CCP SUPERVISORY STRESS TESTS:
REVERSE STRESS TEST
AND LIQUIDATION STRESS TEST

A Report by Staff of the U.S. Commodity Futures Trading Commission

April 2019

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DISCLAIMER

CCP SUPERVISORY STRESS TESTS

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CCP Supervisory Stress Tests—Exhibits

List of Acronyms

BPS	basis points, each equal to 0.01 percent interest
CCP	central counterparty, or clearinghouse
CFTC	U.S. Commodity Futures Trading Commission
CM	clearing member
CME	CME Group
DCO	derivatives clearing organization
F&O	futures and options
GF	guaranty fund
IM	initial margin
IRS	interest rate swaps
LCH	LCH Limited
LIBOR	the London Inter-bank Offered Rate, published by ICE
MPOR	margin period of risk
USD	United States dollar

List of Definitions

Client	clearing member's CCP account for customers
House	CM's own account with a CCP
Liquidity add-on	IM component sized to cover liquidation costs
Mutualized pre-funded resources	GF plus a CCP's own capital
Shortfall (or Exposure)	CM stress loss in excess of IM

Executive Summary

A. Nature and Purpose of the Exercise

This is the third in a series of supervisory stress test (SST) exercises of central counterparties (CCPs) conducted by staff of the Division of Clearing and Risk and the Office of the Chief Economist (Staff) of the U.S. Commodity Futures Trading Commission (CFTC). Each of the CCPs included in these exercises is registered as a derivatives clearing organization (DCO) with the CFTC.[1]

The first report, Supervisory Stress Test of Clearinghouses, published in November 2016 (2016 Report), studied the impact of a set of stressed market conditions and defaults across multiple CCPs, with a focus on firms that held memberships at more than one CCP. The stressed conditions were based on extreme but plausible hypothetical scenarios. The 2016 Report found that the CCPs had the financial resources to withstand a variety of extreme market price changes across a wide range of products as of the date of the stress tests.

The next report, Evaluation of Clearinghouse Liquidity, published in October 2017 (2017 Report), extended the work done in the first exercise. It evaluated (i) how CCPs would seek to obtain, in a timely manner, the funds necessary to meet the settlement obligations resulting from the simultaneous default of two large clearing members (CMs) and (ii) whether the need for multiple CCPs to generate funding liquidity simultaneously had any systemic implications. The 2017 Report found that the CCPs used a wide variety of sources for their funding liquidity needs, and that there was no significant concentration of these sources across CCPs, thus mitigating systemic risk concerns.

This report further extends the work done in earlier exercises. It is comprised of two sections: reverse stress tests of CCP resources, and an analysis of stressed liquidation costs. The reverse stress test does not assume that all scenarios satisfy the extreme but plausible assumption used in the 2016 exercise; instead, it identifies potentially implausible scenarios extreme enough to exhaust all pre-funded resources available to a CCP.

The analysis of stressed liquidation costs was structured to evaluate whether CCPs had sufficient pre-funded resources to meet both the payment obligations resulting from a house account default concurrent with an extreme market move, as well as greater than expected costs resulting from hedging and auctioning the positions of the defaulting CM.

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[1] For more information on DCOs, please see
https://www.cftc.gov/IndustryOversight/ClearingOrganizations/index.htm.

B. CCP Resources

Exhibit 1 provides an overview of a typical waterfall of resources available to a CCP in a default scenario. Often a CCP will maintain separate waterfalls for distinct asset classes, such as futures and options (F&O) or interest rate swaps (IRS). In order and as necessary, the CCP would use the defaulted CM's initial margin (IM), the defaulted CM's own pre-funded contribution to the guaranty fund (GF), the CCP's own capital, non-defaulted CMs' pre-funded contributions to the GF, and lastly assessments from non-defaulted CMs.

Exhibit 1: Default Waterfall

Defaulted Member   CCP   Non-Defaulted Members

Initial Margin → Guaranty Fund → CCP Capital → Guaranty Fund → Assessments
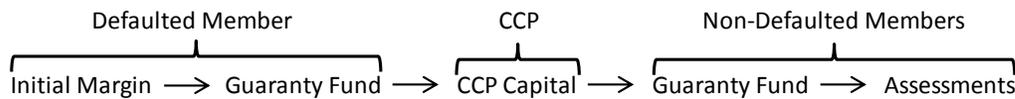
Defaulted CMs' IM, CCP capital and GF contributions from both defaulted and non-defaulted CMs are pre-funded. (Throughout this report, CCP capital and GF contributions are collectively referred to as "mutualized pre-funded resources.") According to most CCPs' rules, if this set of resources is insufficient to cover losses from CM defaults, the CCP can assess non-defaulted CMs for additional contributions up to a specified amount.[2] Non-defaulted CMs must pay these assessments in a timely fashion or be in default themselves. In other words, these CCPs can sustain default losses in excess of pre-funded resources and continue to operate. While assessments may be included in a reverse stress test, Staff took a more conservative approach and excluded assessments in order to focus on the sufficiency of pre-funded resources.

In these exercises, mutualized pre-funded resources were compared to shortfalls, defined as losses in excess of IM at defaulted CMs. For reverse stress tests, only the market component of IM was used, because liquidity add-ons are intended to cover liquidation-related expenses, not market moves. For certain CMs, a relatively small portion of margin intended to cover market moves is categorized as margin add-on in CFTC reports. This margin was necessarily excluded, even though ideally it would have been included. Like the exclusion of assessments, this may be a conservative assumption in that CCP margin requirements may be significantly higher than just the market component.

In addition, the margin posted by CMs to the CCPs sometimes exceeds the margin requirements, often for operational convenience. Because CMs may be able to withdraw this excess margin out of the CCP at any time, Staff took the conservative approach and excluded it from the calculation of a CCP's pre-funded resources for purposes of these exercises.

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[2] Assessments are generally limited in amount to a multiple of the pre-funded GF contributions.

