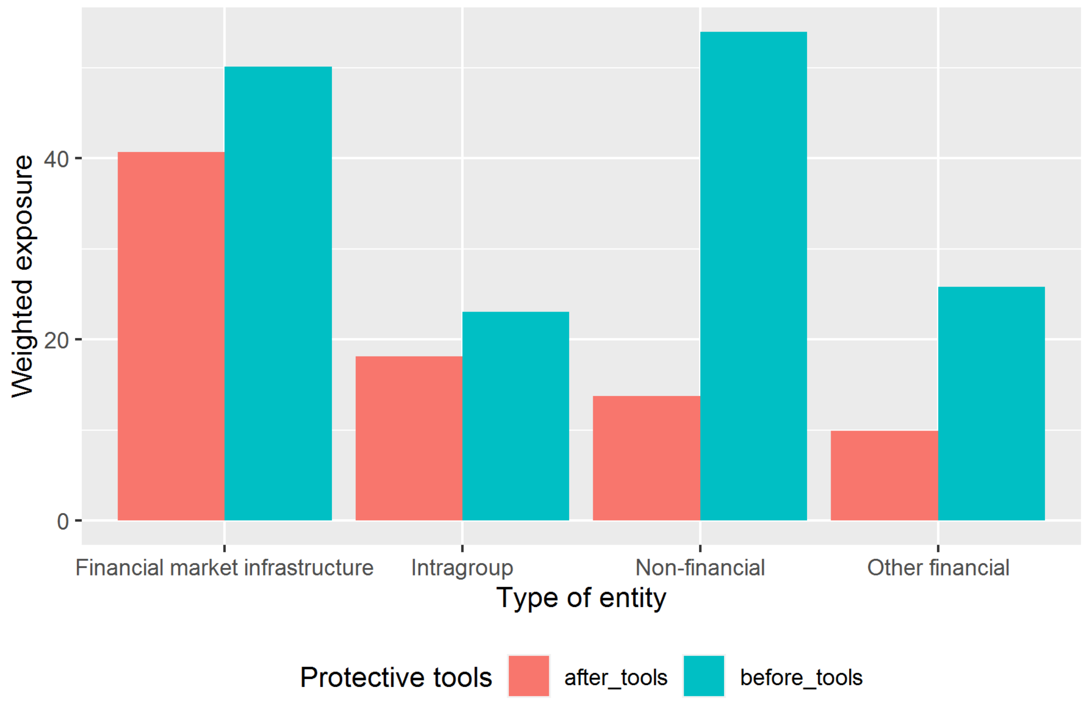


FIGURE 38: RISK REDUCTION FOR CCPS' CLEARING AND SETTLEMENT FUNCTIONS EXPOSURE TO THIRD-PARTY SERVICE PROVIDERS USING OPERATIONAL RISK MANAGEMENT TOOLS

373. This section adjusts the operational risk exposures of CCPs towards third-party service providers by taking into account the operational risk management tools that the CCP applies to manage and mitigate its operational risks toward the critical third-party service providers. When calculating the third-party exposure ESMA staff starts with the total number of providers, adjust individual entity exposures to the CCP's activity they serve (in order to enable comparability and adjust for relative importance) and transform the exposures to residual exposures with respect to the application of operational risk management tools, using the assumption that the mitigation tools work. The exposures after the application of tools are determined by using the residual exposures after tools reported by CCPs (in line with methodology section 3.6.3.6)

374. When analysing the reduction of exposures of CCPs towards critical third-party service providers through the use of operational risk management tools, one first observes that for the FMI category there is very limited change between exposures before and after tools; this may be due to the low substitutability of the services provided by these types of entities (so even if CCPs wanted to build mitigation risk management tools it may not be possible) or the expectation that FMIs will behave in a resilient manner.

375. The change between exposures before and after tools for intragroup entities shows a pattern that is similar to FMIs. In this case the most probable explanation is that intragroup entities are usually an extension of internal systems that are shared across different entities belonging to the same corporate group, hence the logical strategy to increase resilience would be through improvements at an internal level rather than through third-party risk mitigation tools. In any case, different strategies with respect to corporate structure and intragroup services do not imply different levels of risk per se.

376. For exposures to non-financial and other financial entities, one observes a substantial reduction with respect to exposures before considering tools. This can be explained by the availability of alternatives and substitutes in the market that the CCP can engage with, coupled with a motivation by CCPs to build resilient operations and minimize the number of single points of failure that depend on third-party entities out of their direct control.

Overall risk reduction for exposures to entities that would have an impact to critical supporting functions

Operational risk chart 28

Aggregated exposures of CCPs towards third-party service providers before and after taking into account operational risk management tools. Exposure with impact to critical supporting functions.

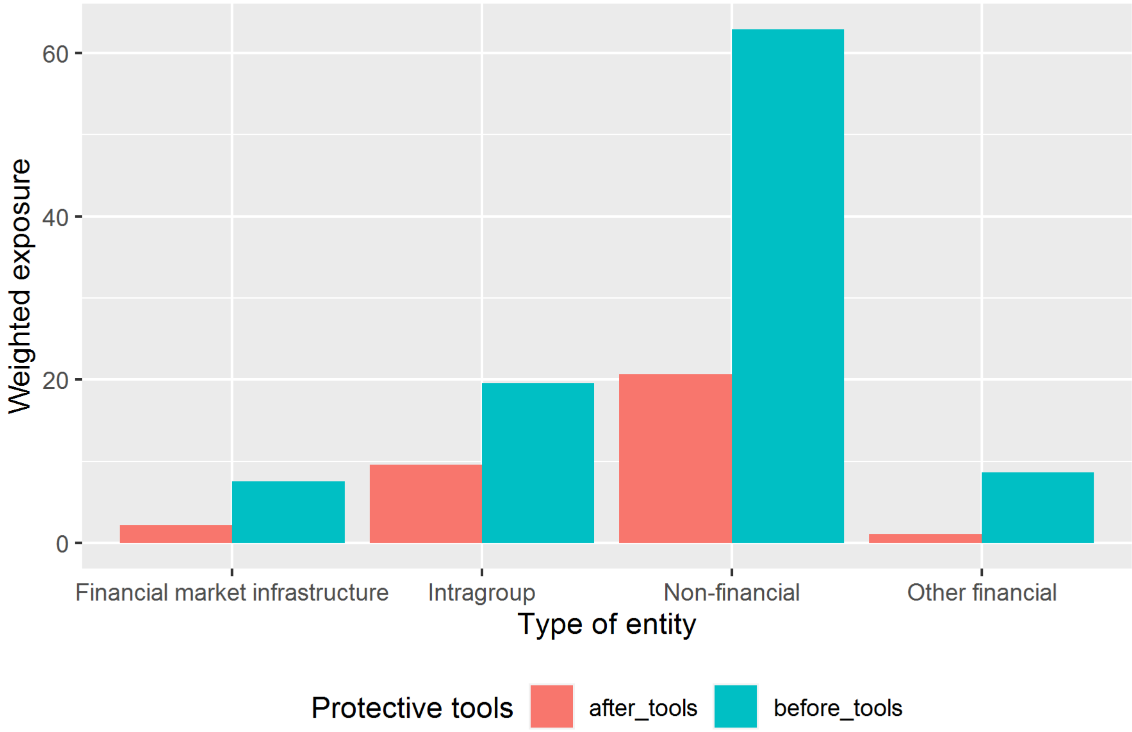


FIGURE 39: RISK REDUCTION FOR CRITICAL SUPPORTING FUNCTIONS USING OPERATIONAL RISK MANAGEMENT TOOLS

377. For critical third-party service providers that would impact critical supporting functions, one observes that the bulk of the operational risk exposure of CCPs is towards non-financial entities, with this category being composed mainly by exposures to Software, IT & Telecom services, around 70% of exposure before the application of risk mitigation tools and around 80% after the application of risk mitigating tools. One also observes that the level of risk reduction is high for all categories, probably reflecting a higher substitutability of these services and ability of CCPs to build risk mitigation tools.

Operational risk exposure per CCP after application of risk mitigating tools towards third-party service providers that would have an impact to critical clearing or settlement functions

Operational risk chart 29

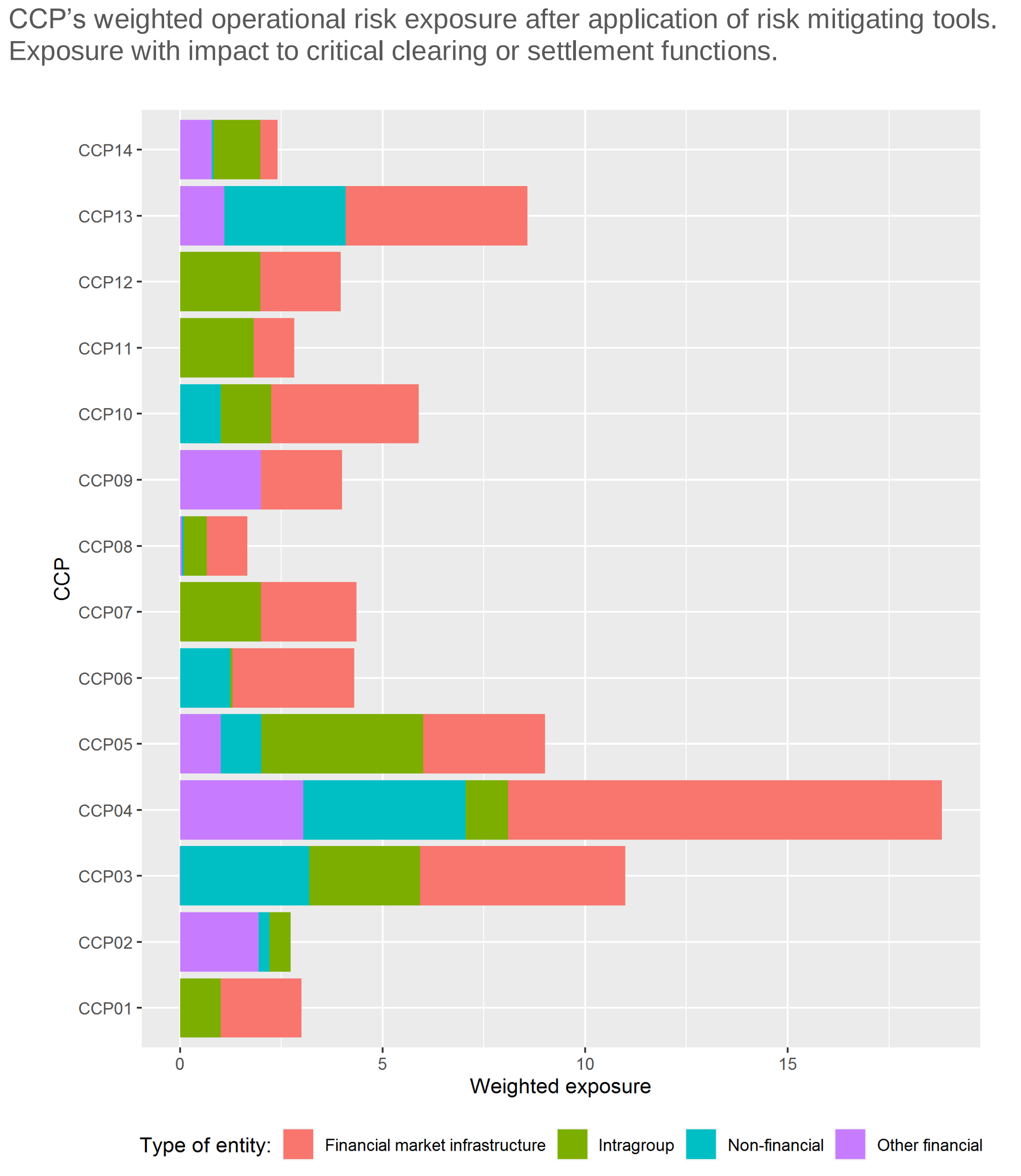


FIGURE 40: WEIGHTED EXPOSURE PER CCP AFTER OPERATIONAL RISK MANAGEMENT TOOLS – CRITICAL THIRD-PARTY SERVICE PROVIDERS

378. The exposure of CCPs toward service providers after the application of operational risk mitigation tools exhibits a significant variance across CCPs; however, one observes the common trend towards a dominant presence of exposures to entities in the FMI group with also a significant presence of intragroup exposures.

379. While it can be difficult to reduce exposure to entities in the FMI and intragroup categories, exposures to non-financial and other financial entities represent opportunities where operational

resilience with respect to a scenario of critical third-party provider failure can be increased if deemed desirable.

Operational risk exposure per CCP after application of risk mitigating tools towards third-party service providers that would have an impact to critical supporting functions

Operational risk chart 30

CCPs' weighted operational risk exposure after application of risk mitigation tools

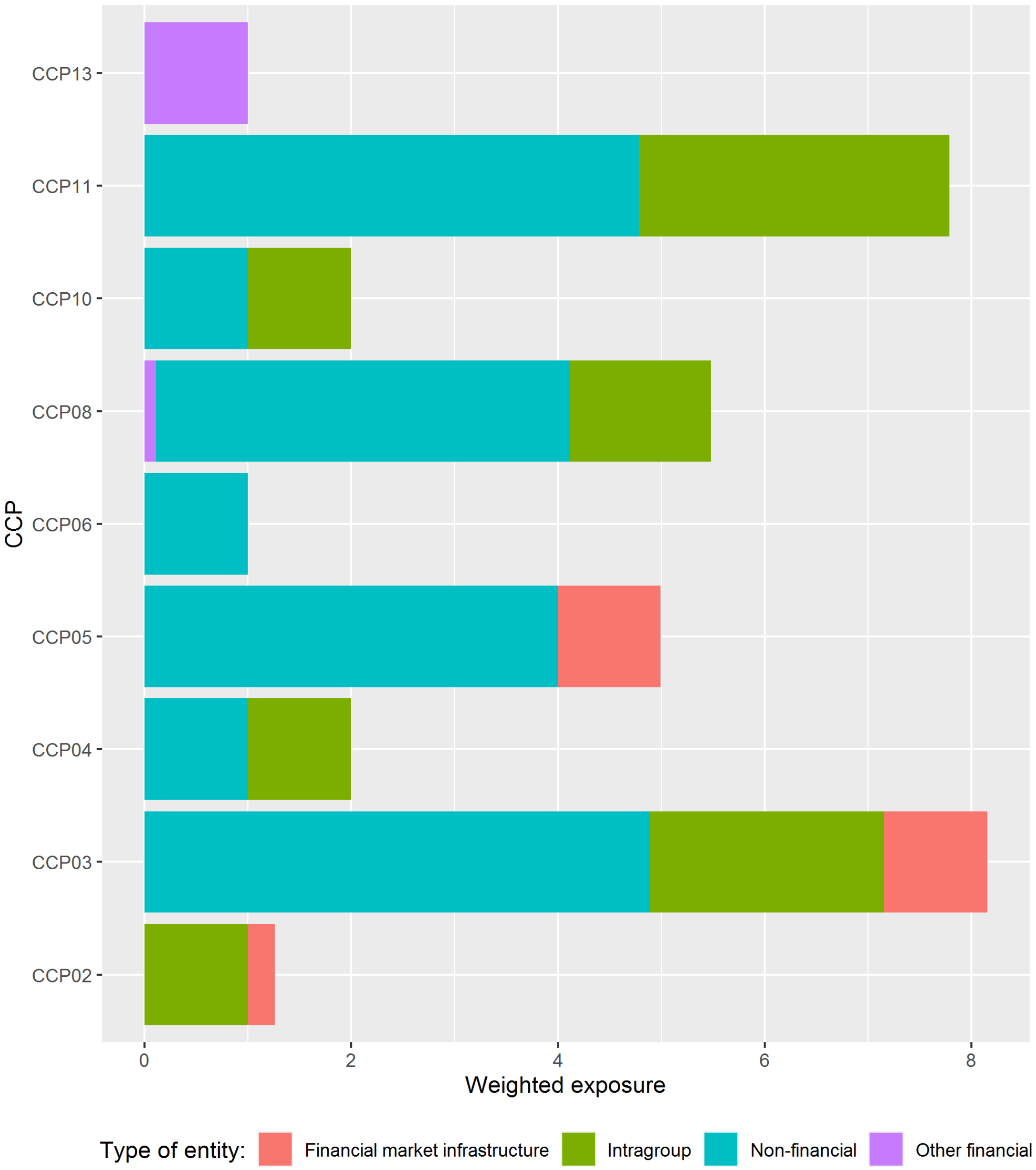


FIGURE 41: WEIGHTED EXPOSURE PER CCP AFTER OPERATIONAL RISK MANAGEMENT TOOLS – CRITICAL THIRD-PARTY SERVICE PROVIDERS

380. The operational risk exposures of CCPs after the application of risk mitigation tools for these critical third-party service providers exhibits a significant variance across entities, with some CCPs able to completely eliminate their exposure to single points of failure in this category.

