NERA
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# Review of CFTC DCR Stress Testing Programs

*Prepared for the Commodity Futures Trading Commission Office of the Inspector General*

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# Executive Summary

The Commodity Futures Trading Commission ("CFTC") Office of the Inspector General ("OIG") asked National Economic Research Associates, Inc. ("NERA") to provide analysis of two stress-testing approaches developed within the Division of Clearing and Risk ("DCR"): the Chicago Group's[1] November 2016 Supervisory Stress Test approach and the Margin Model Group's[2] "Proof of Concept" approach. NERA was asked to analyze the methodologies, models, data, scenarios, and analyses involved with each approach to identify shortcomings and opportunities for improvement, considering factors such as the reliability and sufficiency of the data; the level of sophistication, accuracy, and robustness of each model; and the independence from or dependence on market participants and industry organizations.

NERA consulted several sources that outlined specific factors and metrics that regulators, industry practitioners, and academics concur should be considered when evaluating the design of stress testing frameworks and scenarios. These sources include relevant statutes and regulations, international organization guidance on stress tests, clearinghouse documentation of internal stress testing procedures, and industry and academic publications.

Relevant statutes and regulations require regulated clearinghouses, known as derivatives clearing organizations ("DCOs"), to regularly determine whether they possess sufficient financial resources to meet their financial obligations under a set of "extreme but plausible" scenarios.[3] Any DCO must be able to meet its financial obligations to all clearing members and participants given a default by the single clearing member creating the largest financial exposure for that DCO, commonly known as the "cover-one" standard. Furthermore, systemically important DCOs must possess sufficient resources to cover defaults by their two largest clearing members as measured by exposure, known as the "cover-two" standard.

NERA's analysis of the differing approaches to the design and implementation of "extreme but plausible" stress test scenarios is organized by several important factors.

## A. Robustness and Transparency of Process

The adoption of a formal, transparent, well-documented structure around the statistical analysis and design of stress testing scenarios supports the achievement of the benefits envisioned in the statutes. While neither the November 2016 Stress Test approach nor the Proof of Concept approach follows a formal process with perfect consistency, discretionary or ad hoc

[1] "Chicago Group" is a term that refers to the staff team that developed the November 2016 Stress Test approach, many of whom indicated they primarily work in Chicago, IL.

[2] "Margin Model Group" is a term that refers to the staff team that developed the Proof of Concept approach, many of whom indicated they primarily work in Washington, DC.

[3] 7 USC § 7a-1; 17 CFR § 39.11(a)(1); 17 CFR § 39.33(a)(1).

determinations and modifications at important decision points in the design of the scenarios more often characterizes the November 2016 Stress Test approach. This is in contrast with the Proof of Concept approach, which uses a more methodological process in the implementation of the stress test framework.

For example, the November 2016 Stress Test approach uses combinations of directions of extreme price changes for the different asset classes based on a review of historical volatile periods. However, there is no evidence of formal analysis with specific rules and metrics that guided that process. Similarly, the November 2016 Stress Test approach modifies the stress amounts for certain asset classes based on case-by-case determinations about why the observed extreme historical move was inappropriate. By contrast, the Proof of Concept approach follows a historical scenario design framework, which avoids some of these issues. For example, actual observed historical asset correlations are implicitly incorporated in the stress returns used in a historical scenario. Overall, a greater reliance on formal documentation and a consistent framework for dealing with specification issues will increase confidence in the stress testing program.

## B. Scenario Design

### 1. Correlation Across Asset Groups

Consistent with the stress testing guidance that stress scenarios must be extreme but plausible, both approaches have focused on periods of peak historic price volatilities. However, while the Proof of Concept approach uses combinations of stress amounts and directions from purely historical observed price changes during the weeks after the Lehman bankruptcy, the November 2016 Stress Test approach uses combinations of stress amounts and directions from different time periods and makes ad hoc modifications to some stress amounts. The advantage of the purely historical scenario used by the Proof of Concept approach is that it implicitly accounts for the correlations between the different asset classes during the stress period. By contrast, the scenarios included in the November 2016 Stress Test approach do not consider asset correlations beyond the likely direction of the price move, such as whether rates are likely to go up or down if there is a large negative shock to equities. Because the scenarios of the November 2016 Stress Test approach do not model asset correlations, they end up more extreme than plausible, a concern acknowledged by the Chicago Group. Although subjective to a certain degree, the extreme but plausible guidance is an important stress testing design objective, and the scenarios of the November 2016 Stress Test approach may be considered deficient in that respect.

### 2. Varied Stress Scenarios and Stress Amounts

Different periods exhibit stresses in different markets and with different asset correlations. In addition, the market context for future stress events can be difficult to predict. Thus, to ensure that a broad variety of extreme but plausible stresses are considered, the use of multiple scenarios with varied stress amounts is encouraged as a matter of regulatory and industry preparedness. The Proof of Concept approach includes observed price changes from 11 distinct trading days, ensuring that a variety of combinations of stress amounts and directions are included. While the Proof of Concept approach is only implemented on the period after the Lehman bankruptcy, its methodology can be extended to other peak historical volatility periods so that it considers a wider variety of correlations across asset classes. By contrast, the November 2016 Stress Test approach uses uniform stress amounts across its 11 scenarios, and thus does not incorporate varied stress amounts, although it does incorporate a variety of directional combinations.

### 3. Forward-Looking Scenarios

In addition, the literature recommends that stress testing frameworks include a wide variety of forward-looking scenarios to complement historical and historically-grounded hypothetical scenarios. However, neither approach includes forward-looking scenarios.

### 4. Multiple Day Stress Events

The literature indicates that a robust stress test framework should be able to account for both large one-time price shocks and multi-day price shocks in which credit risks gradually develop. One advantage of the Proof of Concept approach's purely historical scenario approach is that it readily allows for modelling of multi-day stress moves. This is important because some cleared products, such as interest rate swaps, have their margin requirements determined based on an assumed multi-day liquidation period. The scenario design choices incorporated in the November 2016 Stress Test approach do not provide such flexibility and transparency into considering the impact of multi-day moves.

### 5. Curve Risk

In its scenarios, the November 2016 Stress Test approach uses parallel shifts of forward and yield curves. Because curve risk can be significant in stress periods and because some clearing member portfolios may be more exposed to curve risk rather than outright price risk, the assumption of parallel shifts is somewhat limiting and excludes a key real world source of risk. By contrast, the Proof of Concept approach's purely historical scenarios incorporate curve risk by using the actual historical stress moves for every point on the interest rate curve and by mapping all futures positions onto the first three contracts rather than just the front one. This makes the Proof of Concept approach more robust and flexible than the November 2016 Stress Test approach.

## C. Reliability and Sufficiency of Data

The Margin Model Group's data validation process has the potential to provide the CFTC with improved reporting of uncleared derivatives. This will provide increased regulatory visibility into this portion of the derivatives markets.

## D. Independence from Market Participants and Industry Organizations

The Proof of Concept approach is computationally independent of DCOs, only relying on DCOs for regularly reported position data for the cleared products included in the stress test. Consequently, the Proof of Concept approach's results can be validated by DCOs with little risk of a shared source of error. By contrast, the November 2016 Stress Test approach relies upon DCOs for model input data, specifically delta ladders.