C. Scope of the Exercises

Both exercises used positions at CME Group (CME) and LCH Limited (LCH). The reverse stress tests targeted CCP resources in two different product classes: F&O at CME and IRS at LCH. The goal of a reverse stress test exercise is to identify market moves and defaults that would exhaust resources at a given CCP; given this goal, the set of identified market moves and defaults are likely significantly more severe than any historical or anticipated event. The reverse stress test market scenarios used were based on actual market movements on four volatile historic dates, as well as amplified moves equal to 2x and 5x the moves on these dates (see Exhibits 3 and 4 below). This generated a total of 12 different market scenarios; each of the scenarios was applied to all accounts (house and client) at each CCP. Cumulative potential shortfalls for the CCP were calculated by aggregating shortfalls across CMs, sorting shortfalls in descending order - starting with the CM with the largest shortfall, adding the CM with the next largest shortfall, and so on. These cumulative shortfalls were then compared to mutualized pre-funded resources to identify extreme and likely implausible scenarios in which cumulative shortfalls exceeded these resources.

The stressed liquidation cost exercise concentrated on the 10 IRS house accounts with the highest liquidity add-ons. The liquidity add-on is the CCP's estimate of the cost of hedging and auctioning the portfolio after a default; due to limited historical data on actual liquidation costs for CCPs, this estimate is typically based on responses to a survey sent to CMs. The house accounts all belonged to CMs at either CME or LCH. The stress test aggregated costs resulting from a stressed market move as well as stressed portfolio liquidation.

The market component of this liquidation cost was defined as the largest loss across more than 200 stress test scenarios used by Staff for routine risk surveillance, which include both historical and hypothetical scenarios. For stress testing purposes, the liquidation component was set at 100 percent, 150 percent and 200 percent of the liquidity add-on charged to that account by the CCP. For each CM, the sum of the market loss and stressed liquidation cost was compared to the pre-funded resources available at the CCP - the defaulted CM's required margin as well as the CCP's capital and GF. As of June 30, 2018, the accounts tested in the liquidation cost exercise had requirements, in aggregate, of approximately $20 billion in total margin, of which around $9 billion had been allocated to cover liquidation costs.

The initial scope of the 2018 stress test exercise included an assessment of funding liquidity of CMs under stressed market conditions. The exercise included an extreme but plausible IRS stress test on all client positions at LCH for numerous bank FCMs, and further assumed simultaneous defaults of multiple large clients. Each CM was surveyed as to how it would have funded estimated VM for all clients, along with liquidation costs associated with defaulted clients. Responses were encouraging and informative, and serve as a good base for further work in the future, but results are not included in this report.

D. Key Findings

The results of the stress test exercises improve understanding of, and support confidence in, CCP resilience. However, the tests were not designed to assess compliance with regulatory requirements such as "Cover 2", and should not be interpreted in that way.

The results from the reverse stress tests show that the two CCPs included in the exercise have sufficient pre-funded resources to cover all CMs with losses under the selected 1x historical scenarios. In other words, aggregating shortfalls across all CMs with exposures from these price moves does not exceed mutualized pre-funded resources. The same remains true for all but one of the 2x historical scenarios.

In contrast, shortfalls from CM defaults under most 5x historical scenarios (i.e., price moves five times the size of an exceptionally volatile day in history) can exhaust mutualized pre-funded resources at both CCPs. It is important to note that the base historical scenarios were selected from among the most volatile periods of the last 10 years, and market moves within a single trading day equivalent to 5x these historical moves are likely implausible. As an example, one of the 5x historical scenarios equates to an intra-day move of roughly 40 percent in the S&P 500 index, far larger than the largest single-day move in the history of the US equity markets. Interestingly, relevant rules in the US equity markets will cause trading to halt for the day after a 20 percent intra-day move. Such a trading halt would limit the amount of variation margin (VM) required on that day, but not necessarily limit the potential losses to the CCP due to CM default(s).

Results from the 6/24/2016 5x scenario, with price changes five times the size of those on the day following the Brexit referendum, are particularly informative. In F&O at CME, if the two CMs with the greatest shortfalls defaulted, the combined shortfall would be very close to mutualized prefunded resources. In IRS at LCH, if the four CMs with the greatest shortfalls defaulted under that price scenario, the combined shortfall would be very close to mutualized prefunded resources. Though F&O have a minimum margin period of risk of one day and IRS has a minimum of five days, in the reverse stress test analysis we focus on the more general question of what combination of market shock and default(s) would exhaust pre-funded resources, independent of MPOR.

In the stressed liquidation cost test, both CCPs had sufficient pre-funded resources to meet the aggregate market and liquidation costs of each defaulted house account. Even in the most extreme case of 100 percent market loss and 200 percent estimated liquidation cost, at most 57 percent of mutualized pre-funded resources were depleted.

I. Reverse Stress Test

A. Background

The first part of this stress test exercise focused on reverse stress testing two systemically relevant derivatives CCPs, CME and LCH. Regular CCP stress tests assess the resilience of the CCP against losses due to a combination of extreme but plausible market movements and CM defaults.[3] A reverse stress test poses a related, but very different, question. Instead of identifying whether available resources can cover a pre-specified number of defaults under plausible market scenarios, the exercise seeks to identify combinations of market moves and CM defaults sufficiently severe to exhaust pre-specified resources. Unlike in traditional stress tests, the scenarios used in a reverse stress test do not have to meet the "extreme but plausible" standard. Hence, by design a reverse stress test is not intended to assess compliance with Cover 2 or any other regulatory standard.

In the reverse stress test, losses due to market moves are compared to pre-funded resources immediately available to the CCP: the market component of IM of the defaulted CM(s), the CCP's capital, and the GF. Given that assessment powers and the liquidity add-ons are not included, the exercise is considered to be conservative, meaning CCPs could actually absorb greater losses.

B. Scope

The exercise focused on the resiliency of two systemically relevant CCPs under the CFTC's jurisdiction (LCH for IRS and CME for F&O). Both CCPs tested in the exercise are systemically relevant in a different asset class and product type, providing a relatively broad view of resiliency during extreme market conditions.

All tests included the positions of all CMs, both house and client accounts. For both F&O and IRS, a CCP will use gains in a defaulted firm's house account to offset losses in that firm's client account, but client gains cannot be used to offset house losses. Furthermore, for IRS, an individual client's gains were not used to offset any other client's losses.

In Section E, the reverse stress test results are reported at the CM level, not at the level of the parent company (e.g., if a bank holding company has two subsidiary CMs, results are reported separately). The assumption is that the default of one CM does not necessitate default of an affiliated CM.

Section F includes an analysis of shortfalls that could occur concurrently at the two CCPs tested. While many parent companies have CMs at both of the CCPs, for various reasons, the CMs may be different legal entities. For the purpose of this analysis, we remove the assumption that the default of one CM does not necessitate default of an affiliated CM, and assess shortfalls at the parent level.