381. For most entities that have residual exposure after tools, the dominant exposure is with respect to non-financial entities.

4.4.2.3 Evidence of behaviour of operational risk management tools using empirical data from past events.

382. In the analysis above, it is assumed that CCPs' risk management tools work perfectly. In order to verify this assumption, ESMA staff checked the past incidents data collected and linked operational events originating from third-party service providers to the relevant CCP risk management tools, which comprise of the use of alternative service providers and internal tools (tools are described in section 3.6.3.5).

383. For this analysis, we linked each event to each critical third-party provider and each with whether there was any mitigation risk management tools and the type of tool. In order to observe any meaningful trends, we look at the ratio incidents with respect to services (similar to the number of critical third-party providers but takes into account that individual providers can provide more than one service and have associated more than one mitigation tool).

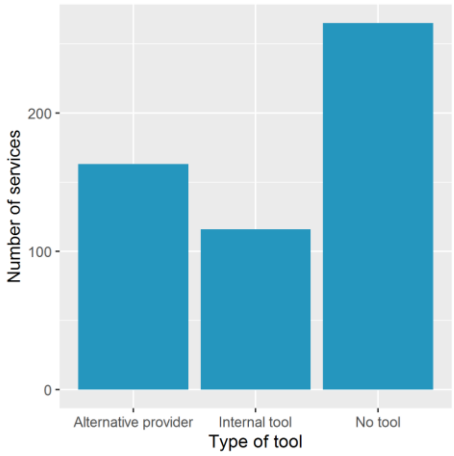
384. Using the Figures below one observes that exposures protected by a tool of type "Alternative provider" have a very low level of experienced incidents, while unsurprisingly the highest level of incidents is in exposures for which no tool is present.

385. Results for exposures protected by an "Internal tool" show an intermediate level of risk; ESMA staff followed up with a questionnaire to understand the reasons behind the events affecting these services in order to understand better their nature.

386. From the compiled results (fourth chart below), one observes that in 75% of the incidents, the Internal tool has an activation time and CCPs didn't make use of the tool. This information points to the fact that these types of tools would not protect against incidents with short durations and would mostly be effective to prevent high severity events.

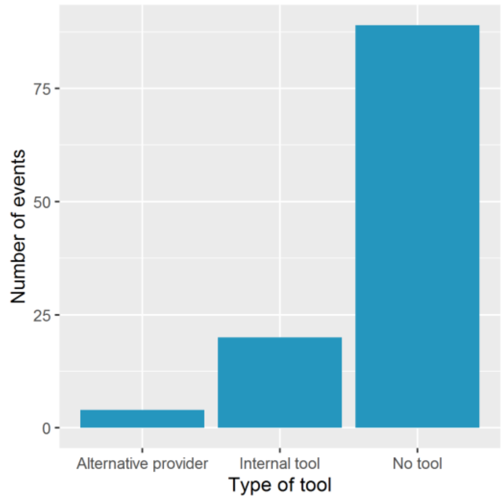
Operational risk chart 31

Number of services by type of risk management tool protecting them



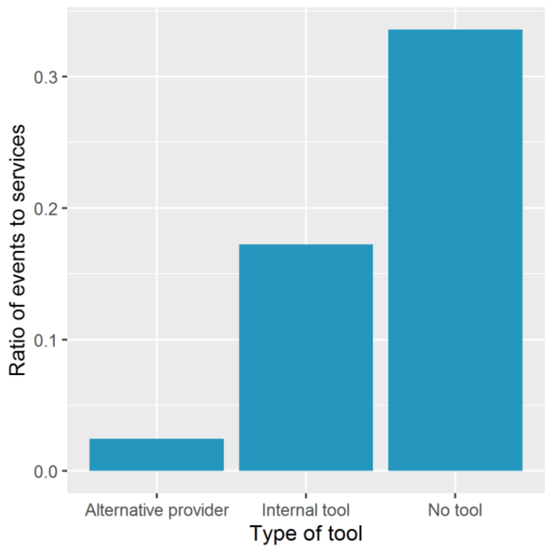
Operational risk chart 32

Number of operational events linked to critical third-party service providers by type of risk management tool associated with the service provider



Operational risk chart 33

Ratio [number of incidents / number of services] by type of risk management tool



Operational risk chart 34

Reasons behind incidents for services protected with an internal tool

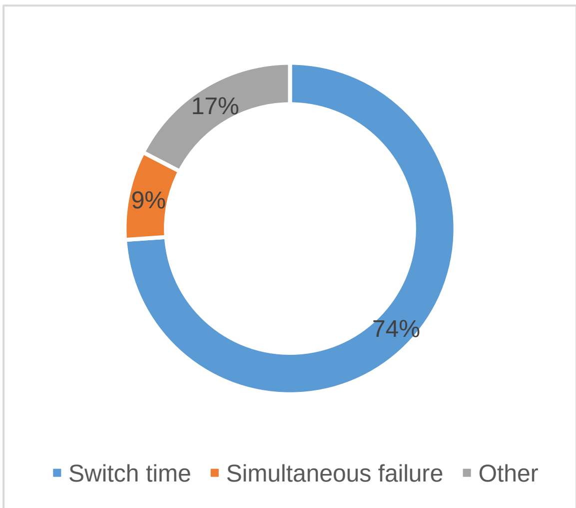


FIGURE 42: BEHAVIOUR OF OPERATIONAL RISK MANAGEMENT TOOLS

4.4.2.4 Conclusions

387. The analysis of the CCPs' operational risk exposures towards third-party service providers provides insights about the different operational dependencies to critical third-party service providers and how CCPs use operational risk management tools to mitigate risk.

388. We develop a methodology and risk indicators that enable us to monitor the single points of failure with respect to a hypothetical scenario involving an outage of a critical third-party provider. The results exhibit differences across CCPs in their relative level of third-party risk. Some of those differences may be explained by the variation in operational complexity that cannot be risk-reduced using mitigation tools (such as the exposure to FMIs due to the business model), but in other cases, it may indicate there is room for increases in operational resilience. With respect to the use of the indicators developed, it must be noted that while a higher number of third-party exposures is indicative of higher risk (under the assumption of similar level of risk for individual entities), the analysis performed has not estimated risk of individual entities and how that would influence the assessment.

389. Overall, all CCPs significantly reduce their exposure to the groups of non-financial and other financial entities, while the reduction of risk through mitigation tools for critical clearing or settlement functions with respect to exposures to FMIs or Intragroup is very limited, which would be consistent with the low substitutability of FMI services and the similarity of Intragroup services to internally managed operations (for which resilience would be managed through improvements at an internal level rather than through third-party risk mitigation tools).

390. Certain CCPs exhibit significant levels of exposure after tools to non-financial or other financial entities. For these entities and exposures further work should be conducted to evaluate the individual circumstances of these exposures and the suitability of taking corrective action.

391. Finally, using incidents data, ESMA staff evaluates the behaviour of the reported operational risk management tools. From the evidence collected, one notes that exposures protected through redundancy exhibit significantly low levels of risk, which is consistent with expectations. The empirical results for exposures protected through tools categorized as "internal tools" are mixed, the follow-up work performed by ESMA staff indicates that many of these tools are probably only suitable to protect CCPs against events of long duration. Given the results, it is recommended that supervisors emphasize the verification of testing results for these types of tools, in order to increase the likelihood that they work as intended in case of an event of long duration materializing.

4.4.3 Results of the assessment of concentration or systemic risks in the network of critical third-party service providers

4.4.3.1 Overview of the network of third-party service providers

Operational risk chart 35

Network graph

Network of all third-party service providers connecting to CCPs

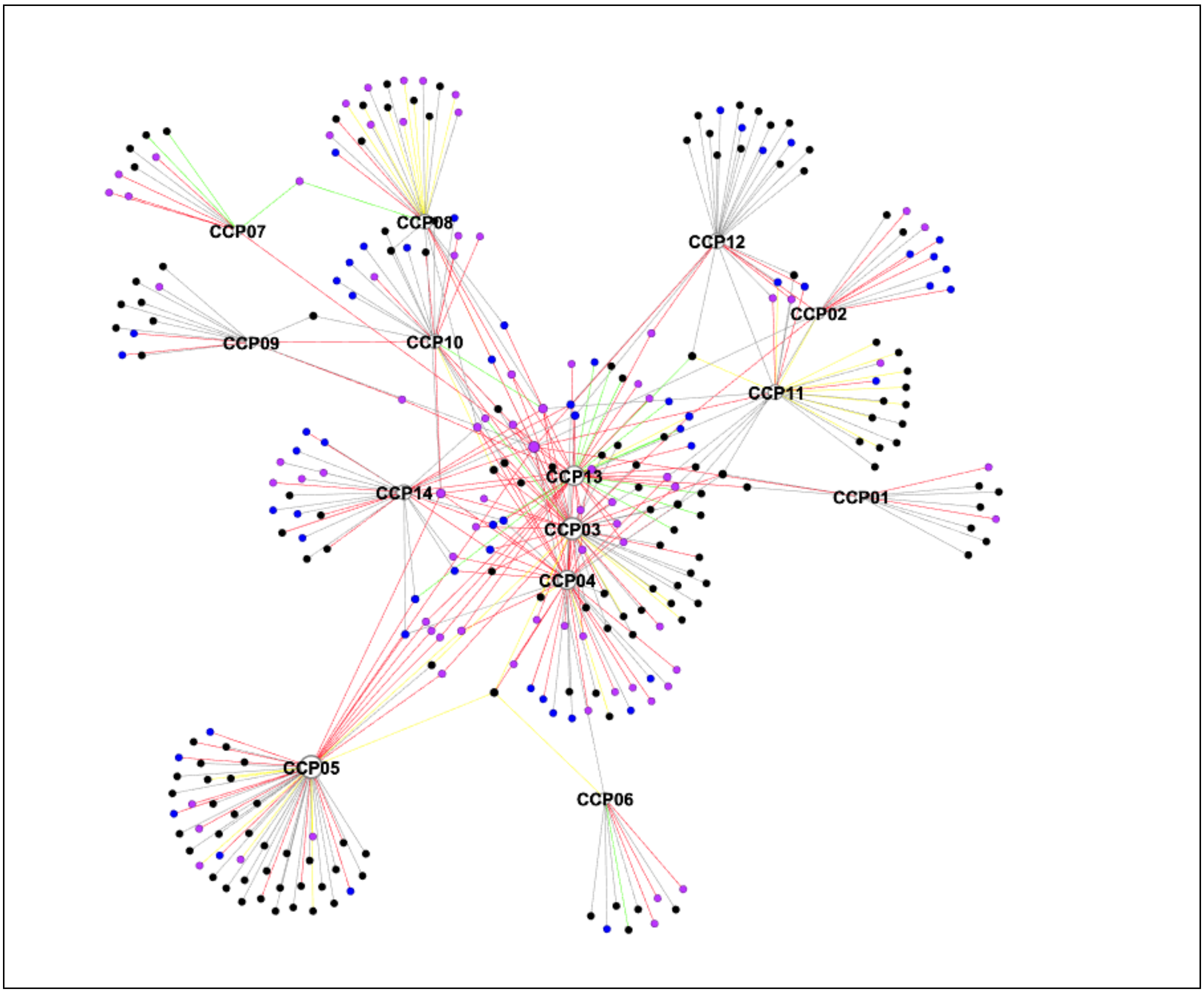


FIGURE 43: NETWORK OF CCPS CONNECTED THROUGH THIRD-PARTY PROVIDERS

392. From the data submissions to ESMA, a network displaying the ecosystem of the third-party providers and the CCPs was constructed (Figure 43). The network is unweighted, meaning that the links between the nodes do not have any associated weights (as opposed to a weighted network). Further, the network is undirected in that the order of the nodes does not matter, only the links between CCPs and third-party providers. The network's layout simulates the forces of attraction between the connected nodes (CCPs and the entities) to show the individual clusters of the network. To further improve visualization, it decreases the crossings of links and evens the node distribution in the layout.

393. The network of critical third-party providers and 14 CCPs contains 295 unique third-party providers, with 19% of them providing services to more than one CCP and the remaining 81% connected to a single CCP. Despite the average number of links per third party entity being 2.5 (the average degree of the whole network), the distribution of links is uneven – it is the CCPs and only a few third-party providers bearing the high number of interconnections.

394. In the constructed network, one can visually analyse clusters - a group of nodes that are more connected to each other than to the other nodes. Those can be identified at three levels. First, at the micro-level, third-party providers connect mostly to the CCPs, which stems from the definitional features of the dataset. Then, at the meso-level, 10 CCPs lie in the outskirts (CCP1, CCP2, CCP5, CCP6, CCP7, CCP8, CCP9, CCP10, CCP11, CCP12), on average sharing 6.8

third party providers with its closest CCPs. Finally, 4 CCPs (CCP3, CCP4, CCP13, CCP14) form a cluster, on average sharing 15.6 third party providers among its closest CCPs.