## E. Sophistication, Accuracy, and Robustness of Models

The two approaches use somewhat different methodologies to calculate stress losses. The Proof of Concept approach applies full valuation models to clearing member positions, whereas the November 2016 Stress Test approach uses a mix of full valuation models for some products (e.g., for credit default swaps) and approximation methodologies for other products (e.g., "delta ladders" for interest rate swaps). Although full valuation is generally preferred in the literature, approximation using delta ladders for interest rate swaps is not unreasonable. However, approximations may be less accurate if stress tests include high volatility and/or extreme price changes, or cover more exotic products with non-linear payoffs. Further, the delta ladders used by the November 2016 Stress Test approach are provided by the DCOs themselves. By contrast, the full valuation models used in the Proof of Concept approach are computationally independent of the DCOs.

Each approach utilizes valuation methodologies that are not unreasonable given the range of products and stress scenarios considered in each. However, the full valuation models utilized in the Proof of Concept approach allow for a wider range of products and sources of risk to be included, and thus the Proof of Concept approach is more robust, flexible, and scalable. For example, the Proof of Concept approach can replicate the results of the November 2016 Stress Test approach, whereas the November 2016 Stress Test approach cannot be used to replicate the results of the Proof of Concept approach without methodological adjustments.

Well-designed stress tests that not only capture historical moves but also help identify weaknesses or predict potential problems will increase regulatory effectiveness and preparedness. NERA finds that the Proof of Concept approach provides a technically sound, independent, innovative, and complementary approach to the November 2016 Stress Test approach.

# I. Background

## A. NERA's Assignment

The Commodity Futures Trading Commission ("CFTC") Office of the Inspector General ("OIG") engaged National Economic Research Associates, Inc. ("NERA") to review the various stress-testing models used within the CFTC's Division of Clearing and Risk ("DCR"). In particular, the CFTC OIG asked NERA to analyze DCR's methodologies, models, data, and scenarios to evaluate the efficacy and efficiency of the models, and identify shortcomings and opportunities for improvement. Specific factors the CFTC OIG asked NERA to consider included the reliability and sufficiency of the data; the level of sophistication, accuracy, and robustness of each model; and the independence from or dependence on market participants and industry organizations.[4]

## B. CFTC Division of Clearing and Risk's Role in the Oversight of Clearinghouses

The DCR oversees DCOs and other market participants in the clearing process. These include futures commission merchants, swap dealers, major swap participants, and large traders. DCR monitors the clearing of futures, options on futures, and swaps by DCOs, assesses DCO compliance with CFTC regulations, and conducts risk assessment and surveillance. DCR also makes recommendations on DCO applications and eligibility, rule submissions, and which types of swaps should be cleared. [5]

CFTC regulations require that DCOs perform internal stress tests subject to particular requirements, particularly 17 CFR 39.11 and 17 CFR 39.33. 17 CFR 39.11 requires that each DCO perform stress testing on a monthly basis to make a reasonable calculation of the financial resources needed to "meet its financial obligations to its clearing members[6] notwithstanding a default by the clearing member creating the largest financial exposure for the derivatives clearing organization in extreme but plausible market conditions"[7] (the "cover-one" standard). 17 CFR

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[4] Commodity Futures Trading Commission, Statement of Work for Solicitation Number 9523ZY-17-Q-OIG0232, September 21, 2017, p. 2.

[5] Commodity Futures Trading Commission, Statement of Work for Solicitation Number 9523ZY-17-Q-OIG0232, September 21, 2017, p. 2.

[6] "Clearing Member: A member of a clearing organization. All trades of a non-clearing member must be processed and eventually settled through a clearing member." Commodity Futures Trading Commission, "Glossary: Clearing Member," available at http://www.cftc.gov/ConsumerProtection/EducationCenter/CFTCGlossary/glossary_c, accessed February 5, 2018.

[7] 17 CFR 39.11(a)(1); 17 CFR 39.11(c)(1).

39.33 further requires that each systemically important DCO[8] maintain sufficient financial resources (e.g., guaranty funds) to "meet its financial obligations to its clearing members notwithstanding a default by the two clearing members creating the largest combined loss to the derivatives clearing organization"[9] (the "cover-two" standard). DCOs have discretion in determining their stress testing methodology, provided that the methodology must take into account both historical data and hypothetical scenarios, and the CFTC may review the methodology and require changes.[10]

DCR's responsibility for both oversight of DCO internal stress testing and independent external supervisory stress tests of DCOs raises the prospect of redundancy and possible reliance upon the DCOs for data, inputs, and methodologies, while also providing the possible benefits of system-wide stress testing using a consistent set of scenarios and methodologies. NERA analyzes these potential implications in Sections II and III of this report, which compare two particular DCR stress testing approaches: (1) that utilized by the DCR Chicago Group in the published November 2016 Supervisory Stress Test of Clearinghouses[11] ("November 2016 Stress Test approach"), and (2) that utilized by the DCR Margin Model Group for a "proof of concept" stress test incorporating full valuation models ("Proof of Concept approach").

## C. Relevant Literature on Supervisory Stress Tests

When considering metrics for comparison of the two approaches, NERA consulted several sources that outlined specific factors and metrics that regulators, industry practitioners, and academics concur should be considered when evaluating the design of stress testing frameworks and scenarios. These sources include relevant statutes and regulations, international organization guidance on stress tests, clearinghouse documentation of internal stress testing procedures, and industry and academic publications.

Relevant U.S. statutes and regulations call for the use of scenarios based on "extreme but plausible" market conditions.[12] United States Code, Title 7, Section 7a-1 ("Section 7a-1") requires that each DCO meet the cover-one standard and regularly engage in internal stress testing of its credit exposures to clearing members.[13] CFTC Regulations authorized in part under

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[8] "Systemically important derivatives clearing organization means a financial market utility that is a derivatives clearing organization registered under section 5b of the Act, which is currently designated by the Financial Stability Oversight Council to be systemically important and for which the Commission acts as the Supervisory Agency pursuant to 12 U.S.C. 5462(8)." 17 CFR 39.2.

[9] 17 CFR 39.33(a)(1).

[10] 17 CFR 39.11(c)(1).

[11] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016.

[12] 7 USC 7a-1; 17 CFR 39.11(a)(1); 17 CFR 39.33(a)(1).

[13] 7 USC 7a-1.

Section 7a-1 include 17 CFR 39.11 and 17 CFR 39.33, which as discussed above, respectively implement the cover-one standard requirement for all DCOs[14] and the cover-two standard for systemically important DCOs. [15]

In May 2009, the Basel Committee on Banking Supervision published "Principles for Sound Stress Testing Practices and Supervision" ("Basel Principles"), that provided general guidance on stress test design for both financial institutions and supervisory authorities, with a particular emphasis on process.[16]

The Committee on Payments and Market Infrastructures ("CPMI") of the Bank for International Settlements ("BIS") and the International Organization of Securities Commissions ("IOSCO"), of which the CFTC is a member, [17] jointly published "Principles for Financial Market Infrastructures" ("PFMI") in 2012, which outlined among other things credit and liquidity risk management standards for central counterparties ("CCPs"), a term covering DCOs.[18] The high level objective of CCP stress testing is described in Principle 4 of the PFMI:

> In conducting [credit risk] stress testing, a CCP should consider the effect of a wide range of relevant stress scenarios in terms of both defaulters' positions and possible price changes in liquidation periods. Scenarios should include relevant peak historic price volatilities, shifts in other market factors such as price determinants and yield curves, multiple defaults over various time horizons, simultaneous pressures in funding and asset markets, and a spectrum of forward-looking stress scenarios in a variety of extreme but plausible market conditions.[19]

In 2017, a follow-up report ("Further PFMI Guidance") from BIS and IOSCO provided further guidance on the issue of CCP resilience.[20] Further PFMI Guidance was intended for use by both

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[14] 17 CFR 39.11(a)(1).

[15] 17 CFR 39.33(a)(1).