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[3] In the 2016 stress test exercise, a set of extreme but plausible historical and theoretical scenarios was used to test CCP resources; for a majority of these market scenarios, the relevant CCPs were found to have sufficient resources not only to cover the default of the two CMs with the largest shortfalls (the regulatory standard) but the default of all CMs. In every test scenario, all CCPs satisfied the Cover 2 minimum standard.

C. Methodology

The analysis is based on open positions for each CM at the close of business on September 5th, 2018,[4] using the daily reports submitted to the CFTC by CME and LCH as registered DCOs.[5] Losses from the market stress scenarios (for house and client accounts) were aggregated for each CM at each CCP and then compared to their IM requirement. Because the stress test is a market stress test, only the market component of required IM was considered (i.e., additional margin, including liquidity and concentration margin charged by the CCPs is not included). House margin and stress gains in the house account were used to offset client credit exposures at each CM legal entity, when applicable, in accordance with CCP rules. In contrast, gains in client accounts were not used to offset losses in the house account.

Once the offset opportunities were exhausted, all CM accounts where required margin at the CCP was not sufficient to cover stress losses were identified. The CCP would need to cover this shortfall if the CM defaulted, making use of default waterfall funds. The shortfalls would be covered by the defaulted CM's GF contribution, followed by the capital posted by the CCP and, finally, by the non-defaulted CMs' GF contributions.

Exhibit 2 presents a summary of mutualized pre-funded resources as of the scenario date (excluding posted IM). Note that the resources here represent the IRS GF for LCH and the F&O GF for CME.

Exhibit 2: Mutualized Pre-funded Resources

CCP	CCP Capital ($)	Guaranty Fund ($)	Total Funds ($)
LCH	56,635,475	6,602,781,350	6,659,416,825
CME	100,000,000	3,654,852,191	3,754,852,191

For each scenario, the minimum and maximum number of CM defaults needed to exhaust these mutualized pre-funded resources is calculated (though in some scenarios, mutualized pre-funded resources cover the default of all CMs with exposure).

D. Scenarios

In the exercise, four historical dates were used as base scenarios for the reverse stress test. The historical tests were comprised of actual one-day price changes from four key global macro market event days from 2008 through 2018. For F&O, price shocks from the nearby contract month were applied to all contract months for simplicity (i.e. parallel shifts were used). For IRS, given that positions are generally more evenly spread throughout the forward curve, actual shocks for each tenor bucket were used. The dates selected include significant market events like the Brexit vote as well as two days during the Global Financial Crisis in 2008. The selection of historical scenarios was partially guided by the products included in the stress tests (F&O and IRS); markets on the dates selected

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[4] The sum of IRS initial margins at LCH and base initial margins at CME on September 5, 2018 were within 1% of the average for the month of September.

[5] For IRS stress tests, Staff used delta and gamma information provided by LCH.

either had large interest rate shifts (e.g. 9/15/2008), large equity shifts (e.g., 11/20/2008), or both. The dates used, along with a short description of each event, are shown in Exhibit 3.

Exhibit 3: Dates for Historical Scenarios

Date	Description
9/15/2008	Lehman Default
11/20/2008	Large Equity Move
6/24/2016	Brexit Vote
2/5/2018	Large Volatility Move

In addition to these four historical scenarios, 8 theoretical scenarios were created by applying 2x and 5x multipliers to the price changes on these dates. A summary of the market moves on these four dates for a sample set of major financial products is included in Exhibit 4.

Exhibit 4: Magnitudes of Changes on Select Products

9/15/2008 - Lehman Default	1x	2x	5x
IRS 2-YEAR USD LIBOR (BPS)	-45	-90	-225
IRS 30-YEAR USD LIBOR (BPS)	-29	-58	-145
S&P 500 STOCK INDEX	-5.0%	-9.9%	-24.8%
CRUDE OIL, LIGHT SWEET	-5.4%	-10.8%	-27.0%
11/20/2008 - Large Equity Move	**1x**	**2x**	**5x**
IRS 10-YEAR USD LIBOR (BPS)	-27	-54	-135
IRS 10-YEAR Fed Funds (BPS)	-47	-94	-235
S&P 500 STOCK INDEX	-7.9%	-15.8%	-39.5%
CRUDE OIL, LIGHT SWEET	-7.5%	-14.9%	-37.3%
6/24/2016 - Brexit Vote	**1x**	**2x**	**5x**
IRS 30-YEAR USD LIBOR (BPS)	-15	-31	-77
S&P 500 STOCK INDEX	-4.1%	-8.3%	-20.7%
CRUDE OIL, LIGHT SWEET	-4.9%	-9.9%	-24.7%
BRITISH POUND STERLING	-7.8%	-15.6%	-38.9%
2/5/2018 - Large Volatility Move	**1x**	**2x**	**5x**
IRS 30-YEAR USD LIBOR (BPS)	-6	-12	-31
S&P 500 STOCK INDEX	-5.4%	-10.8%	-27.0%
CRUDE OIL, LIGHT SWEET	-2.0%	-4.0%	-9.9%
NATURAL GAS	-3.5%	-7.0%	-17.4%

All major products at both CCPs[6] were stressed using the market moves from each of the 12 scenarios, and portfolio gains/losses were calculated for each CM's client and house account. In a few cases, some currently cleared products did not exist on the date of the stress test. In these cases, price moves were based on the moves of highly correlated products.

For the sake of simplicity, to stress short options positions volatility was moved up by 50 percent, relative to the stress test date, in the base (1x), 2x, and 5x scenarios. For example, if the implied volatility of an option was 20 percent on September 5, it was shocked by 10 percent so that the option was repriced with an implied volatility of 30 percent. Given the magnitudes of shocks to futures prices in the more extreme stress tests used, almost all option positions tended to become either so deep in-the-money or so deep out-of-the-money that changing the levels of implied volatilities would have had little impact on these options' values.