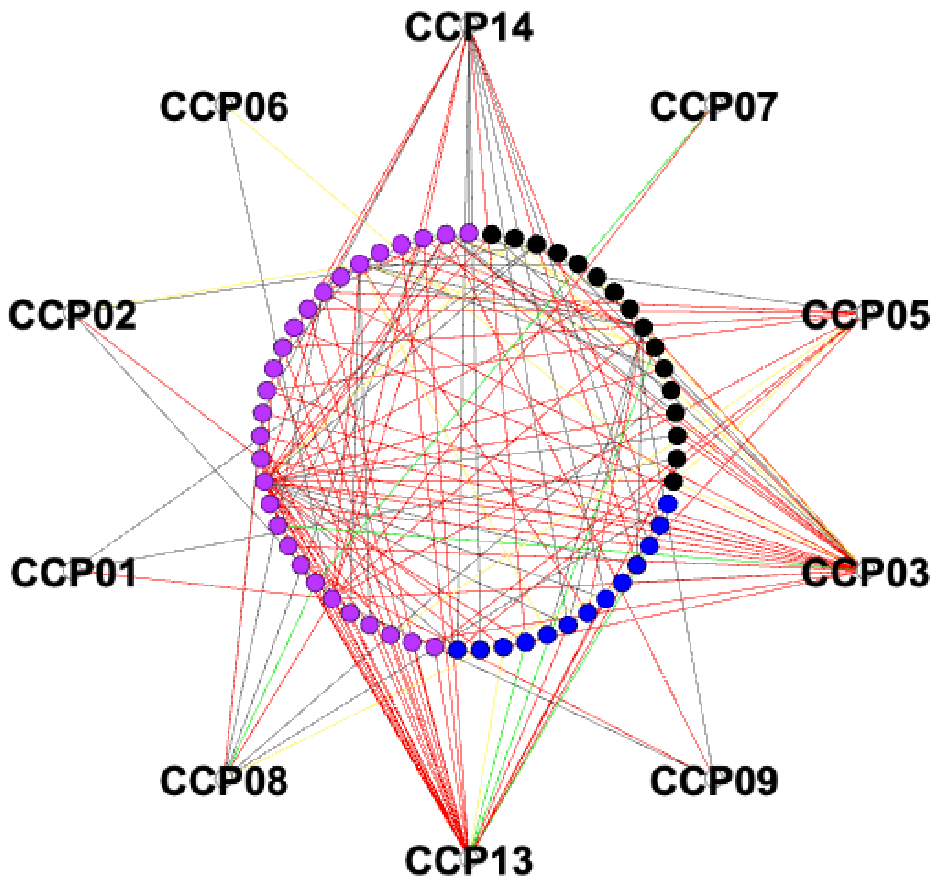
395. When considering only the links between entities and the CCPs, there are, on average, 27 third-party service providers per CCP, with a maximum of 56 and a minimum of 10 third-party service providers per CCP. If the type of entity in the whole network is considered, 27.4% belong to an FMI group (purple), 18.6% belong to the group of other financial entities (blue nodes), and 53.8% are non-financial entities (black). The split of the risk levels of links is 45% for risk level 0 (grey edges), 40% for risk level 3 (red edges), 10% for risk level 2 (yellow edges), and 5% for risk level 1 (green edges). When focusing on entities connected to more than one CCP, one observes that out of the 56 entities, 50% belong to the FMI group, 23.2% belong to the group of other financial entities, and 26.8% are non-financial entities.

396. The focus of the following section is the analysis of the network of third-party service providers to understand aspects of concentration risk and systemic risk in relation to critical third-party service providers. As such, critical third-party service providers connected to single CCPs are filtered out for the rest of the analysis and metrics, leaving third-party service providers that have two or more connections.

Operational risk chart 36

Network graph

Network of third-party service providers connected to at least two CCPs



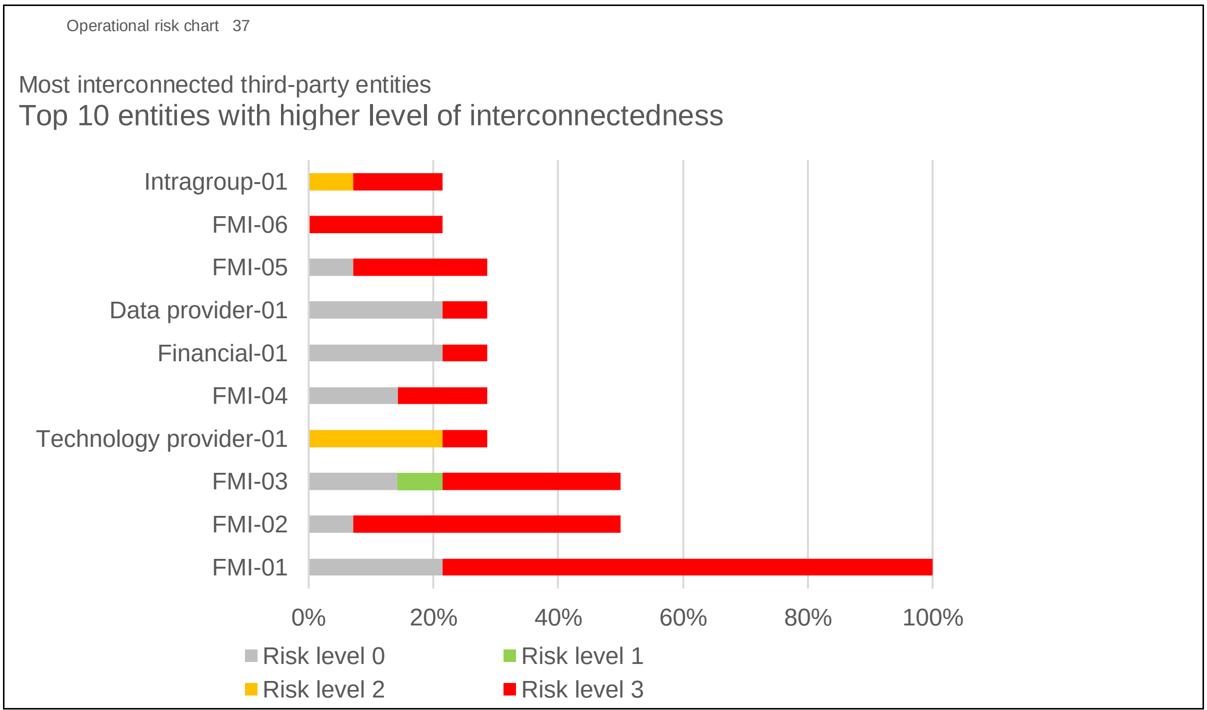


FIGURE 44: NETWORK OF THIRD-PARTY PROVIDERS CONNECTED TO AT LEAST TWO CCPS

397. When looking at the top-10 most interconnected third-party entities one sees that most of them belong to a single FMI group. The bar on the left indicates for each of the top-10 most interconnected third-party entities the percentage of CCPs that have an operational dependency on it. The colors highlight the level of risk of the operational relationship, using the information collected through the hypothetical scenario of section 4.4.2. For example, for FMI 01 the level of interconnectedness reaches 100%, implying that FMI01 is used by all CCPs in this sample. A failure of FMI01 would create substantial issues for around 75% of the CCPs (risk level 3 in red) while for the remaining 25%, the CCPs have systems in place that could be used as a backstop (minimizing the risk to zero).

398. The high level of interconnectedness and risk in the FMI group is consistent with their role in the financial markets. Apart from entities in the FMI group, four other types of entities show a high level of interconnectedness (a technology provider 'Technology provider-01', a financial entity 'Financial-01', a data provider 'Data provider-01' and an entity whose main role is providing intragroup services ' Intragroup-01'); however, when taking into account the level of risk of the interconnections, only one of them could potentially impact simultaneously the critical functions of more than one CCP.

399. In the graph below one can observe details about the distribution of interconnectedness by type of entity for the subsample of entities connected to at least 2 CCPs (14% of CCPs in the sample of CCPs). The mean interconnectedness is 22% for FMIs, 18% for non-financials and 19% for other financial entities. There are two outliers (100%, 50%) that represent three entities (FMIs-01, 02, 03). Apart from these outliers, the max for all groups is 29% (connected to 4 CCPs).

Operational risk chart 38

Box & Whisker plot: Number of CCPs connected by type of entity

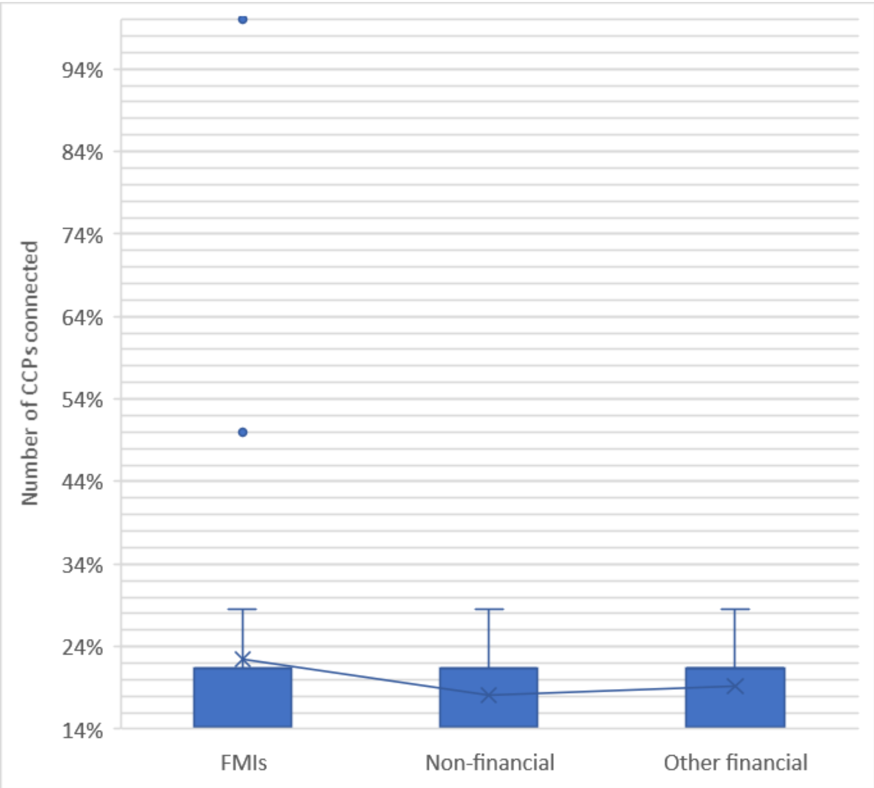


FIGURE 45: BOX & WHISKER PLOT, NUMBER OF CCPS CONNECTED BY TYPE OF ENTITY

4.4.3.2 Detailed analysis for specific types of services and hypothetical groups

400. In order to assess concentration issues for specific types of services, ESMA staff performed the analysis on a more granular level considering a segmentation into four groups of aggregated services covering a range of specific sub-services.

401. It must be noted that entities that provide multiple types of services (such as intragroup entities) may appear in multiple categories showing the sub-set of services and interconnections that belong to the category. The services are grouped in the following manner:

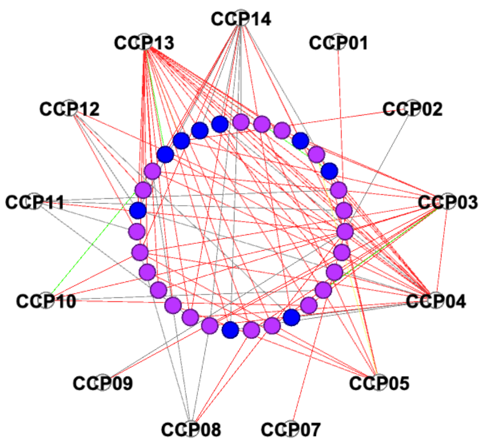
Financial services	• Clearing & risk services • Collateral • Custody • Default Management Process (DMP) • Financial messaging service providers

	• Interoperability link • Investment • Liquidity provider • Payments • Settlement • Trade provider/source
Software, IT & Telecommunications services	• IT providers • Cyber security • Telecommunications (abbreviated as Telco) • Software • Cloud services • Support
Data providers	• Any type of entity that provides data used for pricing or valuation purposes by the CCP
Other services	• Disaster recovery capacities • Electricity provider • Physical infrastructure • Regulatory reporting • Utility operators in commodity derivatives • Other

Financial services

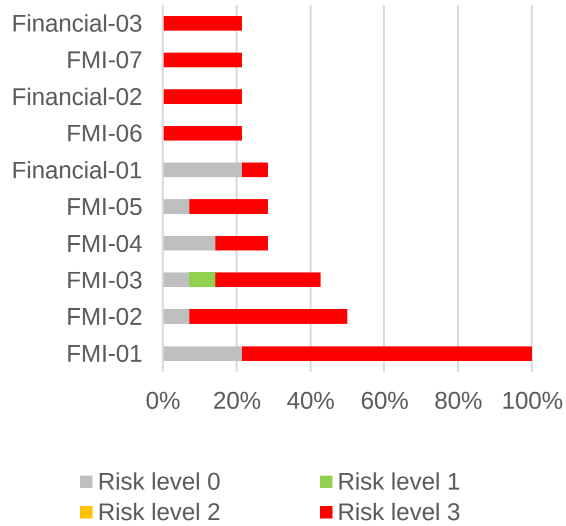
Operational risk chart 39

Network chart
Financial services – LEI level



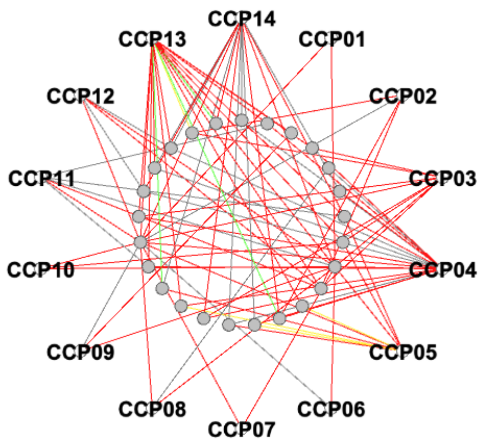
Operational risk chart 40

Most interconnected third-party entities
Financial services – LEI level



Operational risk chart 41

Network chart
Financial services – Hypothetical groups`



Operational risk chart 42

Most interconnected third-party entities
Financial services – Hypothetical groups

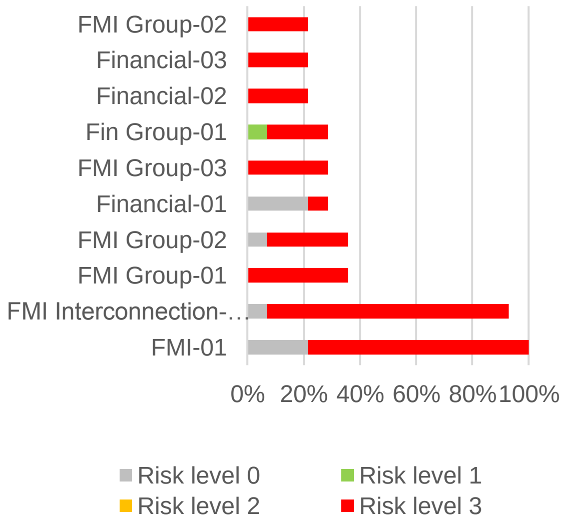


FIGURE 46: INTERCONNECTEDNESS ANALYSIS – FINANCIAL SERVICES

402. When looking at financial services one observes that some Financial Market Infrastructures have high degrees of interconnectedness and their failure would impact the critical functions of multiple CCPs simultaneously, this is consistent with their role in the financial markets and their low level of substitutability.