[16] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018.

[17] International Organization of Securities Commissions, "Ordinary Members of IOSCO," available at https://www.iosco.org/about/?subsection=membership&memid=1, accessed January 31, 2018.

[18] Committee on Payment and Settlement Systems, Technical Committee of the International Organization of Securities Commissions, "Principles for financial market infrastructures," April 2012, available at https://www.bis.org/cpmi/publ/d101a.pdf, accessed January 31, 2018.

[19] Committee on Payment and Settlement Systems, Technical Committee of the International Organization of Securities Commissions, "Principles for financial market infrastructures," April 2012, p. 37, available at https://www.bis.org/cpmi/publ/d101a.pdf, accessed January 31, 2018.

[20] Committee on Payment and Market Infrastructures, Board of the International Organization of Securities Commissions, "Final Report: Resilience of central counterparties (CCPs): Further guidance on the PFMI," July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, accessed January 31, 2018.

CCPs themselves as well as by regulatory authorities in carrying out their supervisory responsibilities. Stress testing of CCPs and practical implementation issues regarding stress testing were among the topics covered, which include:

- Identification of risk sources related to credit exposures, including market risk: "price movements for all cleared products over the liquidation period," as well as "transaction costs or bid-ask spreads associated with liquidating or hedging the portfolio of cleared products in extreme but plausible market conditions."[21]

- Development of "extreme but plausible" stress testing scenarios: "[c]onstructing effective scenarios for stress testing involves designing scenarios that are sufficiently extreme to rigorously stress all identified sources of credit and liquidity risk, while retaining a level of plausibility that supports using the results for risk management."[22]

- Calculation of risk exposures: "[w]hen evaluating its exposure to credit or liquidity risk in extreme but plausible market conditions, the CCP should fully revalue its exposures, where practicable, using sound valuation models to measure the impact of these market conditions on the (liquidity) value of positions, collateral and investments. These models should be documented, and regularly tested under stressed market conditions. Where approximation methods are used, the procedures used should be subject to ongoing validation and testing as part of the overall stress-testing framework."[23]

Also in 2017, BIS and IOSCO published a consultative report ("Consultative Report") on a framework for supervisory stress testing of CCPs.[24] While broadly similar to the earlier PFMI guidance for CCPs on internal stress testing, the Consultative Report provided a valuable regulator's eye view on particular components of supervisory stress test methodology, such as factors to consider when developing stress scenarios[25] and data collection and validation.[26]

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[21] Committee on Payment and Market Infrastructures, Board of the International Organization of Securities Commissions, "Final Report: Resilience of central counterparties (CCPs): Further guidance on the PFMI," July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, accessed January 31, 2018, p. 13.

[22] Committee on Payment and Market Infrastructures, Board of the International Organization of Securities Commissions, "Final Report: Resilience of central counterparties (CCPs): Further guidance on the PFMI," July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, accessed January 31, 2018, p. 16.

[23] Committee on Payment and Market Infrastructures, Board of the International Organization of Securities Commissions, "Final Report: Resilience of central counterparties (CCPs): Further guidance on the PFMI," July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, accessed January 31, 2018, p. 21.

[24] Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)," June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, accessed January 31, 2018.

[25] Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)," June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, accessed January 31, 2018, p. 15.

In addition, the European Securities and Markets Authority ("ESMA") has conducted stress testing of the resilience of CCPs in the European Union.[27] Discussions of ESMA's approach are provided throughout this report for further context. Likewise, clearinghouse internal stress testing documentation, such as the CME Group's August 2015 "Principles for CCP Stress Testing,"[28] is referenced as a relevant point of comparison.

Finally, references are made to industry and academic sources on stress testing and risk management, such as the European Association of CCP Clearing Houses' April 2015 "Best Practices for CCPs Stress Tests,"[29] the Asset Management Group of the Securities Industry and Financial Markets Association's ("SIFMA AMG") September 22, 2017 Comment Letter to BIS and IOSCO,[30] and Fabozzi, Mann, and Choudhry's reference book *Measuring and Controlling Interest Rate and Credit Risk (2nd Ed.).*[31]

# II. Summary of CFTC Stress Testing Methodologies

## A. November 2016 Stress Test Approach

### 1. Stress Scenarios

#### a. Stress Amounts for Each Product

The DCR Chicago Group's November 2016 Stress Test approach uses hypothetical scenarios and covers the following eight distinct product categories: six categories of futures and options on futures (agriculture/"softs," currency, energy, equity, interest rates, and metals); interest rate

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[26] Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissioners, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)," June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, accessed January 31, 2018, p. 30.

[27] ESMA, "Methodological Framework, 2017 EU-wide CCP Stress Test Exercise," February 1, 2017, available at https://www.esma.europa.eu/sites/default/files/library/esma70-708036281-51_public_framework_2017_ccp_stress_test_exercise.pdf, accessed January 31, 2018. See also ESMA, "Report, EU-wide CCP Stress Test 2015," April 29, 2016, available at https://www.esma.europa.eu/sites/default/files/library/2016-658_ccp_stress_test_report_2015.pdf, accessed January 31, 2018.

[28] CME, "Principles for CCP Stress Testing," August 2015, available at https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf, accessed January 31, 2018.

[29] European Association of CCP Clearing Houses, "Best Practices for CCPs Stress Tests," April 2015, available at http://www.eachccp.eu/wp-content/uploads/2015/12/Best-practices-for-CCPs-stress-tests.pdf, accessed January 31, 2018.

[30] Securities Industry and Financial Markets Association, Letter to CPMI Secretariat and IOSCO Secretariat, September 22, 2017, available at https://www.sifma.org/wp-content/uploads/2017/09/SIFMA-AMG-Comments-on-the-CPMI-and-IOSCO-Consultation-Framework-for-Supervisory-Stress-Tests-of-CCPs.pdf, accessed January 31, 2018.

[31] Frank J. Fabozzi, Steven V. Mann, and Moorad Choudhry, *Measuring and Controlling Interest Rate and Credit Risk (2nd ed.),* Hoboken: New Jersey, John Wiley & Sons, Inc., 2003.

swaps ("IRS"); and credit default swaps ("CDS").[32] Not all contracts at each DCO are included in the November 2016 Stress Test approach, as the published report's stated objective was to select "the contracts representing the largest positions in each product category," as well as some "less liquid, related contracts."[33] No precise quantitative thresholds or metrics guide the contract inclusion decision, but the Chicago Group described the November 2016 Stress Test approach as making use of a "holistic" decision-making process based on expert knowledge of the products and the markets in question.[34]

In developing the scenarios, the November 2016 Stress Test approach analyzes the largest historical one-day price changes for each of the products included in the exercise. The November 2016 Stress Test approach then constructs hypothetical combinations of the relevant stress amounts, i.e., the "stress up" and "stress down" values, which are themselves selected on a product-by-product basis. The "stress up" amount represents an extreme price increase, while the "stress down" represents an extreme price decrease. According to the November 2016 Stress Test report, for most products, the selected stress amounts equal or exceed the largest price changes that were historically observed in the 30 years prior to the stress test.[35]

For a few products, the November 2016 Stress Test approach modifies the stress test amounts based on discretionary considerations regarding whether the largest historical move was appropriate given the current macroeconomic context, or to account for multi-day liquidation periods. The meta-level factors considered in deciding whether or not to make modifications are not formally documented, and in NERA's discussions with the Chicago Group, no consistent decision framework was proffered. Modifications to the stress test amounts are made to at least five products: stock index futures, Eurodollar futures, U.S. dollar-denominated IRS, Euro-denominated IRS, and CDS. The November 2016 Stress Test does not provide a description of a specific methodology or decision framework for these modifications, but explains that its modification decisions were made on a case-by-case basis.