E. Results

1. F&O

Exhibit 5 summarizes the results of the stress tests of F&O at CME. The table only includes results for the scenarios where stress test losses were large enough to exceed the IM of at least one defaulted CM. The table includes information on:

- the scenario, identified by date and by multiplier (column 1);
- the number of CMs whose losses exceed their required IM (column 2);
- the minimum number of defaults necessary to fully exhaust the mutualized pre-funded resources, using the CMs with the largest shortfalls (if there were sufficient pre-funded resources to cover all CMs with shortfalls, "SPR") (column 3);
- the combined shortfalls of the minimum number of defaulted CMs required to fully exhaust the mutualized pre-funded resources; if pre-funded resources are sufficient to cover exposures (rows 5 through 13), the number represents the cumulative shortfall at all CMs (column 4); and
- the maximum number of shortfalls that can be covered by the CCP resources (generated by aggregating the smallest CM shortfalls[7]) (column 5).

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[6] Included CME F&O products accounted for 96% of IM, while 100% of LCH IRS positions were included.

[7] The first row of Exhibit 5, for example, indicates that in the 11-20-08 5x scenario one particular CM default would exhaust pre-funded CCP resources, however that does not mean any single default would do so. In fact the CCP could cover up to 28 defaults (when defaults are sorted in the increasing order of shortfall) by CMs with shortfalls under that scenario.

Exhibit 5: Reverse Stress Tests, F&O

Scenario (1)	# of CMs with Stress Losses > IM (2)	Defaults Needed to Exceed Pre-funded Resources (3)	Shortfall in Excess of IM ($bn) (4)	Maximum # of Defaults Covered (5)
11-20-08 5x	33	1	8.27	28
9-15-08 5x	26	1	4.07	24
2-5-18 5x	19	2	3.91	18
6-24-16 5x	24	2	3.86	23
11-20-08 2x	13	SPR*	0.75	All
9-15-08 2x	12	SPR	0.43	All
6-24-16 2x	11	SPR	0.29	All
9-15-08 1x	6	SPR	0.16	All
11-20-08 1x	8	SPR	0.08	All
6-24-16 1x	6	SPR	0.07	All
2-5-18 2x	5	SPR	0.05	All
2-5-18 1x	3	SPR	0.01	All

* Sufficient pre-funded resources to cover all estimated shortfalls.

To illustrate, in the case of scenario 6-24-16 5x (the fourth row in the table), the CCP:

- has 24 CMs with losses exceeding required IM;
- would be able to cover the largest CM shortfall using mutualized pre-funded resources;
- would face $3.86 billion in losses above required IM in the case where the two CMs with the largest shortfalls default, which slightly exceeds mutualized pre-funded resources of $3.75 billion; and
- has mutualized pre-funded resources sufficient to cover losses from the default of the 23 CMs with the smallest shortfalls.

For all base historical scenarios, and even the 2x amplified scenarios, CCP resources could cover exposures resulting from the default of all CMs with shortfalls.

The top 4 rows (shaded) highlight the four theoretical scenarios and the number of CMs that would need to default (column 3) in order to exhaust mutualized pre-funded resources. In two scenarios, the default of the CM with the largest shortfall would have by itself exhausted all of the CCP's pre-funded resources. However, this is in line with the goal of the reverse stress test to explore and size potential market moves that can exhaust a CCP's resources. It is worth noting that with assessments, which are not pre-funded and not included in the exercise, the CCP would have sufficient total resources to cover those numbers of defaults in column 3.

All of the scenarios that exhausted the CCP's resources represent market moves five times as large as had been experienced in already highly stressed extreme historical events. To give some perspective on the size of market moves under the 5x scenarios, equity prices are assumed to fall 40 percent in the

most extreme case. Three of the four scenarios used include equity price falls greater than 23 percent - the largest equity index move in history, which occurred on October 19, 1987. Subsequent to that, circuit breakers were introduced in the US equity markets to halt trading for the day if equity indices change 20 percent or more during the course of a trading day.

For the F&O stresses, the total of shortfalls resulting from the 6-24-16 scenario, assuming all firms having shortfalls default, only used two percent of the mutualized pre-funded resources in the 1x case, 8 percent in the 2x case, but 170 percent in the 5x case. Options positions contribute to a nonlinear rate of growth (across the theoretical multipliers) in market losses. However, even if market losses for a portfolio increase linearly with increasing shocks, growth in the cumulative shortfall will be non-linear. Since a portfolio's IM is the same for the 1x, 2x, and 5x shocks, as market losses increase with the severity of shocks, a smaller percentage of the loss is absorbed by IM. Also, the number of firms with shortfalls grows as shocks increase.

Exhibit 6 contains a more detailed comparison of losses across the three multipliers for the 6-24-16 "Brexit Vote" scenarios. Here, the three solid lines represent the cumulative aggregate losses (after IM is exhausted) faced by the CCP after a given number of CM defaults, while the dashed line represents mutualized pre-funded resources. By construction, these cumulative losses increase as more CMs default, though at a decreasing rate. This chart makes the non-linearity of shortfalls even starker when comparing the 2x and 5x scenarios for a small number of defaults.

Exhibit 6: F&O Shortfalls by Number of Defaults, 6-24-16 Scenario
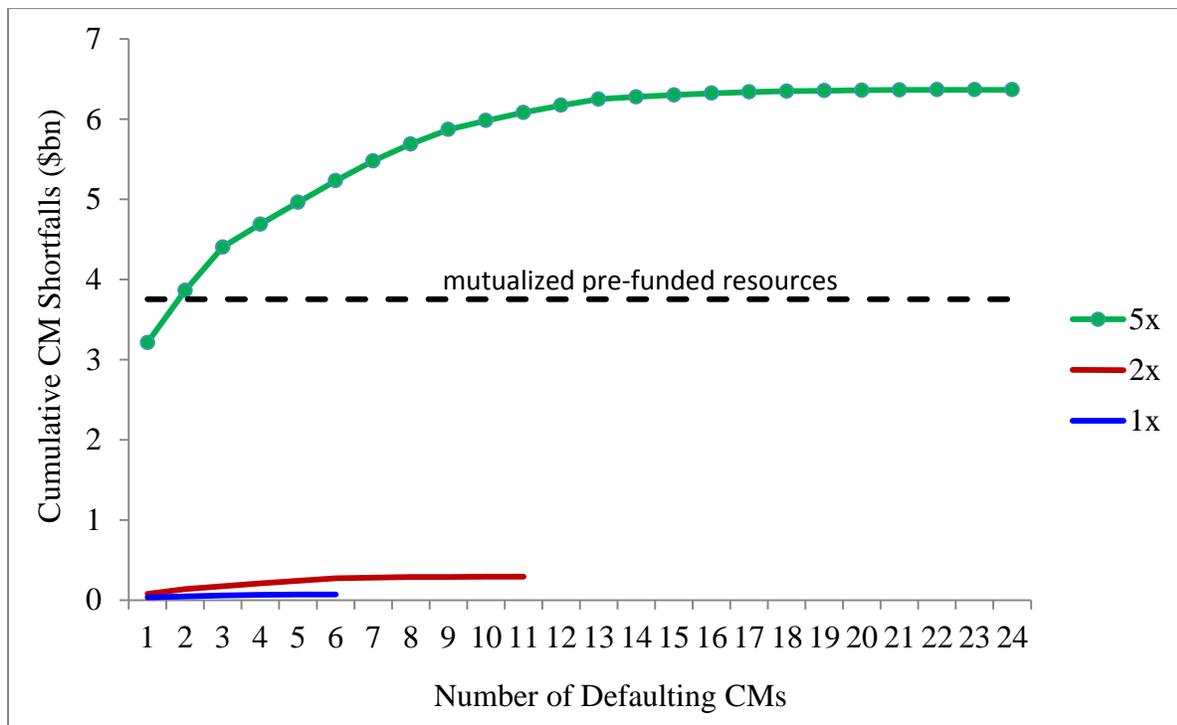
2. IRS