403. The three most interconnected FMIs have a marked systemic nature, as 100%, 50% and 43% of CCPs are connected to these infrastructures for some of their critical functions. Some financial

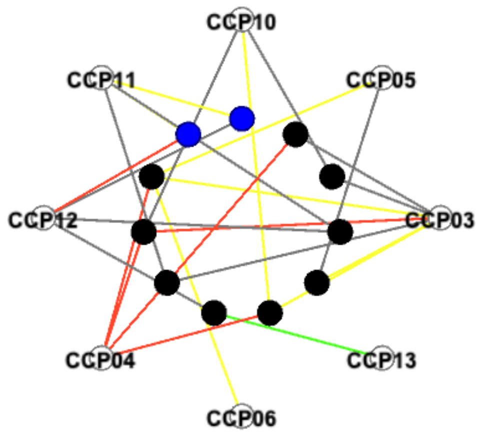
entities also reach high levels of interconnectedness that result in ranges between 28% and 21% of CCPs connected to them.

404. When aggregating in groups of related entities one observes a general increase in the interconnectedness indicators of FMIs, this is due to many entities belonging to financial groups with multiple FMIs. One also observes that some FMIs have operational dependencies within the central banking system that could theoretically lead to correlated operational risk events due to their reliance on common infrastructures. For financial entities, no change in their level of concentration concerning the measurement at individual entity level is observed.

405. Overall, the observed level of interconnectedness for FMIs is in line with the expectations, many FMIs are connected to multiple CCPs providing critical services and there are some components of the financial infrastructure that have a systemic nature as they service the whole network of CCPs either directly or indirectly. With respect to other financial entities, one observes that there are instances where they are connected to more than one CCP, which implies that potential correlated operational events that propagate through financial institutions is a plausible scenario.

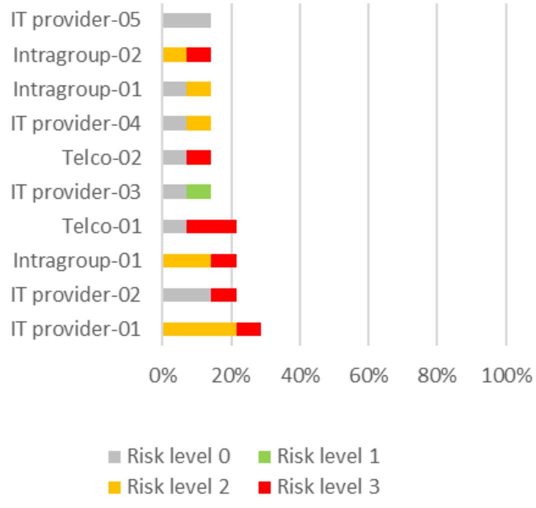
Operational risk chart 43

Network chart
IT, Software & Telco services – LEI level



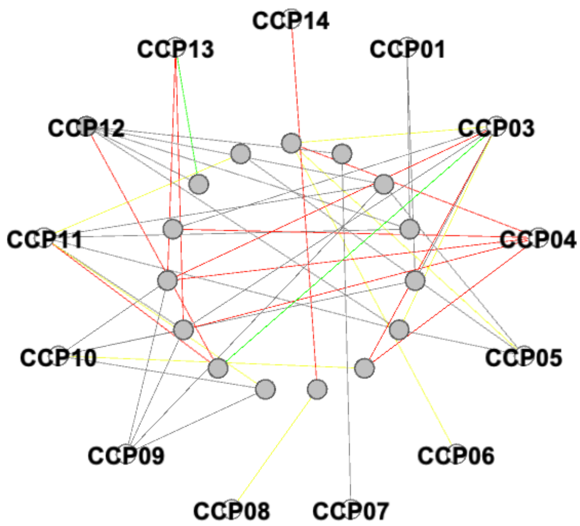
Operational risk chart 44

Most interconnected third-party entities
IT, Software & Telco services – LEI level



Operational risk chart 45

Network chart
IT, Software & Telco services – Hypothetical groups



Operational risk chart 46

Most interconnected third-party entities
IT, Software & Telco services – Hypothetical groups

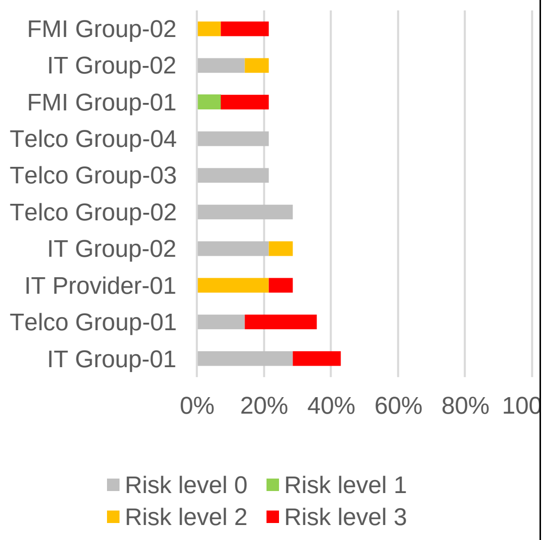


FIGURE 47: INTERCONNECTEDNESS ANALYSIS – SOFTWARE, IT & TELECOMMUNICATIONS SERVICES

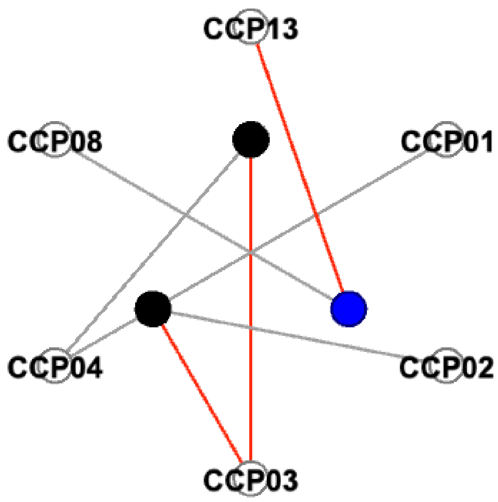
406. When looking at the most interconnected providers of IT services, software, or Telecommunications services one notices one IT entity connected to 28% of the CCPs (IT provider-01) and the rest of the entities between the 14% and 20% mark. One also observes that for the majority of providers, CCPs either have protective tools or the type of impact would be limited to supporting functions. Only one entity (Telco-01) would have the potential to impact critical functions at more than one CCP in a correlated manner.

407. When aggregating in groups of related entities one observes a slight increase in concentration across the board. However, taking into account the risk of the interconnections, for the most part the CCPs have protective tools in place. For critical functions, the maximum risk for critical CCP functions would be linked to one entity connected to 21% of CCPs with a Risk level 3 and three other entities with 14% of CCPs connected each.

Data providers

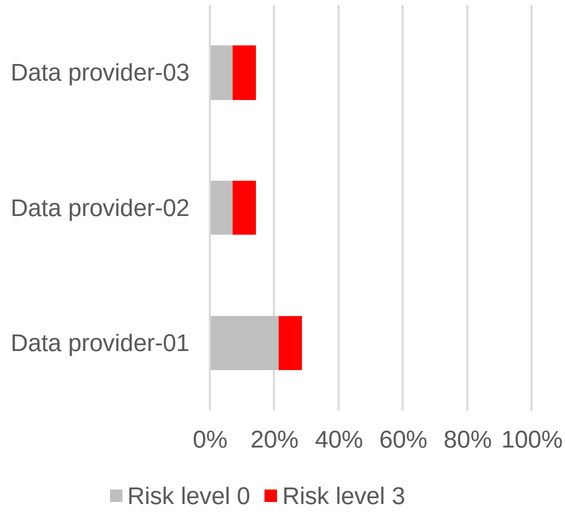
Operational risk chart 47

Network chart
Data providers – LEI level



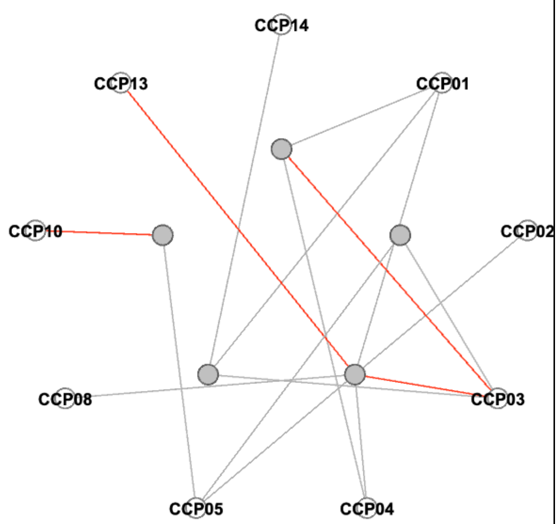
Operational risk chart 48

Most interconnected third-party entities
Data providers – LEI level



Operational risk chart 49

Network chart
Data providers – Hypothetical groups



Operational risk chart 50

Most interconnected third-party entities
Data providers – Hypothetical groups

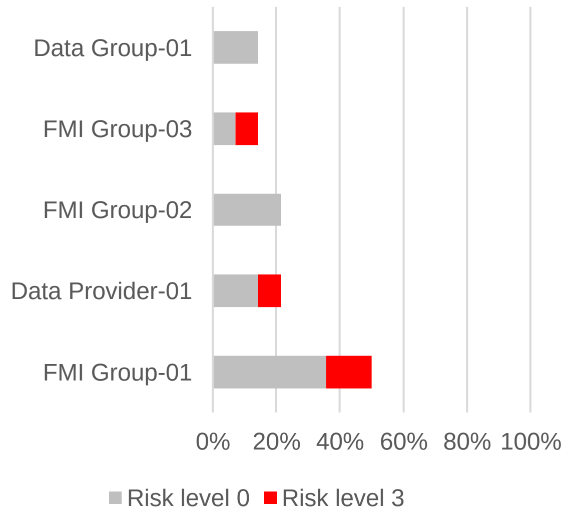


FIGURE 48: INTERCONNECTEDNESS ANALYSIS – DATA PROVIDERS

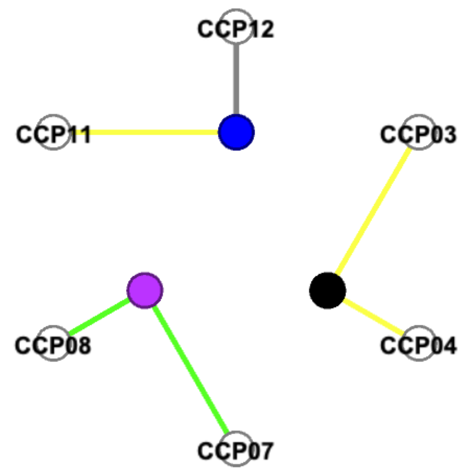
408. When looking at the most interconnected third parties providing data related services, one observes that only three individual entities are connected to more than one CCP, and for the most part risk is mitigated through CCP's protective tools; no individual data provider with the potential to affect the critical functions of more than one CCP in a correlated manner is observed.

409. When aggregating in groups of related entities no material change other than FMIs appearing in the selection of entities is observed. FMIs are providers of data for many CCPs, however this doesn't raise any incremental concerns as their level of interconnectedness and criticality of services is already higher when analysing them from the financial services perspective.

Other services

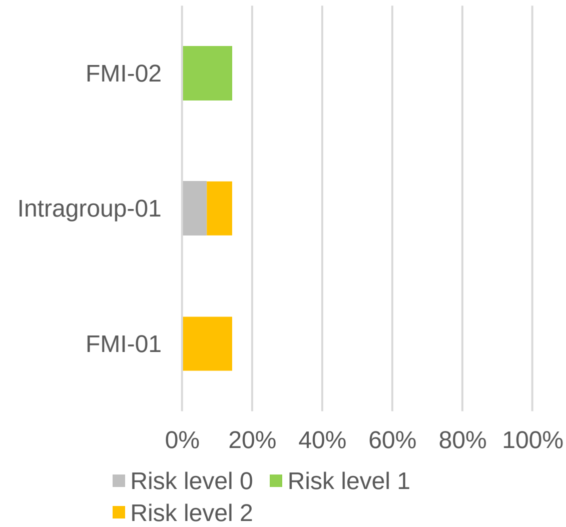
Operational risk chart 51

Network chart
Other services – LEI level



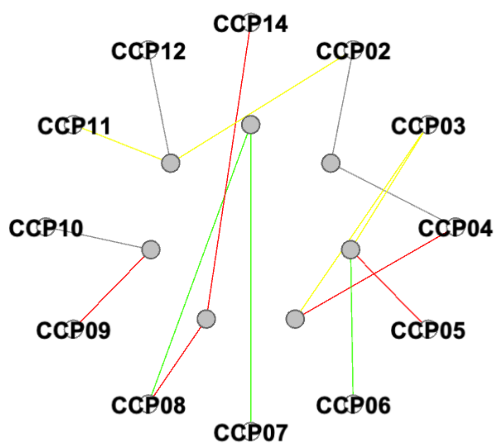
Operational risk chart 52

Most interconnected third-party entities
Other services – LEI level



Operational risk chart 53

Network chart
Other services – Hypothetical groups



Operational risk chart 54

Most interconnected third-party entities
Other services – Hypothetical groups

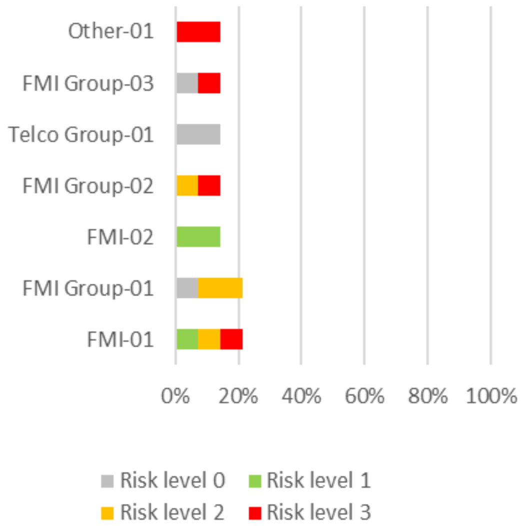


FIGURE 49: INTERCONNECTEDNESS ANALYSIS – OTHER SERVICES

410. When looking at the most interconnected entities providing other types of services, one observes in general low level of interconnectedness and risk.

411. When aggregating in groups of related entities the findings are not materially different, the only entity which has connection to more than one CCP has a limited impact, as it is a provider related to a specific commodity product.

4.4.3.3 Evidence of events affecting multiple CCPs

412. During the five-year period of data collected, there are four events registered that affected more than one CCP during the same day.

Event 1: Telecommunications provider outage

413. A telecommunications provider (Telco-01) experienced an outage causing connectivity issues to two CCPs, impacting some of their critical functions.