- In the case of stock index futures, the Chicago Group explains that market changes, such as the addition of exchange circuit breakers and the rise of electronic trading, made a repeat of the largest decline in the 30 years prior (the more than 20% decline on October 19, 1987, commonly referred to as "Black Monday"), extremely unlikely to occur in the present context. The Chicago Group further points out that the S&P 500 has not declined over 10% on any single day in the last 20 years.[36] The November 2016 Stress Test

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[32] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, pp. 17-18.

[33] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, pp. 17-18.

[34] From NERA discussions with the Chicago Group.

[35] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 20.

[36] The May 6, 2010 Flash Crash did not trigger market-wide circuit breakers. "[T]he staffs of the CFTC and SEC are working together with the markets to consider recalibrating the existing market-wide circuit breakers—none of which were triggered

approach reduces the "stress up" value from 19.4% to 15%, and reduced the "stress down" value from 28.6% to 20%.[37]

- Similarly, the largest one-day historical increase in Eurodollar futures price observed by the Chicago Group was 116 bps. The Chicago Group notes that this occurred in 1987 when interest rates were above 9 percent, and a price change of 116 bps would represent a much larger relative change in the current low interest rate environment. The November 2016 Stress Test approach utilizes stress amounts that would shock Eurodollar futures up and down 40 bps, which the Chicago Group indicates was closer to (but still more extreme than) the relative (percentage) move that was historically observed.[38]

- In addition to the aforementioned stresses on futures prices, the November 2016 Stress Test approach applies a 50% increase in the implied volatility of all options on futures contracts. As explained by the Chicago Group, this meant that an option contract with an implied volatility of 30% would be revalued using an implied volatility of 45% after applying the stress. The Chicago Group indicated that it uses this stress amount because this is the shock used by several DCOs in their internal stress tests.[39]

- For U.S. dollar-denominated interest rate swaps, the November 2016 Stress Test approach uses a 60 bps move even though the largest one-day historical change in swap rates in the past 30 years was smaller, at 46 bps.[40] The Chicago Group said it uses a stress amount larger than the largest historical one-day change in an effort to account for an assumed extended liquidation period,[41] i.e., the expectation that it would take longer than one day to resolve a default in interest rate swaps.[42]

- For Euro-denominated IRS, the November 2016 Stress Test approach uses a stress amount of 30 bps, which is smaller than the largest one-day historical change in rates in the past 30 years, 40 bps. The Chicago Group justified the use of a stress amount smaller

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on May 6[, 2010],--that apply across all equity trading venues and the futures markets." Commodity Futures Trading Commission and Securities & Exchange Commission, "Findings Regarding the Market Events of May 6, 2010," September 30, 2010, p. 6, available at https://www.sec.gov/news/studies/2010/marketevents-report.pdf, accessed January 31, 2018.

[37] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, pp. 20, 22.

[38] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, pp. 20-21, 22.

[39] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 21.

[40] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 23.

[41] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 23.

[42] The assumption that plain vanilla interest rate swaps (the type of interest rate swap comprising the overwhelming majority of those included in the November 2016 Stress Test approach) take substantially longer than one day to close-out or liquidate is disputed, as illustrated by the range of industry opinions expressed in a large number of public comments submitted to the CFTC on the matter. *See* 81 FR 636, January 6, 2016, at 656.

than the largest one that was observed by noting that interest rates were substantially higher when the larger one-day price change was observed.[43]

- The CDS stress test amounts utilized by the November 2016 Stress Test approach are drawn from extreme moves that occurred over several days during the 2008-2009 financial crisis for adverse credit shocks, also known as widening. By contrast, for credit improvements, known as tightening, the Chicago Group indicates it uses extreme hypothetical moves that are larger than the most extreme historical moves, consistent with some DCO internal stress tests.[44]

The November 2016 Stress Test approach assumes parallel shifts in the interest rate yield curve, with no modeled changes in the shape of the yield curve.[45] Similarly, changes in the shapes of forward curves for any products are not considered or modeled. The published report acknowledged that this meant that "curve risk and spread risks within product groups" are not considered in the November 2016 Stress Test approach.[46]

### b. Combinations of Directional Shocks for Different Products

Once stress up and stress down values were selected for each product class, the November 2016 Stress Test approach constructs 11 distinct combinations of these stress up and stress down values by product category or sector, grouping products into equity futures, rate futures, IRS, CDS, energy products, metals products, agricultural products, "soft" products, and currency products. In designing these 11 directional scenarios, the Chicago Group indicated that it considered historical directional price moves across markets.[47]

For example, in a "flight to quality" scenario, the Chicago Group expects that equity futures would be down while interest rate futures would be up. By contrast, in a scenario where financial firms were trying to raise cash, the Chicago Group expects both equity futures and interest rate futures would be down. The directional combinations of stress up and stress down for the product groups are based on actual combinations of market directions from 11 distinct dates between 1999 and 2015.

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[43] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 23.

[44] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 24.

[45] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 23.

[46] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 23.

[47] Although the published report uses the phrase "historical correlations across markets," the Chicago Group's description of the November 2016 Stress Test approach in discussions with NERA emphasized that directional combinations were considered more than magnitudes. Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 25.

In determining the direction of the stress test price shocks for each product category in each of the 11 distinct scenarios, the November 2016 Stress Test approach looks at a small number of liquid contracts within each product category as proxies. In discussions with NERA, the Chicago Group indicated that it looked at approximately 20 years of historical futures price data for this purpose (the reason for the discrepancy between this 20 year lookback and the 30 year lookback used for estimating the magnitude of price shocks to use as stress test amounts was not made clear to NERA). From this data set, the Chicago Group said it examined the price changes across the different asset classes to determine the most "plausible" combinations of directional price changes. However, the Chicago Group did not indicate a specific methodology or decision framework that drove this analysis. The Chicago Group only described a general approach consisting of identifying the most volatile market days and analyzing the relative performance across asset classes on those days.

The Chicago Group explained that for its 11 scenarios, all of the directional scenarios actually occurred at least once in the last 20 years, but the magnitude of the price changes was never as large in all products simultaneously as in this exercise. The Chicago Group acknowledged that this made the November 2016 Stress Test approach more "extreme" than "plausible," but indicated that it believed ESMA had used a similar approach for some "theoretical" (hypothetical) scenarios used in previous stress tests.[48]

### 2. Tests of Entities and DCO Financial Resources

The November 2016 Stress Test approach applies the 11 unique scenarios at five DCOs: CME Clearing ("CME"), ICE Clear Credit ("ICC"), ICE Clear Europe ("ICEU"), ICE Clear U.S. ("ICUS"), and LCH Clearnet Ltd ("LCH").[49] These five DCOs operate a total of eight guaranty funds for the covered products. CME has separate guaranty funds for IRS, CDS, and a base guaranty fund covering futures and options and certain commodity swaps. ICEU has separate guaranty funds for futures and CDS. LCH has a guaranty fund for IRS that is segregated from its guaranty funds for other products. ICC has a guaranty fund for CDS, and ICUS has a guaranty fund for futures.[50]

[48] E.g., "The reverse stress test results change significantly under the scaled market stress scenarios […] More than 100 members are actually considered to be in default under this theoretical [hypothetical] and clearly not-plausible scenario […] This result gives however a good indication of the resulting exposure when the stress conditions themselves are stressed to the limits, illustrating in a way the maximum size of the exposure under very extreme possible but not plausible circumstances." ESMA, "Report, EU-wide CCP Stress Test 2015," April 29, 2016, available at https://www.esma.europa.eu/sites/default/files/library/2016-658_ccp_stress_test_report_2015.pdf, accessed January 31, 2018, p. 52.