Exhibit 7 summarizes the results of the reverse stress tests of IRS at LCH. In the 9-15-08 5x and the 11-20-08 5x scenarios, the shortfall from a single CM default could exceed mutualized pre-funded resources, but this is concurrent with interest rate shocks exceeding 200 bps in some curves or tenors, and in both cases defaults of hundreds of individual clients. Conversely with the 9-15-08 2x scenario, the CCP has sufficient pre-funded resources to cover the combined exposures from the three CMs with largest shortfalls, composed of simultaneous defaults by 860 individual client accounts.

Exhibit 7: Reverse Stress Test, IRS

| Scenario (1)	# of CMs with Stress Losses > IM (2)	Defaults Needed to Exceed Pre-funded Resources (3)	Shortfall in Excess of IM ($bn) (4)	Maximum # of Defaults Covered (5)
9-15-08 5x	37	1	16.62	23
11-20-08 5x	52	1	9.54	25
9-15-08 2x	24	4	7.64	20
6-24-16 5x	34	5	7.16	30
11-20-08 2x	31	SPR*	6.40	All
9-15-08 1x	13	SPR	0.31	All
6-24-16 2x	12	SPR	0.23	All
2-5-18 5x	11	SPR	0.12	All
11-20-08 1x	9	SPR	0.01	All
6-24-16 1x	1	SPR	0.00	All
2-5-18 2x	1	SPR	0.00	All

* Sufficient pre-funded resources to cover all estimated shortfalls.

LCH assumes a five-day liquidation period when sizing its GF for IRS. However, in practice a large five-day price move would almost certainly be smaller than the largest single day move in that period multiplied by five, since it is extremely unlikely that a price would move the same large factor in each of the five days. In fact, empirically Staff has found the largest 5-day change in a particular swap rate tends to be approximately twice the size of the largest 1-day change, not five times as large. This helps to explain why under the first two 5x scenarios a single default consumed mutualized pre-funded resources.

In total, three 5x theoretical scenarios, as well as a fourth scenario representing a 2x move, resulted in losses that could have exhausted pre-funded resources for IRS at LCH if certain large CMs defaulted. Similar to F&O, the base historical scenarios resulted in losses covered by pre-funded resources, even if all CMs with losses defaulted.

Exhibit 8 shows a more detailed comparison of losses for the 6-24-16 "Brexit Vote" scenarios. Here again, the solid lines represent the cumulative aggregate losses (after IM is exhausted) faced by the CCP and non-defaulted CMs for a given number of CM defaults, while the dashed line represents mutualized pre-funded resources. By construction, these cumulative losses increase as more CMs default.

Exhibit 8: IRS Shortfalls by Number of Defaults, 6-24-16 Scenario
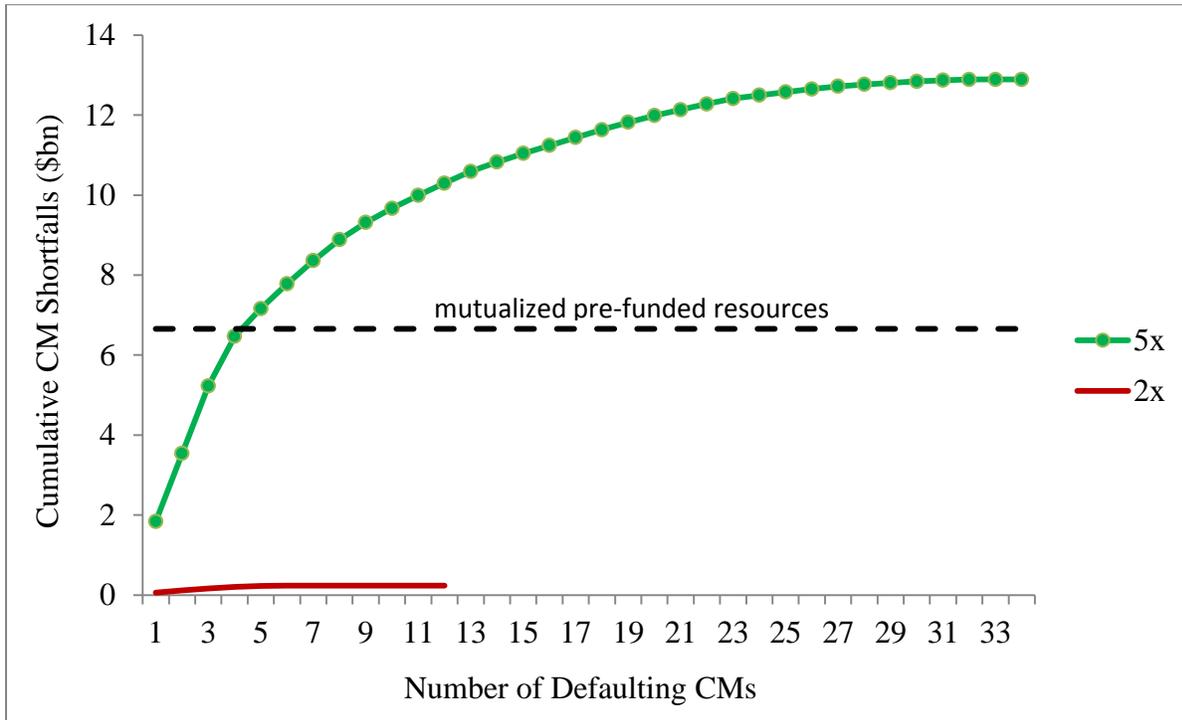
F. Results Aggregated Across CCPs

The previous sub-sections examined the results for the individual CCPs. In this sub-section the results are aggregated to capture the potentially systemic (or cross-CCP) impact of these extreme stress test scenarios. This is important as many parent entities have memberships at multiple CCPs. While no two CCPs are likely to clear the same set of instruments, the analysis helps us understand the differential impact of a common set of shocks on different CCPs.