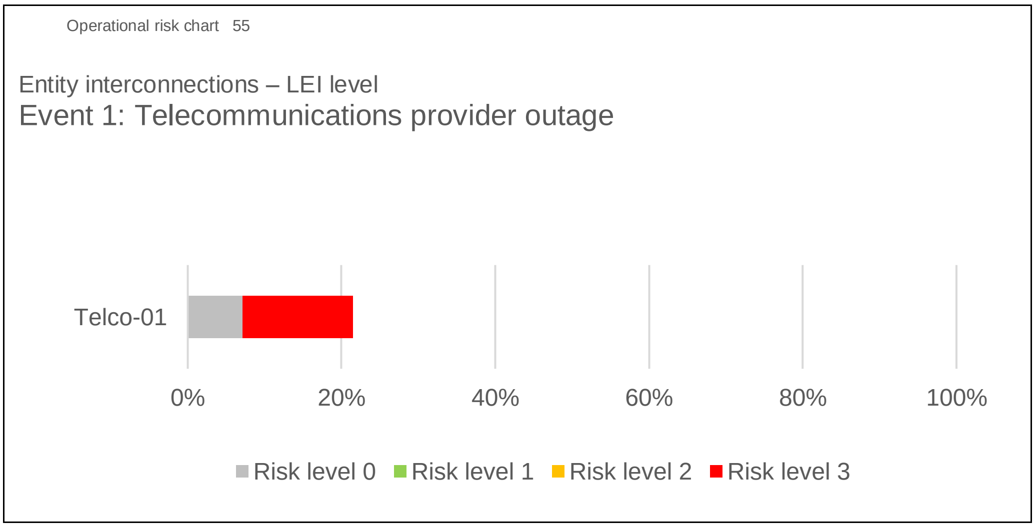


FIGURE 50: TELECOMMUNICATIONS PROVIDER OUTAGE

414. The reported propagation of the outage is consistent with the identified connections and risks as this non-financial entity is connected to three CCPs but one of them has built redundancy as protective tool, mitigating its third-party risk exposure.

415. ESMA staff notes that the reported duration of the event is different between entities, with one CCP reporting approximately 6 hours of incident time and the other CCP reporting approximately 13 hours of incident time.

Event 2: Intragroup entity outage

416. An entity belonging to a financial group with multiple FMIs and providing services to three CCPs experienced a technology network outage impacting some critical functions of two CCPs.

Operational risk chart 56

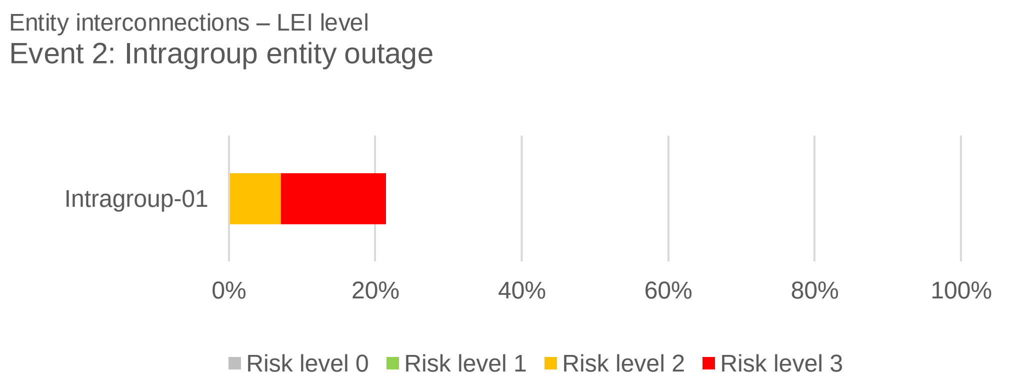


FIGURE 51: INTRAGROUP ENTITY OUTAGE

417. The reported propagation of the outage is consistent with the identified connections and risks for two CCPs, but there was no reported event for the CCP connected to this third-party provider with reported potential impact to affect critical supporting functions. By analysing the description of services provided, the most probable explanation is that the type of service provided to the third entity is of a different nature, so the lack of correlation seems plausible as operational events do not necessarily affect at whole entity level.

The reported duration of the event is similar for both entities, around 3 hours.

<u>Event 3: Financial Market Infrastructure outage</u>

418. A financial market infrastructure (FMI-05) experienced technical issues affecting two CCPs and impacting some of their critical functions.

Operational risk chart 57

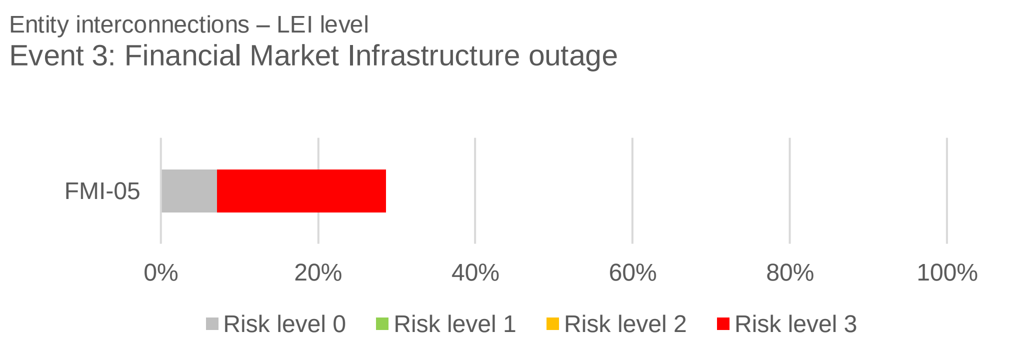


FIGURE 52: FINANCIAL MARKET INFRASTRUCTURE OUTAGE

419. The reported propagation of the outage is consistent with the identified connections and risks for three out of the four CCPs connected to this provider. Using the qualitative information provided, ESMA staff derives as possible reason that the nature of the outage was not at whole entity level, but rather affecting a subset of entities due to common infrastructure element.

420. One notes that there are significant differences in the reported duration of the event between CCPs (17 hours and 2.5 hours) which could be due to reporting inconsistencies or differences in the services used and negative effects experienced.

Event 4: Settlement system outage

421. A settlement system (FMI-04) experienced technical issues affecting two CCPs and impacting some of their critical functions.

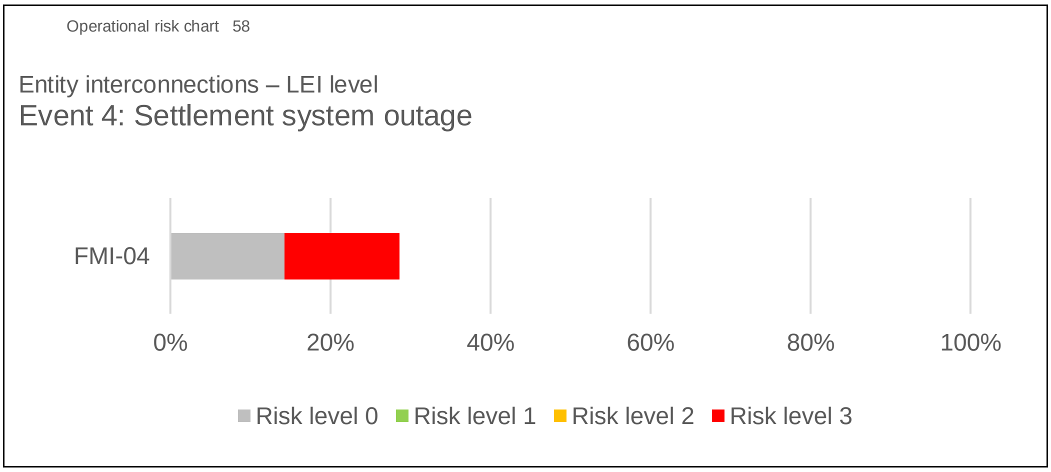


FIGURE 53: SETTLEMENT SYSTEM OUTAGE

422. The reported propagation of the outage is consistent with the identified connections and risks, with the event affecting the two entities with reported exposure after taking into account risk management tools.

423. The reported duration of the event is similar for both entities, which is around 12 hours.

4.4.3.4 Conclusions from the analysis of the network of third-party providers

424. In the analysis of the network of critical third-party service providers ESMA staff aggregates the information provided by individual CCPs in order to understand and assess risks from common exposures to third-party risk. Through the use of the results from the hypothetical scenario of an outage at a critical third-party provider, ESMA staff qualifies the risk of each interconnection to better understand the impact from shocks transmitted through the network of third-party dependencies.

425. Overall, ESMA staff observes a high level of interconnectedness and criticality in services provided by FMIs, which is consistent with their role and low level of substitutivity. Three entities (FMI- 01, 02, 03) have been identified as having a particularly high level of systemic importance, as their levels of interconnectedness reach quantities of 100% and 50% of CCPs connected to them.

426. Some financial entities could impact critical functions in more than one CCP simultaneously. Financial entities may also have roles as clearing members. These aspects should be closely monitored.

427. Some IT, Software & Telco services, including cloud services, are interconnected with multiple CCPs, however when taking into account CCP’s risk management tools the potential impact is substantially mitigated. There is one entity which has critical interconnections with more than one CCP and has already caused a correlated outage in the past. This interconnection deserves specific monitoring.

428. For data providers and other types of services, when assessing at LEI level, there does not seem to be potential for correlated events affecting CCP’s critical functions.

429. Intragroup entities providing services to multiple CCPs should be closely monitored given their potential to cause correlated operational risk events.

430. When analysing past events, we found no empirical evidence of events affecting groups of entities (such as the hypothetical groups included in our analysis), only events affecting single entities (at LEI level) have been registered in the historical timeframe evaluated.

5 Conclusions

431. The fourth ESMA CCP stress test aimed to assess the resilience of all 15 authorised EU and recognised Tier 2 CCPs against adverse market developments and the default of clearing members. In accordance with the methodology published in June 2021, this exercise covered both credit and concentration risks, with targeted improvements compared to the previous exercise. In addition, this exercise included a new operational risk component, which aimed to assess the level of operational resilience of CCPs with a focus on third-party service provider risk. As with the previous exercises, the ESRB has delivered the narrative and the adverse scenario used for this 4th stress test exercise.

432. As with all exercises of this scale and type, it is subject to a number of limitations. While residual risks from the in-scope components have been highlighted in the report, CCPs are also subject to other types of risks that are either not or only partially covered in the exercise, but which could still in isolation challenge their resilience. For example, legal and any type of business risk have been left outside of the scope of the exercise, as well as environmental risk. ESMA remains committed to further improve and develop the methodology and scope of the future CCP stress tests.

433. The report analysed the financial resources held by the 15 in-scope CCPs as of 19 March and 21 April 2021. The aggregate amount of resources available to CCPs on these reference dates was respectively 423 and 409 billion EUR, an increase compared to the previous exercise. There was no significant structural change in the overall share of excess collateral or allocation of resources between margin and default fund contributions. The analysis shows that, while there was a general increase of provided resources by all clearing members, at the same time the top participants increased their relative share, pointing to a concentration at clearing member level.

434. The credit stress test results have been computed for two default scenarios and on two reference dates (19 March end of day and 21 April 2021 intraday). For the March date, additional costs were considered, namely concentration costs and costs related to wrong-way risk. Under the Cover-2 per CCP scenario, ESMA assessed the resilience of each CCP to the default of its top-2 clearing members groups. In all cases, the prefunded resources would be sufficient to cover the resulting losses under the core credit stress test results. The CCPs could have covered losses generated by the common market stress scenario with relatively low or moderate percentage consumptions of available resources. ESMA also performed a sensitivity analysis and the conclusions seem robust to small changes in the baseline shocks. For one of the dates, the impact due to concentration and specific wrong-way risk stemming from cleared positions was included in the baseline scenario calculations. This led to higher losses and consumption for almost all CCPs but under the considered market scenario these were contained within the default waterfalls of the CCPs and there was no shortfall of prefunded resources.

435. For the All CCPs cover-2 scenario, two clearing members groups as defaulting at system-wide level were selected, i.e. the same two clearing member groups for all CCPs. The majority of CCPs would experience a default of at least one of their clearing members. However, these consistent scenarios did not put significant stress to any CCP with the % consumption of default fund-level prefunded resources being relatively low in all cases. This indicates that while CCPs are highly interconnected through common clearing participants, the exercise did not highlight any pairs of groups that are at the same time and under the common tested scenario highly impactful at multiple CCPs.

436. The reverse stress tests analysis assessed the sensitivity of the credit stress results to stepwise increases in both the number of defaulting groups and the severity of market shocks. Overall, the analysis shows that incremental changes in market shocks severity are more harmful than increases in the number of defaulting members. The results have not indicated any systemically

relevant adverse impact following small changes in the underlying stress assumptions. For very large increases of the severity of the market shocks, the observed maximum shortfalls of prefunded resources following the default of two clearing member groups would not be spread across CCPs implying that there are different pairs of defaulting groups that would maximise the shortfalls at different CCPs for these particular dates.

437. The concentration analysis showed that concentrated positions could represent a significant risk for CCPs, with the overall risk clustered in one or two CCPs for most asset classes.

438. ESMA calculations show that fixed income derivatives have the most concentration risk, with a total over 29bn EUR. Bonds (including bonds from Repo clearing services) come next with a total modelled concentration risk of around 11 bn EUR.

439. Concentration in commodity derivatives and in the equity segment (securities and derivatives) is very significant as well, with around 7bn EUR of concentration risk calculated for each asset class. There is a very large coverage gap between the system-wide estimated market impact under ESMA methodology and margin add-ons, for commodity derivatives and to a lesser extent for equity products.

440. The concentration risk is factored in explicitly in a majority of CCPs through dedicated margin add-ons. Although all CCPs have market impact risk, 4 CCPs (KDPW, CCPA, KELER, CCG) did not report any concentration add-ons. Since the data request date, KDPW and CCG have implemented or are in the process of introducing concentration addons. KELER relies on a monitoring system to require additional collateral in case of elevated concentration.

441. In the operational risk analysis, ESMA derived insights with respect to the level of operational resilience of CCPs for 14 CCPs (one was excluded due to the absence of historical operational events data) and took an in depth look at third-party risk.

442. Using information about internal incidents of CCP's systems and third-party providers ESMA developed two methodologies to measure operational risk from historical events. With the computed results, ESMA identified varying degrees of operational reliability for the CCPs included in the exercise and identified specific CCPs where further work should be conducted to understand the drivers of these differences, the root causes of the events and the remediation actions taken. Further detailed conclusions are provided in section 4.4.1.5.

443. Through the use of a hypothetical scenario, ESMA evaluated the exposures to critical third-party providers and the ability of CCPs to reduce risk through operational risk management tools. Using exposure indicators, differences across CCPs in their relative level of third-party risk were identified. Further work should be conducted to evaluate the individual circumstances of these exposures and the suitability of taking corrective action to improve operational resilience against operational shocks affecting critical third-party service providers. Further detailed conclusions are provided in section 4.4.2.4.

444. In the analysis of the network of critical third-party providers ESMA aggregated the information provided by individual CCPs in order to understand and assess risks from common exposures to third-party risk. Overall, ESMA analysed a number of critical third-party service providers, which have the potential to affect the critical functions of multiple CCPs in a correlated manner. In addition, ESMA identified the critical third-party service providers with the highest systemic importance for the CCP sector due to both the criticality of the services provided and their level of interconnectedness with CCPs.. Further detailed conclusions are provided in section 4.4.3.4.

445. As with the three previous exercises, this year’s stress test exercise showed that EU and Tier 2 CCPs are overall resilient to common shocks and multiple defaults. However, the credit stress test highlighted differences in resilience between CCPs under the selected market stress scenarios, although no systemic risk has been identified. Similarly, the concentration component highlighted the need for CCPs to accurately account for liquidation cost within their risk framework. Finally, with respect to operational resilience, a series of areas and entities have been identified where further supervisory attention should be put in order to assess discrepancies in the measured levels of operational risk.