[49] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 16.

[50] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 17.

November 2016 Stress Test approach measures the effects of each scenario's simultaneous stresses across product categories both at each guaranty fund at each DCO individually, and cumulatively across all eight guaranty funds at all five included DCOs. It considers the pre-funded financial resources[51] of each DCO and the pre-defined sequence of pre-funded resource use in the event of a default by a clearing member: 1) margin required, segregated by clearing member and house versus customer account; 2) guaranty fund contributions of firms in default; 3) DCO contribution; and 4) guaranty fund contributions of other clearing members.[52] It reports that, "[f]or each scenario, staff calculated whether the guaranty fund would cover the losses of the clearing members with the largest two losses after application of their initial margin (cover-two). Then staff looked at how many clearing members would have to default before the clearinghouse's guaranty fund was exhausted."[53]

The Chicago Group also measures the effects for particular corporate groups of clearing members across all five DCOs. For example, under each scenario, staff determine whether a particular corporate group of clearing members that had losses at one DCO also would have losses at the other DCOs or would instead have gains at one or more of the other DCOs.[54]

This exercise only covers potential defaults by the largest 15 clearing members as measured by initial margin at any DCO: if an affiliate or subsidiary of a corporate group is among the 15 largest clearing members by initial margin at any DCO, all of the positions of all of that corporate group's affiliates and subsidiaries are stressed at all DCOs. Due to the largest clearing members having substantial exposures at multiple DCOs, this results in 23 distinct corporate groups being stressed at all DCOs.[55] Applying the 11 distinct scenarios across the five DCOs and eight guaranty funds results in 36 unique tests across guaranty funds because some scenarios produce identical effects on a particular guaranty fund due to the presence of only a limited subset of the nine asset categories in that particular guaranty fund.

The decision to include only the 15 largest clearing members at any DCO was made at the discretion of the Chicago Group without reference to a desired threshold for a particular coverage metric. The November 2016 Stress Test approach indicates that the use of the top 15 clearing members from each DCO results in the inclusion of corporate groups responsible for posting approximately 88% of initial margin at the five DCOs.[56] The clearing members who

[51] "[P]re-funded financial resources […] include initial margin, financial contributions of clearinghouses, and guaranty funds." Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 27.

[52] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, pp. 9-10, 27-30.

[53] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 30.

[54] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 26.

[55] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, pp. 18-19.

[56] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 18; NERA discussions with the Chicago Group.

were not among the 15 whose positions are stressed also contribute to the guaranty fund. The contributions of these smaller clearing members are included in the Chicago Group's calculations even though the smaller clearing members are not stressed,[57] which may result in a slight overestimation of the resiliency of the guaranty funds.

### 3. Calculation of Stress Profit and Loss

The November 2016 Stress Test approach uses three separate models to estimate changes in the value of different product categories: GlobalRisk's "FirmRisk" model[58] for futures and options on futures, a "delta ladder" model[59] for IRS, and a SAS implementation of the ISDA CDS Standard Model ("ISDA CDS") for CDS. Although the Chicago Group indicated that it has not independently validated the models it used for its stress tests, it noted that its models are promulgated by respected entities (Global Risk, DCOs, and ISDA for futures/options on futures, interest rate swaps, and credit default swaps, respectively).

The Chicago Group stated that the delta ladder model relies upon data provided by DCOs for key inputs, e.g., the deltas and gammas used to estimate the changes in the value of IRS. The DCOs also utilize delta ladder models for interest rate swaps and swaptions, and the Chicago Group's inputs (e.g., delta ladders, settlement prices, and curves) are primarily supplied by the DCOs. The Chicago Group also relies upon DCOs for some position data, as well as settlement prices and curves for all products.

The Chicago Group indicated that it validates its model outputs by comparing its results to internal stress tests by DCOs and clearing members. For the purpose of validating model inputs, the Chicago Group primarily relies upon its day-to-day risk surveillance data quality and validation processes to ensure that input data is accurate and complete. Examples provided to NERA include:

1) Determining availability of data being used prior to processing any valuations or stress tests, and in the event that data was not available, initiating a coordinated process to resolve any issues, often by reaching out to a data submitter or internal service provider.

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[57] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 33.

[58] "GlobalRisk, a developer of risk management software, [provides the CFTC with] FirmRisk [which] captures real-time or delayed equities, futures and options data from Interactive Data's Consolidated Feed and runs stress tests and analytics to help calculate intra-day risk exposure metrics." GlobalRisk, "GlobalRisk and Interactive Data Collaborate to Support CFTC's Derivatives Oversight Operations," November 19, 2015, available at https://globalrisk.com/wp-content/uploads/2016/10/GlobalRisk-and-Interactive-Data-Collaborate-to-Support-CFTCs-Derivatives-Oversight-Operations.pdf.

[59] A delta ladder is traditionally the change in the value of a portfolio in response to a given quantum of change in the underlying variable, such as a one basis point change in interest rates for a portfolio of interest rate swaps.

2) Issuing automated alerts to users of data flagged with potential data quality issues based on certain rules and conditions, such as: missing settlement prices, anomalous risk parameter assumptions, and outlier valuations or profit/loss estimates.

## B. Proof of Concept Approach

### 1. Stress Scenarios

The Margin Model Group's "Proof of Concept" approach to stress testing uses constructed historical scenarios, specifically stress amounts from the financial crisis period following the bankruptcy of Lehman Brothers. The Margin Model Group defines the period as stretching from September 15-30, 2008, which covers 11 trading days, with the corresponding market moves. From these 11 scenario dates, the Margin Model Group creates 11 distinct combinations of stress amounts for the different products. The use of 11 consecutive historical trading days also allows the Margin Model Group to engage in multi-day stress testing, i.e., to calculate the change in the value of certain positions based on historical price moves over a multi-day stress period.

The Margin Model Group describes its scenarios as unfiltered historical scenarios, which capture the actual changes in asset prices that occurred on the selected dates. Consequently, the scenarios implicitly capture the historical correlations among the stressed asset classes on those dates. The Margin Model Group acknowledges that asset correlations can evolve over time, and different crisis periods often exhibit different asset correlations. Nevertheless, consideration of historical correlations is widely accepted as a primary means of ensuring that scenario designs are plausible. The Margin Model Group recognizes that one way of addressing the issue of possibly different asset correlations is to run stress tests based on different crisis periods, and points out that their approach can be implemented using stress amounts for other crisis periods.[60]

The Proof of Concept approach utilizes a mix of relative or absolute shocks based on the actual price changes observed on the 11 scenario dates, based on the Margin Model Group's judgment regarding the plausibility of the absolute shocks in the context of prices on the portfolio date. Relative shocks move the portfolio date's price level by the percentage change that occurred on the scenario date. Absolute shocks move the portfolio date's price level by the observed price change that occurred on the scenario date. While the overall correlation direction remains the same using the two different methods, the amount of the shock might differ.

The Proof of Concept approach does not rely on an assumption of parallel shifts of forward and interest rate curves. It takes into account curve risk by applying stress amounts that varied with the tenor level. The Margin Model Group's stated intent is to calculate stress amounts at the

[60] In discussions with NERA, the Margin Model Group described its methodology for dealing with historical data availability limitations, which involved using regression models to fill in missing historical data based on the prices of closely related products for which data was available.

most granular level possible given the data. For example, within the IRS space, the Proof of Concept approach uses 26 different stress amounts for different points of the yield curve, which span from one day to 50 years.