While many firms are CMs at both CME and LCH, the membership may be different legal entities. Therefore, in this sub-section shortfalls at affiliated CMs are aggregated and reported at the parent level. Also, since it is difficult to know a priori whether the default of one affiliate will result in the default of a different affiliate, it adds value to analyze the data both ways.

As shown in Exhibit 9, there were six different scenarios in which at least one parent firm had shortfalls at both CCPs. There were 78 parent firms with shortfalls at either CCP, but only 10 with shortfalls at both CCPs under any scenario. Seven of those 10 firms had shortfalls at both CCPs under the 11-20-08 5x scenario. This is probably the most implausible of the scenarios included in the analysis.

Exhibit 9: Parent Firms with Shortfalls at Both CCPs

Scenario	Number of Firms
11-20-08 5x	7
6-24-16 5x	3
9-15-08 5x	2
9-15-08 2x	1
11-20-08 2x	1
2-5-18 5x	1

The distribution of shortfalls by parent firm differed across the two CCPs. At CME, cumulative shortfalls were smaller but more concentrated than at LCH. For example, under the 11-20-08 5x scenario, the largest percentage contribution by a single firm to the total shortfall was 12 percent at LCH but 41 percent at CME. Aggregating across both CCPs, no single parent firm accounted for more than 12 percent of the total shortfall under this scenario.

Six unique parent firms had shortfalls in excess of mutualized pre-funded resources at either CME or LCH, but none at both CCPs. Only one of those six firms had shortfalls at both CCPs (greater than mutualized pre-funded resources at CME but less than mutualized pre-funded resources at LCH for both the 11-20-08 5x and 9-15-08 5x scenarios). At LCH, two firms had shortfalls in excess of mutualized pre-funded resources in both the 11-20-08 5x and 9-15-08 5x scenarios, and two others in only the 9-15-08 5x scenario. At CME, one firm had a shortfall in excess of mutualized pre-funded resources in both the 11-20-08 5x and 9-15-08 5x scenarios, and another firm in only the 11-20-08 5x scenario (both CME firms distinct from the four at LCH).

In the 6-24-16 5x scenario, 24 parent firms had shortfalls at CME and 29 had shortfalls at LCH, but only three had shortfalls at both CCPs. Those three firms had a combined F&O shortfall essentially equal to mutualized pre-funded resources at CME, but their combined IRS shortfall would have used only 14% of mutualized pre-funded resources at LCH (none of those three firms were in the top five shortfalls at LCH).

Under the 9-15-08 5x scenario, if the two parent firms with shortfalls at both CCPs defaulted, the combined shortfall would have been slightly greater than mutualized pre-funded resources at both CCPs. However, these market losses are likely implausible and likely exceed any historical market losses for these portfolios. Note the scenario includes market shocks of -225 bps in 2-year USD LIBOR IRS, and -25% in S&P 500 Stock Index futures. Also, assessment powers are not included in this analysis, so the CCP would have access to additional resources. Still, this is an interesting example of an approximate level of market shock and defaults that would consume pre-funded resources across two systemically relevant CCPs.

II. Liquidation Cost Stress Test

This section provides a high-level overview of how account liquidation occurs in the event of a CM default. This overview is followed by a description of the resources held by CCPs to cover costs incurred during the liquidation process. The section ends with a detailed description of the stress test methodology and a discussion of the results.

A. CCP's Liquidation Procedures

As background for the liquidation stress test results, Exhibit 10 below provides a hypothetical example of the type and sequence of expenses that might be incurred by a CCP in the hedging and auctioning of a defaulted portfolio. Utilization (right column) is the percentage of the defaulted firm's IM, the first layer of the default waterfall, used to cover losses in the account. If this utilization was greater than 100%, subsequent layers of the default waterfall would be used.

Exhibit 10: Hypothetical House Default

Initial Margin	1,500,000,000 ($)	Utilization (%)
Day 1 Friday EOD VM	-150,000,000	-10
Day 2 Default Management (market move + hedging cost)	-300,000,000	-20
Day 3 VM	-250,000	0
Day 4 VM	-200,000	0
Day 5 market move (before the auction)	+175,000	0
Final Liquidation Auction Premium	-15,000,000	-1
Total Costs	**-465,275,000**	**31**

This scenario represents a series of events similar to those that may lead to losses summarized in the test results.

- Day 1: The CM must meet a VM requirement charged against its house account based on market moves on a Friday. This VM payment is due by market open on Monday. If the CCP does not receive the payment by the specified time, a default event is declared and the CCP's Default Management Group is convened to supervise the default management process. The required VM for Day 1 ($150 million in this example) is met by the CCP using the defaulted firm's IM. The market component of IM is sized to cover this type of risk.

- Day 2: Further adverse market movements contribute to another VM requirement for the defaulted firm's positions. In order to reduce the risk of additional market losses prior to auction, the Default Management Group may choose to hedge the portfolio. Hedging costs may be significant depending on the number and sizes of the required hedges, and market liquidity. The liquidity add-on component of IM is intended to cover these hedging costs. In this example, $300 million of IM is used to meet a VM requirement driven by both market losses and hedging costs.

- Days 3 and 4: Non-defaulted firms are invited to participate in one or more auctions for the defaulted portfolio. Given the size of the positions (possibly greater than the average daily trading volume), firms are given sufficient time to ingest the information, price positions and

prepare bids. Assume that the auction closes on day 5. In this example, while firms are preparing for auction, market movements result in additional VM demands against the defaulted account. The size of the VM demands are now substantially smaller ($250,000 and $200,000 on Day 3 and Day 4, respectively) due to the portfolio hedges that were executed.