6 Annexes

6.1 List of CCPs included in the scope of the exercise

no	CCP	CCP code
1	Athens Exchange Clearing House	ATHX
2	BME Clearing	BME
3	Cassa di Compensazione e Garanzia S.p.A.	CCG
4	CCP Austria Abwicklungsstelle für Börsengeschäfte GmbH	CCPA
5	Eurex Clearing AG	ECAG
6	European Commodity Clearing	ECC
7	European Central Counterparty N.V.	EUROCCP
8	ICE Clear Europe	ICEEU
9	ICE Clear Netherlands B.V.	ICENL
10	KDPW_CCP	KDPW
11	Keler CCP	KELER
12	LCH.Clearnet SA	LCHSA
13	LCH.Clearnet Ltd	LCHUK
14	Nasdaq OMX Clearing AB	NASDAQ
15	OMIClear – C.C., S.A.	OMI

6.2 Concentration Stress Test annex

6.2.1 Methodology worked example

446. The present section provides a worked example of market impact computation for equity. An analogous approach is adopted for the other asset classes, with some differences for Fixed Income and Credit (as specified in 6.2.2).

Data reported and Reference volume computation

447. For each aggregation level (ISIN for equities), CCPs reported the account position values and the relevant Average Daily Volume (ADV).

448. For equities, the reference volume is by default taken as the systematic internaliser data average volume, or the ADV submitted by the CCP as a fallback.

Market impact

449. The market impact (in basis points) is retrieved at {ISIN, CM} level by computing in turn the following quantities:

- Position value to liquidate: the net positions across all accounts of this CM for this ISIN.
- Position size to liquidate: ratio of the Position value to liquidate and the reference volume.
- Only absolute positions greater than 0.25 are considered significant.
- The market impact is then interpolated linearly from the Sensitivity tables using the significant position size to liquidate. For positions larger than 200% of the reference volume, a flat extrapolation is applied.

450. The table below illustrates the computation.

ISIN	CM LEI	Position Value	REF VOLUME	POSITION VALUE TOLIQ	POSITION SIZE TOLIQ	SIGNIFICANT POSITION SIZE TOLIQ	MARKET IMPACT
ISIN 1	CM1	-5000	10000	-5000	-0.5	0.5	292
ISIN 1	CM2	15000	10000	12000	1.2	1.2	700
ISIN 1	CM2	-3000	10000	12000	1.2	1.2	700
ISIN 1	CM3	-	10000	-10000	-1	1	583
ISIN 1	CM3	-10000	10000	-10000	-1	1	583

451. Notice that the Market impact is retrieved by the relevant entry of the Sensitivity table.

Asset Class	Sub-Asset Class	Size cost (bps) 25% Ref Volume	Size cost (bps) 50% Ref Volume	Size cost (bps) 100% Ref Volume	Size cost (bps) 200% Ref Volume
Stocks	Mid cap	146	292	583	1,166

Market impact delta PnL

452. Finally, the market impact delta PnL is computed by scaling the market impact by the account position, also considering the case where account positions reduce the positions to be liquidated.

ISIN	CM LEI	Position Value	POSITION VALUE TOLIQ	MARKET IMPACT	MARKET IMPACT DELTA PNL
ISIN 1	CM1	-5000	-5000	292	146
ISIN 1	CM2	15000	12000	700	1050
ISIN 1	CM2	-3000	12000	700	-210
ISIN 1	CM3	-	-10000	583	0
ISIN 1	CM3	-10000	-10000	583	583

6.2.2 Specific Concentration Methodologies

6.2.2.1 Fixed Income Derivatives Methodology

453. For both Fixed Income Derivatives and Credit Default Swaps, the concentration risk is assessed through the market impact cost of setting-up a relevant hedging portfolio. The further costs incurred from auctioning the portfolio are not considered.

454. To allow the accurate pricing and hedging of swaps, CCPs have reported the position sensitivities to both forecasting and discounting curves on 15 maturity points spanning 1Y to 50Y.

455. In each relevant currency, it is assumed that the main risks can be adequately hedged through hedging the exposures to both the discounting and the forecasting curves on 4 different maturity points (2Y, 5Y, 10Y, 30Y). ESMA staff apportioned the sensitivities to the 4 hedge maturity points on a time basis.

456. Basis swaps between OIS and IBOR were also considered as a possible hedge. The most favourable market impact using one of the 3 possible hedging strategies {forecasting + discounting, forecasting + basis and discounting + basis} was kept.

457. For each pillar, a concentration cost per hedge maturity is computed by using the relevant size through interpolation.

458. A separate market impact for each of the 3 reporting sub-asset classes (Bond futures / forwards, IR futures and FRA and Swaps) is computed.

6.2.2.2 Credit Derivatives Methodology

459. CDSs are modelled similarly to interest swap derivatives: the CDS curve is assumed to be hedged on the 4 different maturity points (1Y, 2Y, 5Y, 10Y).

460. Given the practice of the market to use 5Y instruments as a hedge (with the exception of distressed credits close to default but this is expected to be a minor part of the inventory of positions), the expected cost of setting up a hedge takes the 5Y as a reference. Costs to set up hedges for the other maturities (1Y,2Y,10Y) are defined as multiples of the 5Y reference.

461. Although the model was enriched in this exercise with a term structure for the hedging costs, CCPs clearing CDSs use more complex models than the approach chosen by the framework. Moreover, with the parameters provided by the 2 CCPs, the model produced much lower concentration risk than what the CCPs charge their clearing members.

462. It is therefore difficult to draw conclusions from the results on that asset class.

6.2.3 Sensitivity parameters

463. Based on the data reported by CCPs, and in accordance with the methodology described in section 3.5, system-wide sensitivity tables have been built for each sub-asset class.

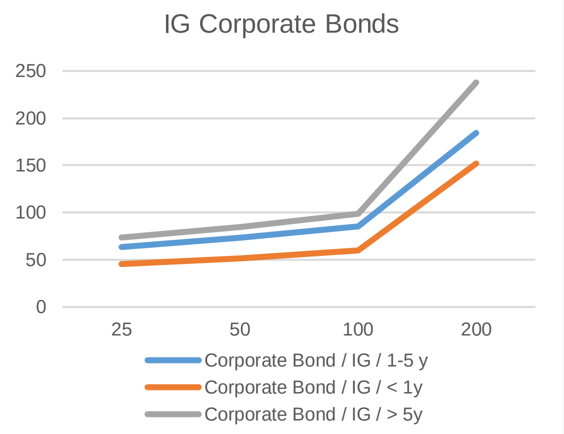
464. A selection of the most important system-wide sensitivity parameters is reported below.

465. For each asset class, the Figures below show how the market impact rises when increasing the position size (in bps).

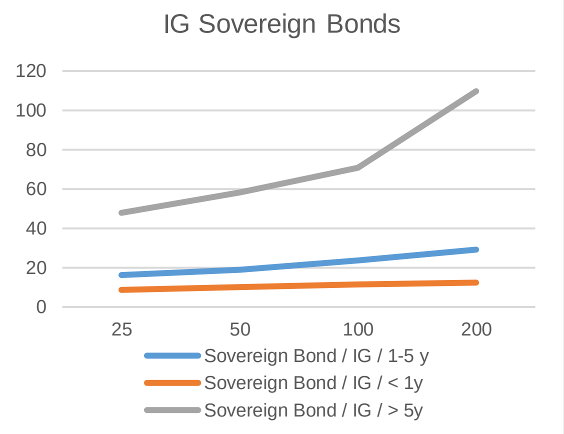
466. Below are provided worked out examples (Table 7 to Table 17) of the market impact for representative large positions in each asset class. This ensures transparency on the parameters and inputs used, which are based on the CCPs' inputs.

<u>Bonds</u>

467. Bonds sensitivity estimates are provided by issuer type (Corporate/Sovereign), rating (Investment grade/ Non-investment grade) and maturity. Figure 54 and Table 7 show that, based on data reported by CCPs, for similar positions the market impact for bonds is generally higher for corporate than for sovereign bonds and tends to grow faster with position size for longer maturities.



Note: Market impact vs relative position size in bps.
Sources: ESMA



Note: Market impact vs relative position size in bps.
Sources: ESMA

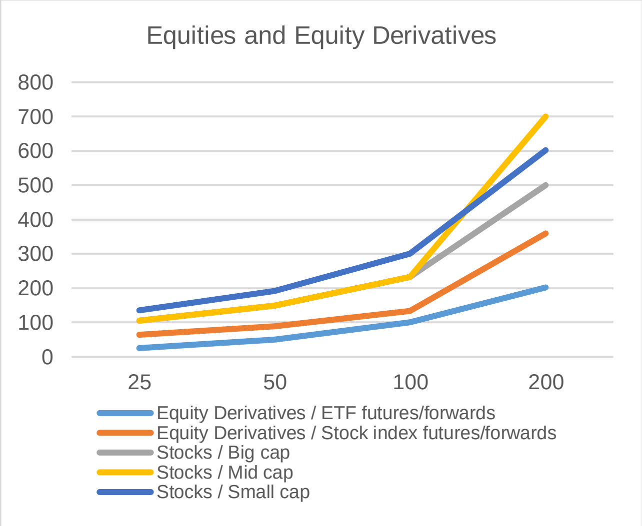
FIGURE 54: MARKET IMPACT VS. RELATIVE POSITION SIZE, INVESTMENT GRADE CORPORATE AND SOVEREIGN BONDS

TABLE 7: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, INVESTMENT GRADE BONDS

Investment Grade Bonds						
Sub-asset Class	Maturity	POSITION VALUE TOLIQ (k€)	Reference Volume (k€)	Significant Position Size	Market Impact (bps)	Market Impact (k€)
Sovereign Bond	1 to 5 years	-555,916	75,191	7.40	29	1,622
Corporate Bond	1 to 5 years	-6,572	1,681	3.91	184	121
Corporate Bond	< 1 year	5,014	3,050	1.64	119	60
Sovereign Bond	> 5 years	55,542	28,300	1.96	108	601

Equities

468. Equities sensitivity estimates are differentiated by capitalization size (Small/Mid/Big cap). Overall, Figure 55 shows a similar evolution of the market impact with size across all equity instruments (although for no clear reason, according to the data reported by CCPs market impact for Mid Cap tends to grow faster with size).



Note: Market impact vs relative position size in bps.
Sources: ESMA

FIGURE 55: MARKET IMPACT VS. RELATIVE POSITION SIZE, EQUITIES AND EQUITY DERIVATIVES

TABLE 8: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, SINGLE NAME EQUITY DERIVATIVES AND SECURITIES

Single Name Equity Derivatives and Securities					
Sub-asset Class	POSITION VALUE TOLIQ (k€)	Reference Volume (k€)	Position Size	Market Impact (bps)	Market Impact (k€)
Small cap	-447,313	207,920	2.15	602	27
Small cap	-42,445	24,189	1.75	528	1,599
Mid cap	11,327	6,580	1.72	570	155
Mid cap	27,744	13,070	2.12	700	1,513
Big cap	18,799	9,092	2.07	500	664
Big cap	30,679	16,710	1.84	456	431

TABLE 9: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, OTHER EQUITY DERIVATIVES

Other Equity Derivatives					
Sub-asset Class	POSITION VALUE TOLIQ (k€)	Reference Volume (k€)	Significant Position Size	Market Impact (bps)	Market Impact (k€)
ETF futures/forwards	-6,906	24,250	0.28	67	46
Stock index futures/forwards	1,023,950	175,263	5.84	359	36,794
Stock index futures/forwards	-4,265,135	1,144,257	3.72	359	153,263
Stock index futures/forwards	-302,723	357,426	0.85	120	3,634

<u>Energy and other commodity derivatives</u>

469. Figure 56 shows that for comparable positions median sensitivities for electricity are lower than for other commodities. Overall, for most commodities the sensitivity growths almost linearly with the size of the position.

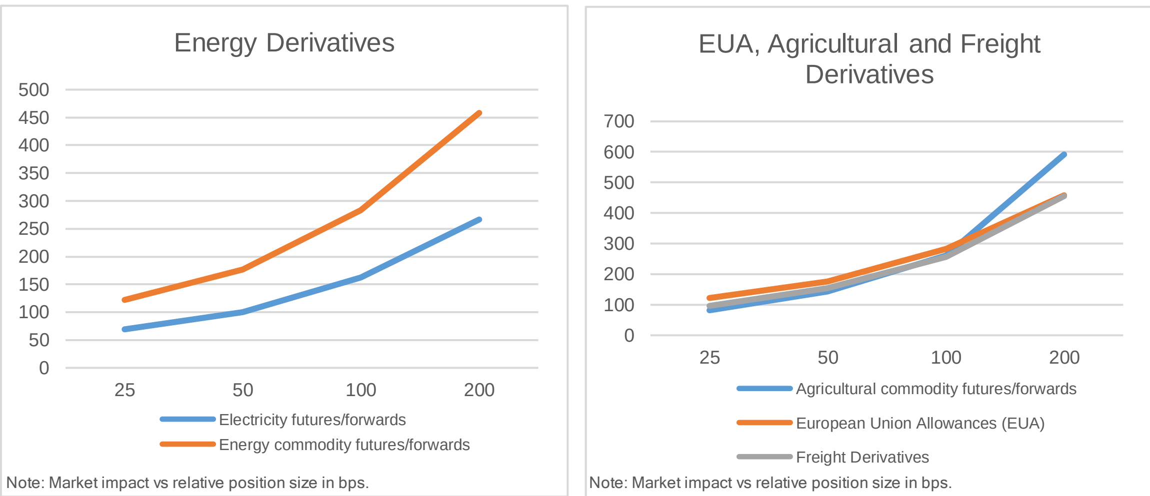


FIGURE 56: MARKET IMPACT VS. RELATIVE POSITION SIZE, ENERGY AND COMMODITY DERIVATIVES

TABLE 10: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, ENERGY COMMODITY FUTURES/FORWARDS

Energy commodity futures/forwards								
Sub-asset Class	Segment	Underlying Energy	Maturity	POSITION VALUE TOLIQ (k€)	Reference Volume (k€)	Position Size	Market Impact (bps)	Market Impact (k€)
electricity	BSLD	baseload	1Y-2Y	191,731	48,656	3.94	267	5,112
natural gas	NCGG	baseload	0-1M	254	104	2.44	458	12
coal	COAL		1Y-2Y	349,168	85,779	4.07	458	2,120
oil	KERO		1Y-2Y	-91,340	30,555	2.99	458	4,185
oil	BRNT		1Y-2Y	2,926,389	2,671,941	1.09	300	23,730

Note: the delivery point is a segmentation criterium for electricity derivatives.

TABLE 11: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, AGRICULTURAL COMMODITY FUTURES/FORWARDS

Agricultural commodity futures/forwards						
Underlying	Maturity	POSITION VALUE TOLIQ (k€)	Reference Volume (k€)	Significant Position Size	Market Impact (bps)	Market Impact (k€)
DIRY	0-3M	-3,407	821	4.15	592	13
CCOA	1Y-2Y	95,546	28,601	3.34	592	131
WHSG	0-3M	128,745	140,536	0.92	242	3,178
SEAF	0-3M	394	119	3.31	592	23

TABLE 12: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, FREIGHT DERIVATIVES

Freight Derivatives								
Segment	Segment	Segment	Maturity	POSITION VALUE TOLIQ (k€)	Reference Volume (k€)	Significant Position Size	Market Impact (bps)	Market Impact (k€)
Dry bulk	Capesize	CPT	2Y-3Y	660	76	8.70	456	60
Dry bulk	Supramax	SPT	1Y-2Y	518	23	22.8	456	24
Dry bulk	Panamax	PTC	2Y-3Y	-8,715	108	81	456	397
Tanker	265,000mt	ME Gulf to China	1Y-2Y	-86,733	1,562	55.52	455	3,952
Tanker	55,000mt	ME to Japan	1Y-2Y	-4,573	150	30.42	455	208
Tanker	130,000mt	W Africa to Cont	9M-1Y	777	59	13	455	35

Note: freight positions are typically very large compared to the average daily notional amounts.