For futures and options, the Proof of Concept approach considers curve risk by using three different stress amounts for each product class: the price changes of the futures contract closest to expiry, second closest to expiry, and third closest to expiry. The contracts that had expiration dates further out into the future are mapped to the third closest to expiry contract. This mapping was described to NERA as a conscious compromise between capturing spread moves and maintaining analytic parsimoniousness.

### 2. Tests of Entities and DCO Financial Resources

The Proof of Concept approach utilizes the same selection criteria for clearing member inclusion as the November 2016 Stress Test approach: the top 15 clearing members in terms of initial margin at any DCO are included, consolidated on a corporate group basis to account for all affiliates and subsidiaries as a single corporate entity. While the precise selection criteria utilized are somewhat arbitrary, they were designed to include the corporate groups responsible for posting the overwhelming majority of initial margin without including so many distinct corporate entities that analysis would become challenging. The Margin Model Group, like the Chicago Group, does not conduct robustness checks to determine the impact of using a cutoff threshold different from the top 15 clearing members by initial margin.

Guaranty funds are not expressly considered in the Proof of Concept approach, as the stress test is intended to assess firm-level risk for clearing members across both cleared and uncleared positions rather than to assess the impact of cleared positions on DCO financial resources. However, the Margin Model Group describes in detail how their stress test could be used to examine DCO resources by incorporating additional data in future iterations.

### 3. Calculation of Stress Profit and Loss

The Margin Model Group told NERA it intended for the Proof of Concept approach to utilize full valuation models independent from the modelling done by the DCOs. The Margin Model Group describes its valuation models as based on commonly accepted discounted cash flow methodologies, and indicates that for some asset classes the models were developed in-house, and for others the models were sourced from commercial software designed to value particular asset types.

For futures and options on futures, the Proof of Concept approach uses a pricing model implemented in SAS, which incorporates linear pricing for futures and Black-Scholes pricing for options on futures. For credit default swaps, it uses a Matlab implementation of the ISDA CDS model. For interest rate swaps, it uses an in-house implementation of a Matlab interest rate swap pricing model. For interest rate swaptions, it uses a Matlab implementation of a stochastic alpha, beta, rho (“SABR”) pricing model. For uncleared foreign exchange options, it uses an in-house pricing model based on Black-Scholes.

The Proof of Concept approach relies on a broad array of data sources for its modeling. Data reported to the CFTC[61] are used to determine clearing members’ positions in cleared futures and options on futures, credit default swaps, and interest rate swaps and swaptions. Swap Data Repository (“SDR”) data are used to determine clearing members’ positions in uncleared credit default swaps, interest rate swaps and swaptions, and foreign exchange options. Bloomberg data are used for most market price, spread, rate, and implied volatility movements. DCO data supplements Bloomberg data for credit default swaps historical spread movements and interest rate swaps and swaptions historical rate movements.

In discussions with NERA, the Margin Model Group described detailed input data and output data quality control and validation processes:

- Quality control of the SDR uncleared position data inputs was an ongoing process in which a data filter would check for missing values, errors in position taxonomy, nonsensical values, outdated mark-to-market prices, and other issues. The proportion of each type of error would be recorded and tabulated with the data submitter. This quality control required one or two staffers part-time, but was reported to gradually improve the quality and formatting consistency of data submitted to SDRs.

- Validation of cleared position data inputs occurred as part of day-to-day internal validation processes.

- Validation of the output of futures and options on futures full valuation models was limited to options on futures output because futures prices are a linear function of price changes in the underlying. Because stressed futures prices could be computed manually or by means of a multiplication table, they were not subject to regular validation processes. Option prices were subject to simple “sanity checks” such as ensuring the stressed implied volatility curve did not involve a negative value.

- Validation of credit default swap model outputs (prices) occurred by comparing output results against the outputs of stress tests conducted by DCOs, such as the weekly internal stress scenario run by ICC, which clears the majority of the credit default swap market. The Margin Model Group told NERA its profit-and-loss figures generally matched ICC

[61] E.g., 17 CFR Part 39 requires that DCOs engage in reporting on a daily, quarterly, annual, event-specific, and requested basis. Such reports include but are not limited to: initial margin requirements and initial margin on deposit for each clearing member (broken down by house origin and by each customer origin), variation margin for each clearing margin (broken down by house origin and by each customer origin), end-of-day positions for each clearing member (broken down by house origin and by each customer origin), all clearing and settlement cash flows, and DCOs’ financial resources. See 17 CFR 39.19.

output within a few hundred dollars on gross profits and losses in the millions or billions of dollars.

- Validation of the output of models for interest rate swaps and swaptions, as well as foreign exchange options, occurred via comparison against mark-to-market valuations submitted by market participants. Those that did not match were flagged for further position-by-position analysis.

# III. Analysis

## A. Robustness and Transparency of Process

There is a broad consensus in the relevant literature that the process and governance surrounding stress test design and implementation should be formally structured, transparent, well-documented, and guided by objective criteria supplemented where necessary by expert judgment.

For example, the May 2009 Basel Principles provides guidance that stress tests should "have written policies and procedures" and "be appropriately documented […] particularly in relation to […] the methodological details of each component, including the methodologies for the definition of relevant scenarios and the role of expert judgment" in designing the stress test.[62] The Basel Principles further recommend documenting "the assumptions and fundamental elementals for each stress testing exercise[, including] the reasoning and judgments underlying the chosen scenarios and the sensitivity of stress testing results to the range and severity of the scenarios."[63]

BIS and IOSCO guidance in the 2012 PFMI report advises entities designing stress tests to determine "stress scenarios, models, and underlying parameters and assumptions" based on references to objective criteria such as "historical data of prices of cleared products and participants' positions."[64] BIS and IOSCO guidance in the 2017 Further PFMI Guidance similarly recommends that "the criteria for and selection of all relevant extreme but plausible scenarios and market conditions are clearly defined, justified and documented,"[65] and that entities designing stress tests should "perform a comprehensive and thorough analysis of stress-

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[62] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 11.

[63] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 11.

[64] Committee on Payment and Settlement Systems Technical Committee of the International Organization of Securities Commissions, "Principles for financial market infrastructures", April 2012, available at https://www.bis.org/cpmi/publ/d101a.pdf, p. 37.

[65] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 6.

testing scenarios, models, and underlying parameters and assumptions used to ensure they are appropriate […] in light of current and evolving market conditions."[66]

In addition, CME's August 2015 Principles for CCP Stress Testing interprets the stress testing literature as recommending that entities designing stress tests "should adhere to a principles-based framework for scenario construction,"[67] as well as the more general recommendations that such entities ought to abide by principles like "Maintain[] a Robust Governance Structure"[68] and "Transparent[ly] Appl[y] Stress Testing Principles and Practices."[69]

The adoption of a formal, transparent, well-documented structure around scenario design and the associated statistical analyses supports the achievement of desired benefits from stress testing. Neither the November 2016 Stress Test approach nor the Proof of Concept approach perfectly abides by the literature consensus on process, as evidenced by both approaches' utilization of expert judgment rather than an objective criterion such as a target initial margin coverage metric to determine how many clearing members to cover.[70] However, the November 2016 Stress Test approach departs from the literature consensus on process in several places where the Proof of Concept approach remains consistent.

For example, while the November 2016 Stress Test approach mixes the direction of the extreme price changes for the different asset classes based on a review of historical volatile periods, there is no formal analysis, rule, or objective metric that guided that process. Expert judgment is applied in place of a consistent process, and the reasoning and assumptions underlying that judgment are often not formally described and recorded with supporting analyses.