- On Day 5, the market moves in favor of the defaulted account by $175,000 prior to the close of the auction, benefiting the defaulted account. At the auction close, the CCP no longer has risk as the auction winner owns the portfolio. However, in this example the winning bidder required a $15 million discount to the market mid at the close of the auction, so an additional $14.825 million of IM ($15 million less $175,000) is used on the day.

- In aggregate, for this example, 31 percent of the account's IM was needed to cover claims from market losses, portfolio hedging and auctioning costs.

The test below focuses on a set of large house accounts and assesses whether, in stressed market conditions, losses due to the liquidation of the account could overwhelm the pre-funded resources of the CCP. House accounts in IRS tend to be larger than client accounts, and thus have larger liquidity add-ons. There are large client accounts, but these tend to spread their positions across multiple CMs. This test is guided by the post-default process described above.

B. Liquidity Add-On Calculation

As noted in the example above, IM posted by a CM for its house account is available to cover default losses. IM requirements are often based on a number of factors. The market component of IM for swaps is typically sized to cover five-day price moves (the margin period of risk, or MPOR) in extreme but plausible market conditions. In addition to this market charge, CCPs often include IM add-ons based on the size and/or composition of the cleared portfolio. One of these, the liquidity add-on, is designed to cover the potential costs associated with the liquidation, or hedging and auctioning, of a defaulted portfolio, over and above changes in the mid-market price covered by the market-based margin component. This cost is largely reflected in the bid-ask spread, which increases during a period of market stress. Furthermore, the process could put additional pressure on mid-market prices, resulting in more losses. CCPs look to cover these expected losses with a liquidity add-on. For large portfolios, these losses could be significant; a few of the accounts tested have liquidity add-ons that are similar to, or exceed, the size of the base market charge.

CCPs have a wide variety of analytical techniques to estimate margin levels which would cover market moves over the relevant MPOR even during volatile periods. They can use long lookback periods and market correlations to identify the distribution of losses in both historical and theoretical scenarios.

On the other hand, estimating the cost to hedge and auction the portfolio of a defaulted CM can be difficult. The small number of historical portfolio liquidations by CCPs makes this exercise challenging and possibly fraught with measurement and estimation errors. Instead, liquidity add-ons are often derived from estimates provided by CMs. On a periodic basis (e.g., annually), CCPs send each of their CMs a survey, asking how much they would charge (i.e., the premium or discount relative to the mid-market price) to trade a given position during a period of stress.[8] These surveys usually request costs broken down by currency and maturity of the instrument, and size of the

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[8] Unlike F&O, which tend to trade actively in a centralized limit order book with observable quoted bid-offer prices, swaps are traded through alternate execution methods with different transparency protocols. Hence the reliance of the CCPs on a survey of their CMs for potential liquidation costs.

transaction. For example, transaction costs may be requested for purchasing $100 million of 10 year USD LIBOR swaps. The responses to these surveys are then aggregated to estimate the cost to liquidate a portfolio, i.e., the liquidity add-on described above.

As these survey responses are not executable quotes, CCPs have to make appropriate adjustments to estimate costs during stressed market conditions. For instance, if a CCP receives multiple responses to its survey, and the lowest quote for a given position is five basis points (bps), in theory there should be at least one participant willing to purchase the position at a discount of only five bps. However, in practice it may cost the CCP more because in an actual stressed market, some participants may not be as aggressive, or the best quote in the survey may have been from a now defaulted CM.

In order to protect against some of these contingencies, CCPs often use the mean or median survey response rather than the minimum. In addition to this potentially conservative assumption, for very complex portfolios a CCP may also use other metrics which lead to a liquidity add-on greater than what would be called for by the survey alone.

C. Methodology

Even with conservative estimation methodologies, it is reasonable to be concerned that in stressed market conditions, bidders may not be willing to take on new risk, causing actual liquidation costs to be higher than expected by the CCP. The stress test described below sought to assess whether a CCP would have sufficient financial resources to cover both stressed market losses and stressed liquidation-related losses resulting from the default of a CM with a large cleared IRS position. To test this, Staff assumed the cost for the CCP to return to a matched book[9] after a CM default is equal to the sum of a stressed market charge as well as a multiple of the collected liquidity add-on.[10] In the hypothetical example given above, the stressed market charge would be roughly equivalent to the VM payments assessed against the defaulted portfolio, and the stress liquidity add-on would cover the costs to hedge and auction the portfolio.

The stress test included a total of 10 house accounts clearing at either CME or LCH. These house accounts represent the top 10 accounts with the largest CCP-assigned liquidity add-ons. In aggregate, these accounts represent $20 billion in total IM, of which $9 billion is the liquidation component. Data on house accounts was sourced from the applicable CCPs, and represented positions and margin as of June 30, 2018. The 10 CMs tested comprised a variety of risk profiles with a diverse set of currency, tenor, and directional risks. The stress losses of these accounts, as described above, were then compared to the pre-funded resources held by the CCPs as of the end of that quarter.

The exercise included three tests of increasing levels of liquidation stress. For all three tests, the assumed losses due to market moves remained the same. To calculate these potential market losses, each house account was subjected to more than 200 stress scenarios[11] (both historical and theoretical) similar to the set of five-day scenarios used by the CCPs in their day-to-day risk oversight. These

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[9] Absent default, CCPs are counterparties to both sides of every position, giving them a "matched book" with no market risk.

[10] The market-related losses on stress scenarios are based on those commonly run by both the CFTC and the CCPs. The stress of the liquidation component, which is benchmarked as multiples of the collected liquidity add-on, is based on conversations with the CCPs on how much variation there might be in liquidation costs during a stressed period.

[11] Market shocks are applied to sensitivities (gamma and/or delta ladders) received from CCPs to represent CM portfolios.

scenarios represented a wide variety of market conditions, across numerous currencies. For each house account, the largest stress test loss across this set of scenarios was used as the market stress.

In contrast, the liquidation cost assumed for the three tests was benchmarked at 100, 150 and 200 percent of the CCP's liquidity add-on. This range of multipliers represents potential "stressed" liquidity conditions. In cases where the base liquidity add-ons are already conservative relative to survey-based liquidation cost estimates, the multiplier scenarios are conservative stresses on an already conservative base.