TABLE 13: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, EUA

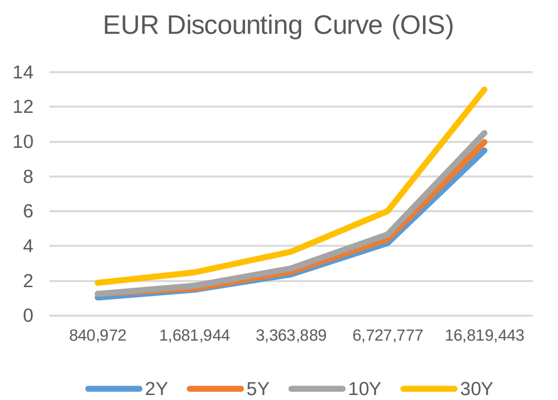
Emission Allowances - European Union Allowances (EUA)

Maturity	POSITION VALUE TOLIQ (k€)	Reference Volume (k€)	Significant Position Size	Market Impact (bps)	Market Impact (k€)
0-4M	133,915	47,833	2.8	458	6,136
1Y-2Y	-1,008,797	622,562	1.62	392	39,538
2Y-3Y	408,174	196,353	2.08	458	20,865
5Y-6Y	395	39	10.1	458	18

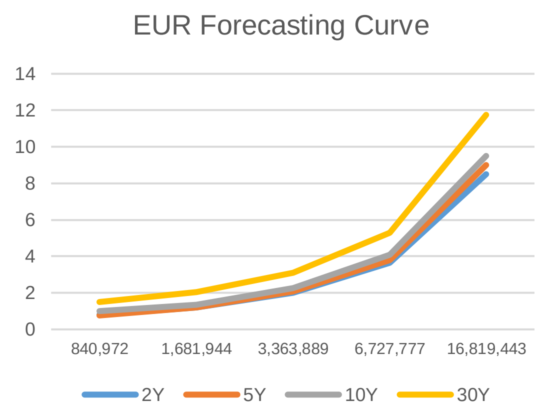
Fixed Income Derivatives

470. For each currency, curve type (Discounting, Forecasting, OIS vs IBOR) and maturity point (2Y, 5Y, 10Y, 30Y), the highest submitted PV01 reference notional was chosen to ensure the best possible coverage across clearing members concentrated positions.

471. A linear fit was used to generate the common sensitivity table for each currency. Figure 57 shows a similar behaviour for all maturity points of the curve, with very steep increases (almost exponential) for large position sizes. Moreover, for comparable positions median sensitivities for 30Y are higher than for other maturities.



Note: Hedging market impact vs position size in bps.
Sources: ESMA



Note: Hedging market impact vs position size in bps.
Sources: ESMA

FIGURE 57: MARKET IMPACT VS. RELATIVE POSITION SIZE, EUR FIXED INCOME DERIVATIVES

472. The following tables show worked out examples of market impact computation for typical representative fixed income derivatives positions.

Table 14: Market impact on representative large positions, EUR fixed income derivatives

EUR - Fixed Income Derivatives					
Curve Type	Maturity	Hedge PV01	Hedge Size	Market Impact (bps)	Market Impact Pnl EUR
Discounting	2Y	-6,255,485	1.86	3.92	20,441,036
Discounting	5Y	7,837,568	2.33	5.00	-404,604
Discounting	10Y	5,103,520	1.52	3.72	198,429
Discounting	30Y	15,106,506	4.49	11.82	178,497,700
Forecasting	2Y	2,999,695	0.89	1.84	27,351
Forecasting	5Y	7,769,832	2.31	4.34	5,688,355
Forecasting	10Y	8,236,009	2.45	4.88	38,903,982
Forecasting	30Y	-7,520,312	2.24	5.79	27,255,892

Table 15: Market impact on representative large positions, GBP fixed income derivatives

GBP - Fixed Income Derivatives					
Curve Type	Maturity	Hedge PV01	Hedge Size	Market Impact (bps)	Market Impact Pnl GBP
Discounting	2Y	-9,751,769	3.38	9.42	66,315,816
Discounting	5Y	835,349	0.29	1.57	1,315,221
Discounting	10Y	6,318,825	2.19	6.77	42,761,202
Discounting	30Y	-9,171,831	3.18	11.27	5,756.15
Forecasting	2Y	-5,642,366	1.96	5.71	21,448,955
Forecasting	5Y	835,349	0.29	1.57	1,315,221
Forecasting	10Y	-1,824,578	0.63	2.40	4,380,934
Forecasting	30Y	-7,586,368	2.63	9.49	6,472,623

Table 16: Market impact on representative large positions, USD fixed income derivatives

USD - Fixed Income Derivatives					
Curve Type	Maturity	Hedge PV01	Hedge Size	Market Impact (bps)	Market Impact Pnl USD
Discounting	2Y	13,089,362	3.27	13.35	174,793,884
Discounting	5Y	24,606,161	6.15	15.94	3,975
Discounting	10Y	-8,184,405	2.05	7.80	63,869,864
Discounting	30Y	11,335	2.83	12.82	659,925
Forecasting	2Y	7,310,734	1.83	4.64	81,805
Forecasting	5Y	13,635,768	3.41	9.17	15,513,998
Forecasting	10Y	10,903,113	2.73	7.74	2,663,816
Forecasting	30Y	13,714,725	3.43	11.95	136,917

Credit Derivatives

473. The concentration risk for credit derivatives is assessed through the market impact cost of setting-up a relevant hedging portfolio. Such hedging is assumed to be done using the 5Y maturity only.

474. CCPs reported identical hedging cost parameters for off-the-run and on-the-run series.

475. Overall, Figure 58 shows that the sensitivity growths in a similar way with position size for all sub-asset classes considered. As expected, the market impact is somehow higher when the credit quality of the underlying decreases (e.g. market impact for CDX HY is higher than for CDX IG Main).

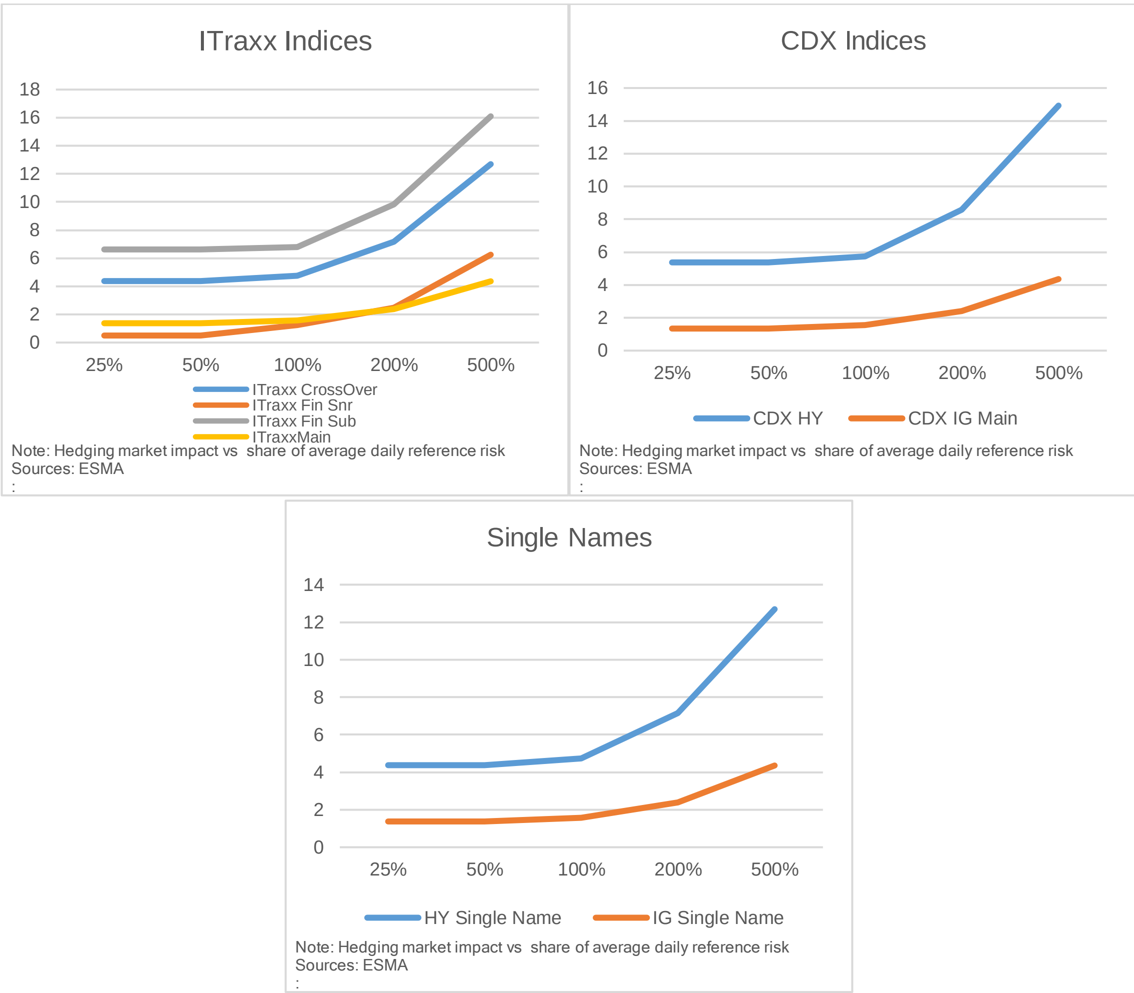


FIGURE 58: MARKET IMPACT VS. RELATIVE POSITION SIZE, CREDIT DERIVATIVES

TABLE 17: MARKET IMPACT ON REPRESENTATIVE LARGE POSITIONS, CREDIT DERIVATIVES

Credit Derivatives						
Currency	Curve Type	Average Daily Risk Per Basis Point	Position Risk Per Basis Point	Relative Hedge Size	Market Impact (bps)	Market Impact Pnl
USD	CDX.HY off-the-run	33,080	23,361	0.71	22.81	448,122
USD	CDX.HY on-the-run	645,067	-691,480	1.07	5.95	291,145
USD	CDX.IG Main on-the-run	3,263,256	-906,974	0.28	1.34	607,924
EUR	CrossOver off-the-run	372,885	177,779	0.48	4.38	777,783
EUR	CrossOver on-the-run	654,561	-598,076	0.91	4.69	2,501,753
EUR	Fin Snr off-the-run	167,740	-274,625	1.64	3.07	10,871
EUR	Fin Snr on-the-run	571,759	-692,724	1.21	1.51	1,115,416
EUR	Fin Sub off-the-run	472,156	-287,071	0.61	6.67	1,913,469
EUR	Fin Sub on-the-run	118,134	-220,401	1.87	9.41	2,490,812
EUR	HY Single Name	22,710	17,096	0.75	14.26	243,877
EUR	IG Single Name	23,565	-59,063	2.51	2.72	160,868
EUR	ITraxxMain off-the-run	488,572	-1,558,635	3.19	5.55	8,813,460
EUR	ITraxxMain on-the-run	3,348,303	-2,259,130	0.67	1.44	2,239,382

6.2.3.1 Position overlap analysis

476. The impact of liquidating overlapping positions held by one (or more) clearing member(s) at one (or more) CCP(s) is driven by their total net exposure, which is used to determine the market impact in bps. Therefore, offsetting (resp. same direction) positions will reduce (resp. increase) the cost of liquidating each position.

477. Under a real-life default scenario, it is assumed that all CCPs would liquidate the defaulting clearing members' positions at the same time. Similarly, a default of clearing member group would trigger the liquidation of the positions of all its clearing members.

478. Across all asset classes, the aggregation at clearing member group level somewhat reduces the total market impact risk.

TABLE 18: GROUPING ASSUMPTIONS ON TOTAL SYSTEM-WIDE MARKET IMPACT

	by Clearing Member	by Group	Difference
Fixed Income Derivatives	33,367	29,043	-12.96%
Bonds	11,432	11,110	-2.81%
Commodity Derivatives	7,544	7,425	-1.58%
Index Equity Derivatives	3,827	3,456	-9.69%
Single Stock Equities & Derivatives	3,462	3,409	-1.51%
Emission Allowances	2,491	2,405	-3.47%
Credit Derivatives	676	626	-7.34%
Freight Derivatives	132	128	-2.99%

479. The biggest offsets appear to be between clearing members of the same group in fixed income derivatives, index equity derivatives and credit derivatives.

480. The aggregation of the positions held by clearing member groups across multiple CCPs has little impact on the concentration risk.

TABLE 19: IMPACT OF THE LEVEL OF AGGREGATION OF CM GROUPS POSITIONS

	at CCP Level	across CCPs	Difference
Fixed Income Derivatives	29,043	29,279	0.81%
Bonds	11,110	10,948	-1.46%
Commodity Derivatives	7,425	7,408	-0.23%
Single Stock Equities & Derivatives	3,409	3,540	3.82%
Index Equity Derivatives	3,456	3,366	-2.63%
Emission Allowances	2,405	2,336	-2.86%
Credit Derivatives	626	626	0.00%
Freight Derivatives	128	128	0.00%

481. As the aggregation of positions across multiple CCPs has no significant impact for all asset classes, and to simplify the interpretation and reconciliation of the results, market impacts have been reported assuming a liquidation at the CCP level unless specified otherwise.

6.3 Operational risk analysis annex

6.3.1 Modelling, calibration and model risk analysis for the model used to estimate percentile quantities of unavailability per CCP

Modelling approach

482. In terms of modelling approaches, the frequency of operational risk events is assumed to follow a Poisson distribution. This distribution implies that losses happen randomly through time, so that in any short period of time Δt (a year on this case) there is a probability $\lambda \Delta t$ of an operational risk event occurring. The probability that k operational risk events arise over a year is given by:

$$p_k = Pr[N = k] = \frac{\lambda^k}{k!} e^{-\lambda}$$

483. Regarding the severity distribution X (which relates to the duration of disruption time), it is assumed that the duration of events follows a lognormal distribution: $X \sim LN(\mu, \sigma)$, which has a fatter tail than the (truncated) normal distribution. The probability density function f is given by:

$$f(x) = \frac{1}{x\sqrt{2\pi\sigma^2}} exp\left(-\frac{(ln(x) - \mu)^2}{2\sigma^2}\right)$$

Estimation

484. ESMA staff applies the method outlined above separately to two datasets: the events related to clearing and settlement unavailable and the events related to critical supporting functions unavailable. In both cases events that affect less than 10% of the clearing activity of the CCP are excluded.

485. For the frequency distribution, the parameter λ is estimated separately for each CCP and the two types of events, equal to the average number of events per year rounded up to the nearest integer (since the Poisson distribution requires an integer parameter). The average is rounded up to ensure that the analysis remains conservative.