Similarly, the November 2016 Stress Test approach proposes a general methodology for determining stress amounts centered on the largest historical one-day price changes for each product. However, it then deviates from that methodology for many asset classes by modifying the stress amounts based on case-by-case expert judgment regarding whether the extreme historical move was inappropriate. While the case-by-case explanations of stress amount

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[66] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 22.

[67] CME, "Principles for CCP Stress Testing," August 2015, available at https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf, accessed January 31, 2018, p. 11.

[68] CME, "Principles for CCP Stress Testing," August 2015, available at https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf, accessed January 31, 2018, p. 15.

[69] CME, "Principles for CCP Stress Testing," August 2015, available at https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf, accessed January 31, 2018, p. 16.

[70] Both approaches ultimately included the top 15 clearing members in terms of initial margin at any of the 5 DCOs included in the stress test. Both groups acknowledged using expert judgment rather than an objective target metric to make that selection, despite the fact that both groups justified their decision after the fact by reference to the amount of initial margin covered at the 5 included DCOs.

modifications are generally reasonable,[71] a greater reliance on a consistent, well-documented, formal framework for dealing with specification issues, resulting in fewer "ad hoc" decisions and changes, would be more consistent with the literature consensus on process.

By contrast, the Proof of Concept approach follows a historical scenario design framework, which avoids some of these issues. For example, actual observed historical asset correlations are implicitly incorporated in the stress returns used in a historical scenario.

Overall, greater reliance on formal documentation and a consistent framework for dealing with specification issues increases confidence in the stress testing program. Neither group has tested the robustness of its approach's conclusions to different assumptions about stress test coverage, such as whether including slightly more or slightly fewer clearing members would have affected their conclusions in any way. Both approaches would benefit from such robustness checks.

## B. Scenario Design

### 1. Correlation Across Asset Groups

The literature on stress test scenario design advises that plausibility of "extreme but plausible" scenarios ought to be verified by reference to objective metrics such as historical price correlations across asset groups. The CME's internal Principles for CCP Stress Testing recommends that, "[g]lobal standards, and the local regulatory adoption thereof, require that stress testing encompasses market scenarios that are deemed 'extreme but plausible.' Determining what constitutes extreme but plausible market conditions depends on a number of factors including, but not necessarily limited to, asset class, product volatility, historical market movements and current market conditions."[72]

BIS and IOSCO's Further PFMI Guidance advises that scenario design should account for relationships between different asset groups' prices and possible changes in those relationships:

> [I]f a CCP constructs forward-looking scenarios by aggregating shocks across a number of risk factors across different time periods, the CCP should model the dependence between these risk factors under stressed conditions [and] contemplate the market prices of ordinarily uncorrelated products moving

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[71] While the explanations were reasonable, the November 2016 Stress Test report appears to mix up terminology with respect to CDS on pages 24-25, attributing the rationale for modifications made for widening to tightening and vice versa for some products.

[72] CME, "Principles for CCP Stress Testing," August 2015, available at https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf, accessed January 31, 2018, p. 4.

> together or scenarios in which market prices of ordinarily correlated products diverge.[73]

Further PFMI Guidance also explicitly recommends considering the plausibility of stress amounts in combination rather than as discrete components of scenario design:

> As a general matter, for any given scenario, the CCP should aim to ensure internal consistency in its modelled risk factor shocks. That is, within a particular scenario, modelled risk factor shocks should be plausible not only individually, but also when viewed in combination.[74]

Consistent with the guidance, in determining the stress amounts in their scenarios, both the November 2016 Stress Test and the Proof of Concept approaches make references to historical price correlations across asset groups during periods of stress. The Proof of Concept approach uses a purely historical scenario from the weeks after the Lehman bankruptcy to determine both the combinations of stress amounts and stress magnitudes. The November 2016 Stress Test approach, on the other hand, uses in its scenarios extreme price changes from different time periods and limits the analysis of historical correlations to only determining likely combinations of *directional* moves. That analysis did not inform or validate the combinations of stress *magnitudes* which were used.

The advantage of the purely historical scenario used by the Proof of Concept approach is that it implicitly accounts for the correlations between the different asset classes during the stress period. BIS and IOSCO's Consultative Report endorses the inherent plausibility of historical stress scenarios, stating, "Using historical market events as the basis for establishing the shocks to core risk factors can help to promote plausibility and internal consistency in the combination of modelled risk factor shocks."[75]

By contrast, the scenarios utilized by the November 2016 Stress Test approach do not consider asset correlations beyond the likely direction of the price move, for example, whether rates are likely to go up or down if there is a big negative shock to equities. Because the scenarios of the November 2016 Stress Test approach do not model asset correlations, they are more extreme than plausible, and they depart from BIS and IOSCO's guidance. In conversations with NERA,

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[73] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 20.

[74] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 17.

[75] Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissioners, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)." June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, p. 24.

the Chicago Group acknowledged that the November 2016 Stress Test approach utilizes stress scenarios that are more extreme than plausible. Although the literature's guidance on designing "extreme but plausible" scenarios recognizes some room for subjective judgments guided by expertise, it is an important stress testing design objective, and the scenarios of the November 2016 Stress Test approach are somewhat deficient in that respect.

### 2. Varied Stress Scenarios and Stress Amounts

The stress testing literature presents a consensus that financial entities and supervisors ought to consider a range of stress scenarios and stress amount combinations, both as a form of robustness checking and in order to ensure market and regulatory preparedness for plausible future market stresses. For example, the Basel Principles advise that stress testing programs should "use multiple perspectives and a range of techniques in order to achieve comprehensive coverage"[76] and include multiple extreme but plausible scenarios "along a spectrum of events and severity levels."[77] Likewise, BIS and IOSCO guidance recommends that because "different portfolios are exposed to underlying risk factors differently […] therefore the use of multiple historical stress scenarios will be required." [78] Similarly, ESMA's stress test documentation states that "in order to ensure that all CCPs clearing a wide range of financial products are subject to sufficient stress, it was needed to use multiple […] scenarios" and both the 2015 and 2017 ESMA stress tests make use of multiple scenarios.[79]

The November 2016 Stress Test approach uses 11 scenarios which include different combinations of asset price changes generally based on historical experience. The use of multiple scenarios is consistent with the guidance to consider various potential scenarios. However, the November 2016 Stress Test approach utilizes "a set of uniform scenario[]" stress amounts,[80] such that for each product only a single magnitude of price change is utilized in each direction.[81] Consequently, the November 2016 Stress Test approach falls short of the guidance

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[76] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 10.

[77] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 13.

[78] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 24.

[79] ESMA, "Methodological Framework, 2017 EU-wide CCP Stress Test Exercise," February 1, 2017, available at https://www.esma.europa.eu/sites/default/files/library/esma70-708036281-51_public_framework_2017_ccp_stress_test_exercise.pdf, pp. 7-8. See also ESMA, "Report, EU-wide CCP Stress Test 2015," April 29, 2016, available at https://www.esma.europa.eu/sites/default/files/library/2016-658_ccp_stress_test_report_2015.pdf, p. 19.

[80] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 12.

[81] *See, for example,* Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 22.

recommending the use of scenarios incorporating a variety of stress magnitudes and a range of stress event severities.

By contrast, the Proof of Concept approach uses a purely historical scenario based on observed price moves on 11 consecutive trading days during a major financial crisis. Its stress scenarios incorporate both a variety of stress amounts and combinations of stress directions from multiple historical trading days, which is consistent with the stress testing literature and the "extreme but plausible" guidance. While it is only run on the period after the Lehman bankruptcy, it can be extended to other peak historical volatility periods so that it considers a wider variety of correlations across asset classes.