For example, assume that the defaulted CM had an IM requirement of $2 billion, comprising $1 billion of liquidity add-on and $1 billion of additional posted margin. After subjecting this portfolio to the set of theoretical and historical scenarios, the largest market loss experienced by the portfolio was $1.2 billion. In this case, the "base" liquidation stress test would equal the sum of the largest market loss ($1.2 billion) and the liquidation loss represented by the liquidity add-on ($1 billion), for a total of $2.2 billion. The second liquidation stress test of the portfolio, benchmarked against 150% of the liquidity add-on ($1 billion * 150 percent), represents a loss of $2.7 billion. Finally, in the most extreme liquidation scenario, where costs are 200 percent of the charge ($1 billion * 200 percent), losses were $3.2 billion. These three increasingly stressed scenarios translate into CCP exposures of $0.2 billion, $0.7 billion, and $1.2 billion, respectively.

As in the hypothetical example above, for each of the three liquidation scenarios and for each CM, the sum of the market and liquidation charges was subtracted from the total margin held by the CCP against the CM's house account. Because this aggregate cost represents both extreme market and extreme liquidation scenarios, the CCP had a resource shortfall for all of the house accounts. This shortfall was then compared to the remaining pre-funded resources at the CCP: the combination of the GF contributions and CCP's capital.

D. Results

Exhibit 11 summarizes the stressed liquidation exposures (in excess of IM) facing an individual CCP after a CM default. For each house account, the table provides information on the market losses due to the largest stress scenario, and the level and percent of mutualized pre-funded resources used in the three liquidation scenarios. The second column of the table summarizes the largest market losses for the CMs across the tested scenarios. In aggregate, nine different market scenarios drove the largest loss for at least one of the 10 house accounts, indicating a relatively diverse set of portfolios held by the largest CMs. Generally, the currencies driving the largest loss were the US dollar, the euro or the British pound.

The third through eighth columns in Exhibit 11 summarize CCP exposures in the three liquidation tests. For instance, CM1 experiences a stressed market loss of $3.71 billion. After adding this to the liquidation cost for each scenario, and offsetting with total IM, the CCP is left with exposures of $1.62 billion, $2.68 billion, and $3.74 billion across the three tests. These shortfalls represent 24.5, 40.5, and 56.6 percent of the mutualized pre-funded resources of the given CCP.

Exhibit 11: CM Losses and CCP Exposures

Member	Largest Market Stress Loss $bn	Stressed Liquidation Exposures - Nominal Amount and as % of CCP's Pre-funded Resources					
		100%		150%		200%	
		$bn	%	$bn	%	$bn	%
CM1	-3.71	1.62	24.5%	2.68	40.5%	3.74	56.6%
CM2	-3.08	0.99	15.0%	1.80	27.3%	2.62	39.5%
CM3	-1.15	0.42	6.3%	0.93	14.0%	1.44	21.7%
CM4	-1.62	0.35	5.3%	0.84	12.6%	1.32	19.9%
CM5	-1.56	0.61	9.3%	1.02	15.4%	1.43	21.6%
CM6	-0.84	0.14	2.1%	0.55	8.3%	0.95	14.4%
CM7	-2.35	0.81	12.2%	1.19	17.9%	1.57	23.7%
CM8	-2.10	1.23	42.0%	1.43	48.6%	1.62	55.2%
CM9	-0.58	0.23	8.0%	0.28	9.5%	0.32	10.9%
CM10	-1.24	0.79	27.0%	0.82	28.1%	0.86	29.3%

More generally, in the 100 percent scenario (where the liquidation cost equals 100 percent of the liquidity add-on), the percentage of mutualized pre-funded resources used ranged between 2 and 42 percent, as seen in column 4. When the liquidation cost was benchmarked at 150 percent of the CCP's liquidity add-on, this range increased from roughly 8 to 49 percent of mutualized pre-funded resources. Finally, in the test where the liquidation cost was benchmarked at 200 percent of the CCP's liquidity add-on, the range was from 11 to 57 percent of mutualized pre-funded resources.

As discussed above, the market scenarios driving the largest market stress loss are almost always different for different members. Because of this, the aggregate stressed liquidation cost associated with the default of multiple members would be lower than the sum of losses in the table, and possibly significantly lower.

In short, either CCP would have sufficient pre-funded financial resources to cover a scenario in which:

- A CM defaults in its house account after experiencing a market move that is very extreme but plausible; and
- The CCP's cost to liquidate the house portfolio is 200 percent[12] of the cost estimated by the CCP.

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[12] Not included in Exhibit 11, further analysis showed that pre-funded resources were sufficient if the CCP's cost to liquidate any one of the ten CM portfolios was 300% of the cost estimated by the CCP. This scenario is considered implausible.

III. Conclusions

The CFTC's third SST included two separate analytical exercises: a reverse stress test, and a test of pre-funded CCP resources when liquidation costs are higher than expected.

The results of the reverse stress test demonstrate that the two tested CCPs have sufficient pre-funded resources to cover losses even if all CMs with losses defaulted under historic scenarios. The same remains true for all but one of the 2x historical scenarios.

Because a reverse stress test is intended to identify combinations of defaults and market moves which exhaust CCP resources, an even higher multiplier than 2x was tested. At the much more significant 5x level, there were stress scenarios where losses were near and/or exceeded the boundary defined by pre-funded resources. A few of the combinations near that boundary include:

1. CME F&O: market movement equal to five times that on 6-24-16 "Brexit Vote" (i.e., S&P 500 down 21 percent, crude oil down 25 percent); the two CMs with the largest shortfalls default.

2. LCH IRS:

    a. Market movement equal to five times that on 6-24-16 (i.e., USD LIBOR rates down 77 bps at the 30 year tenor); the four CMs with the largest shortfalls default.
    b. Market movement equal to two times that on 11-20-2008 (i.e., USD LIBOR rates down 54 bps and Fed Funds down 94 bps at the 10 year tenor); all 31 CMs with shortfalls default.

Because the one-day historical scenarios were selected from the most volatile periods of the last 10 years, market moves equal to multiples of these historical moves are likely implausible.

The results of the stress test of the liquidity add-on demonstrate that either CCP would have sufficient pre-funded resources to cover stress losses resulting from the default of a house account, defined as an extreme market move as well as the liquidation of the account at a cost twice the anticipated cost.