	Clearing or settlement unavailable		Critical supporting functions unavailable	
	Average per year	λ	Average	λ
CCP1	1	1	0.2	1
CCP2	0.6	1	0.6	1
CCP3	1.8	2	0.4	1
CCP4	3	3	NA	NA
CCP5	3.6	4	1	1
CCP6	0.8	1	NA	NA

CCP7	5.2	6	2.8	3
CCP8	0.2	1	1	1
CCP9	2.8	3	1.6	2
CCP10	0.4	1	4	4
CCP11	1.4	2	0.2	1
CCP12	0.6	1	1	1
CCP13	1	1	0.4	1
CCP14	0.6	1	0.8	1
Average	1.6	2	1.2	2

TABLE 20: FREQUENCY POISSON DISTRIBUTION – ESTIMATED PARAMETER Λ

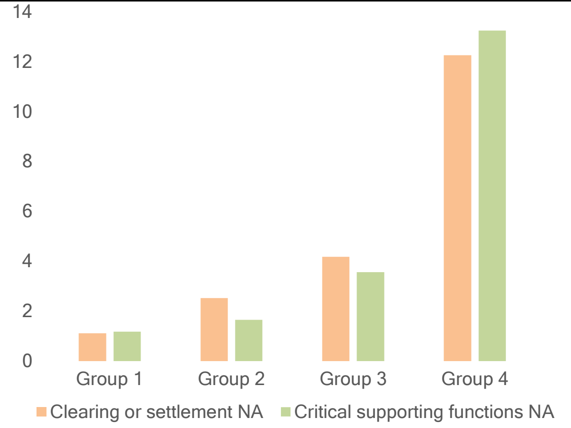
486. Regarding the severity distribution, it is not possible to obtain reliable estimates of the distribution separately for each CCP due to the shortage of data points[44]. In order to tackle this limitation in the available data, CCPs are classified into four buckets (of 3 or 4 CCPs) for each type of events based on their average disruption time (Chart 59). For each bucket as well as for the whole sample (labelled 'average'), the parameters of the lognormal distribution are estimated by maximum likelihood. This approach allows us to approximate the severity distribution of individual CCPs by using groups that have exhibited similar average disruption times.

487. Chart 60 shows the resulting distributions for the clearing unavailable events for the four buckets as well as when using all the data (orange series). Group 1 and 2 have distributions concentrated around the average, while group 3 and 4 have larger tails (with a larger proportion of events above 5 hours).

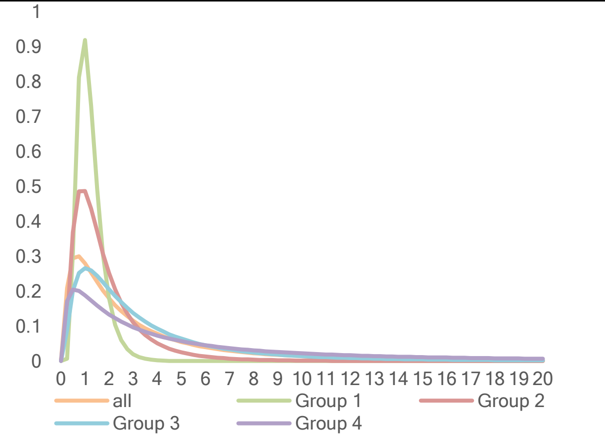
488. As an illustration, Chart 61 shows an example of the estimation of the severity distribution for the clearing and settlement unavailable events (red line) and the histogram of the actual data.

Operational risk chart 59 Average disruption time by group of CCPs	Operational risk chart 60 Severity distributions for clearing NA

[44] As described in the previous section, some CCPs report one single event over the reporting period and most CCPs report less than 10 events. Given the small sample size, the estimation of parameters would not be reliable.



Note: Average diisruption time by type of events and by group of CCPs, in hours.
Sources: CCPs, ESMA.



Note: Distribution of disruption time for clearing or settlement unavailable by group.
Sources: CCPS, ESMA.

Operational risk chart 61

Data for clearing NA and estimated severity distribution

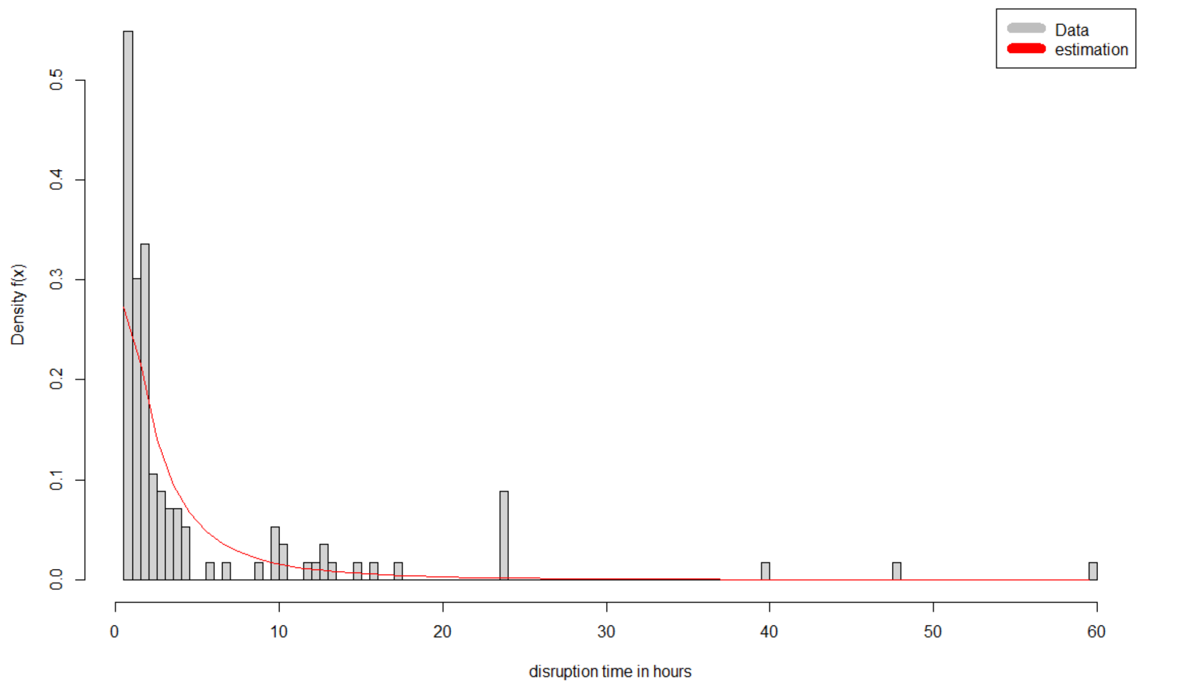


FIGURE 59: SEVERITY DISTRIBUTION – AVERAGE DISRUPTION TIME AND SEVERITY DISTRIBUTION ESTIMATE BY GROUPS OF CCPS

489. Based on the severity distributions, it is possible to calculate the probability that if an event were to occur, it would last longer than the 2-hour recovery target. As shown in the chart below, for CCPs in the high/highest severity groups, there is more than a 50% probability that an operational risk event occurring could last more than the target recovery time.

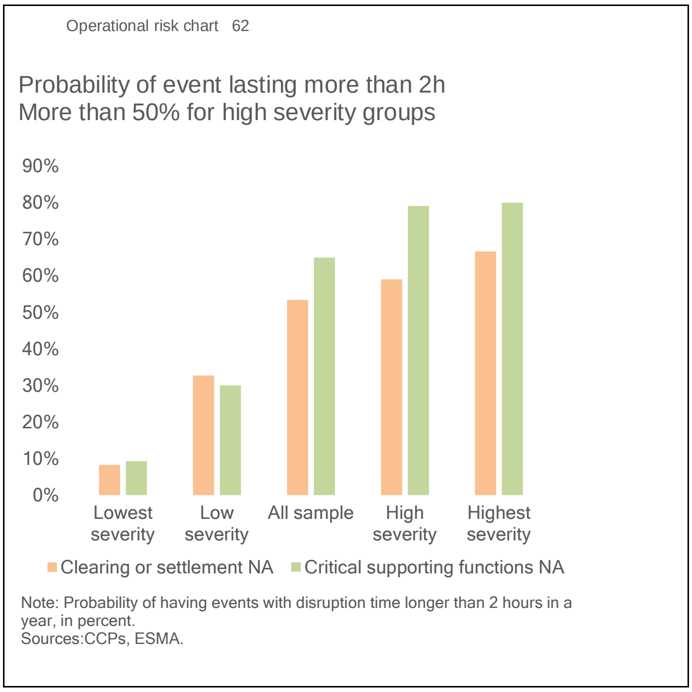


FIGURE 60: PROBABILITY OF EVENT LASTING MORE THAN 2H BY SEVERITY GROUPS

490. Finally, for each CCP and type of events 100,000 Monte Carlo simulations are run to estimate the aggregated disruption time distribution. This distribution provides the total amount of disruption time for each CCP and type of events over one year. From the distribution one derives percentile risk measures of aggregated time of unavailability / disruption over a one-year period: average and median disruption time over one year, as well as the 95% VaR (the total disruption time in 95% of the cases) and the 95% expected shortfall (the average of total disruption time above the 95% VaR). Although VaR and expected shortfall are usually metrics linked to monetary quantities, this terminology is used for quantifications of time as they allow a straightforward interpretation of the underlying mathematical formulation.

Model risk

491. The model of operational risk events presented above and that was used to derive the simulation results rests on a number of assumptions. These are generally inherited from the Loss Distribution Approach for operational risk, upon which the model was based.

492. One fundamental assumption is that of independence, both between the number of events occurring in a period and their severity, and between the severity of different events. This assumption is made for simplicity, as the introduction of a consistent correlation structure requires careful consideration. Given the early stages of this exploration of operational risk in CCPs and the relatively sparse dataset, calibrating the parameters required to represent a logical correlation structure satisfying these constraints would be very challenging.

493. The other assumptions in the model are distributional assumptions, in particular the choice of Poisson distribution for the number of events and the lognormal distribution for their severity. The choice of Poisson distribution is very common for models of discrete events. Alternatives such as the negative binomial are available, but they usually require the calibration of additional parameters. With the current data limitations this is not straightforward. Considering also the

conservativeness in the calibration of the Poisson distribution, where the observed frequencies were rounded up substantially, it was decided not to investigate this aspect further for the moment.

494. On the other hand, the representation of the events' severity via a lognormal model can be challenged in a more concrete way. From a statistical point of view, the P-value of the Jarque-Bera test applied to the logarithms of the severities of the 'clearing or settlement unavailable' events is 0.04%, while for the 'critical supporting function unavailable' events it is 9%. Therefore, while the assumption of lognormality is plausible for the second dataset, it is very unlikely for the first. However, for practical reasons one may still accept the lognormal assumption as starting point in both cases, and then test the sensitivity of the model to alternative choices. In particular, statistics such as the high percentiles, averages and expected shortfall previously reported may depend on the right tail of the distribution used in the model. While the lognormal distribution has a relatively heavy right tail, other distributional choices might produce substantially different results.

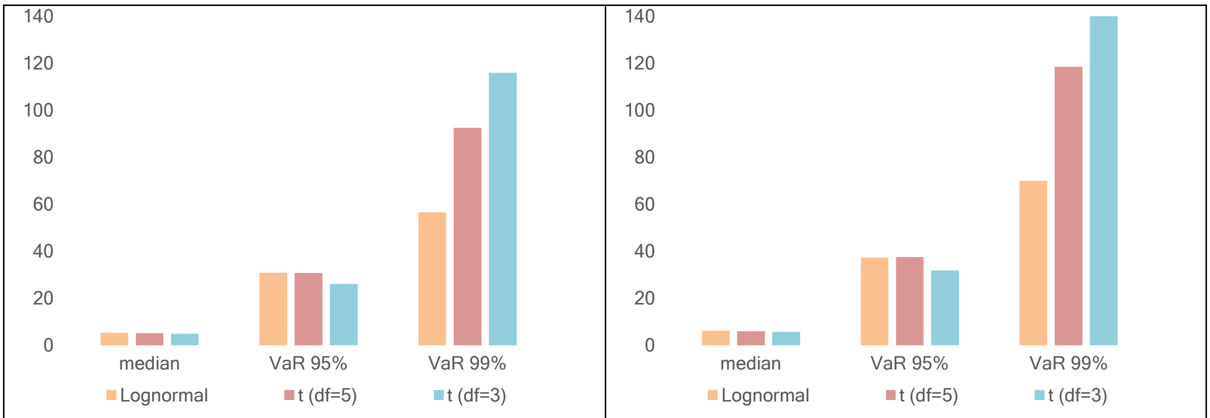
495. To test the robustness of the simulation results to the choice of distribution for the events' severity, alternative models based on Student t distribution were fitted to the data. To be more precise, the logarithms of the 'clearing and settlement unavailable' and 'critical supporting function unavailable' severity data sets were modelled with two alternative distributions each, obtained from t distributions with 3 and 5 degrees of freedom by a linear transformation in order to match the mean and standard deviation of the observations.

496. In other words, the events' severity was modelled as $X \sim e^{a+bt}$ where t indicates a Student t random variable with 3 or 5 degrees of freedom, and a and b are location and scale parameters designed to match mean and standard deviation. This is in contrast with the lognormal model $X \sim LN(\mu, \sigma) = e^{\mu+\sigma Z}$ where Z is a standard normal variable.

497. ESMA staff would like to stress that this does not endorse the choice of the t distribution as an appropriate model for the dataset at hand. The purpose of the exercise is to assess the impact of the lognormal distribution assumption on statistics derived from the model, in particular where these depend on the tails of the distribution. In this context, the t distribution with low degrees of freedom was chosen simply for its well-known property of very heavy tails. Therefore, the results from the t-based model should be seen as a boundary case to assess the sensitivity of the simulation results to distributional assumptions.

498. The simulation results show that the choice of an alternative distribution with very heavy tails has little effect on the median and 95% VaR metric. This indicates that the information in the data, together with the other assumptions of this model (independence and modelling of the events frequency), is sufficient to obtain reliable tail statistics at this level of confidence.

Operational risk chart 63 Clearing or settlement unavailable Total disruption time for the Average group	Operational risk chart 64 Critical supporting function unavailable Total disruption time for the Average group



Note: Sum of disruption time over one-year for clearing or settlement unavailable, in hours

Note: Sum of disruption time over one-year for critical supporting function unavailable, in hours

FIGURE 61: COMPARISON BETWEEN LOGNORMAL DISTRIBUTION AND STUDENT'S T-DISTRIBUTION

499. The situation changes when looking further into the tails. For example, the 99% VaR is significantly higher for the t-based models compared to the lognormal. This indicates that statistics at this level or those that may be affected by realisations in the far tails of the simulation model, such as the average or expected shortfall measures, should be taken with caution. This is a natural observation given the early stage of the investigation into operational risk for CCPs and the limited amount of data available.

Use of the model and its limitations

500. After developing this model and assessing its limitations, ESMA staff considered that a 95% percentile measurement is a useful risk metric to help understand how the entities in scope could potentially behave in a "bad year" (1/20 year) and complement the assessment based on average metrics that describe how is an "average year"; ESMA staff considered that usable percentile metrics at higher levels of confidence or measures such as expected shortfall cannot be derived reliably from the current model due to the small sample size.