### 3. Forward-Looking Scenarios

While the stress testing literature consensus advocates the use of historical and/or historically-grounded scenarios, it also advises undertaking complementary "rigorous, forward looking stress testing in order to identify possible adverse events."[82] This recommendation is explained in the literature by considerations such as, "historical stress scenarios alone are not sufficient [because] extreme but plausible market conditions that a CCP could face in the future may not be captured in historical data." [83] The literature's general conclusion is that market and regulatory preparedness are enhanced by supervisors and market participants being prepared both for recurrences of market stresses akin to previous stress periods and novel market stresses arising from ongoing trends in financial markets activities and clearing member balance sheets.

Neither of the approaches considered in this report include forward-looking scenarios, and consequently both approaches could be improved by the addition of such scenarios.

### 4. Multiple Day Stress Events

The literature advises analyzing stresses over multiple defined periods of time. For example, the Basel Principles advise that stress tests "should include various time horizons depending on the risk characteristics."[84] Similarly, SIFMA AMG recommends that supervisory stress tests "should use extreme but plausible scenarios that may include a sequence of stress events, as opposed to […] a single event[; such as when] an initial event results in weaknesses being realized by

[82] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 17.

[83] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 16.

[84] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 13.

cascading failures[.]"[85] Consideration of multi-day stress events is important because some products' margin requirements are based on an assumed multi-day liquidation period. For example, the CME internal Principles for CCP Stress Testing document interprets the literature as indicating that stress tests should account for factors like the need for "financial resources [to] cover potential losses over a period-of-time, i.e. over the course of 5 days in the case of OTC instruments […] and support position-related risk [during that period.]"[86] The literature generally suggests that stress tests should include both one-time shocks calibrated to account for long liquidation periods and/or stress periods of risk,[87] as well as multi-day shocks to test both the financial resources and liquid resources of financial institutions over a period of time.[88]

While the November 2016 Stress Test approach states that its "instantaneous shocks [are] calibrated using a liquidation period of at least two days,"[89] it lacks transparency and details behind how this calibration was done. It is thus difficult to assess how extreme or plausible its stress amounts are in the context of a multi-day stress test. On the other hand, the Proof of Concept approach's use of a historical scenario drawn from observed price changes on multiple consecutive trading days provides a ready-made, extreme but plausible, multi-day stress scenario.

The literature also advises that stress tests consider secondary impacts of market price moves, such as changes in the value of collateral held by clearing firms and/or DCOs and wrong-way risks arising from collateral whose value correlates strongly with changes in the financial position or creditworthiness of a clearing member.[90] Neither approach took such secondary impacts into account.

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[85] Securities Industry and Financial Markets Association, "Comments on the CPMI and IOSCO Consultation Framework," September 22, 2017, available at https://www.sifma.org/wp-content/uploads/2017/09/SIFMA-AMG-Comments-on-the-CPMI-and-IOSCO-Consultation-Framework-for-Supervisory-Stress-Tests-of-CCPs.pdf, accessed January 31, 2018, p. 2.

[86] CME, "Principles for CCP Stress Testing," August 2015, available at https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf, accessed January 31, 2018, p. 10.

[87] *See, for example,* European Association of CCP Clearing Houses, "Best Practices for CCPs Stress Tests," April 2015, available at http://www.eachccp.eu/wp-content/uploads/2015/12/Best-practices-for-CCPs-stress-tests.pdf, accessed January 31, 2018, p. 8.

[88] *See, for example,* CME, "Principles for CCP Stress Testing," August 2015, available at https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf, accessed January 31, 2018, p. 10.

[89] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 12.

[90] Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissioners, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)." June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, p. 18.

### 5. Curve Risk

The stress testing literature advises incorporating all risks relevant to the stability and solvency of financial institutions, including curve risk and spread risks. For example, BIS and IOSCO advised that:

> [S]ome […] portfolios may reflect trading strategies that entail exposure to basis or curve risks (eg long and short positions at different points on a forward or yield curve which may be more sensitive to correlation shifts rather than general price movements). A CCP should ensure, as appropriate, that its stress scenarios adequately reflect the trading strategies employed by its direct and indirect participants.[91]

The Proof of Concept approach incorporated curve risk and spread risks by using the observed historical stress moves for every point on the interest rate curve and by mapping all futures positions onto the first three contracts rather than just the front one. By contrast, the November 2016 Stress Test approach assumed parallel shifts of forward and yield curves and did not model curve risks.[92]

## C. Reliability and Sufficiency of Data

The stress testing literature recommended that input data should be verified and validated according to a formal process, and that this process should itself be validated. For example, BIS and IOSCO recommend that authorities conducting stress tests should "maintain and implement procedures to verify the historical data set,"[93] and "regularly test and validate the methods used to verify data accuracy."[94]

The November 2016 Stress Test approach relied primarily on data reported by DCOs for both position data as well as DCO-calculated figures such as delta ladders that serve as inputs to the valuation models. Because the November 2016 Stress Test approach was limited to cleared

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[91] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 17.

[92] Commodity Futures Trading Commission, "Supervisory Stress Test of Clearinghouses," November 2016, p. 23.

[93] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 18; Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissioners, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)." June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, p. 31.

[94] Final Report of the Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissions, "Resilience of central counterparties (CCPs): Further guidance on the PFMI", July 2017, available at https://www.bis.org/cpmi/publ/d163.pdf, p. 18.

products, and DCO data on cleared products is relatively standardized, input data validation was primarily conducted via an automated CFTC process. DCOs were invited to comment on the November 2016 Stress Test's methodology and validated its outputs and results.

The Proof of Concept approach made use of data from a wider array of sources than the November 2016 Stress Test approach, in part because of the use of full valuation models and in part because of the inclusion of uncleared products for which DCOs cannot provide the relevant data. For DCO position data, the validation process was the same automated process as for the November 2016 Stress Test approach.

For uncleared products, the Proof of Concept approach relied on data from SDRs. Validation of that data identified issues which needed to be addressed. One to two Margin Model Group staff members working part-time on this issue made substantial progress on identifying issues with SDR records and working with submitters to improve data completeness, accuracy, and formatting. Given the relatively small staff time commitment required, and the potential to substantially improve the usefulness of SDR data, the Margin Model Group's SDR data validation process has the potential to provide the CFTC with improved reporting of uncleared derivatives. This will provide increased regulatory visibility into this portion of the derivatives markets.

## D. Independence from Market Participants and Industry Organizations

The stress testing literature generally advises that stress testing methodologies and results should be validated by independent third parties, and that potential shared sources of error should be avoided where possible. For example, the European Association of CCP Clearing Houses' April 2015 Best Practices for CCPs Stress Tests recommends, "independent validation […] confirming the accuracy and appropriateness of the stress testing methodology[.]"[95] Likewise, the Basel Principles state that "[s]tress testing should provide a complementary and independent risk perspective to other risk management tools"[96] available, and "use multiple perspectives and a range of techniques in order to achieve comprehensive coverage"[97] across all stress tests conducted.

The Proof of Concept approach is computationally independent of DCOs, only relying on DCOs for regularly reported position data for the cleared products included in the stress test.

[95] European Association of CCP Clearing Houses, "Best Practices for CCPs Stress Tests," April 2015, available at http://www.eachccp.eu/wp-content/uploads/2015/12/Best-practices-for-CCPs-stress-tests.pdf, accessed January 31, 2018, p. 13.

[96] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 9.

[97] Basel Committee on Banking Supervision, "Principles for Sound Stress Testing Practices and Supervision," May 2009, available at http://www.bis.org/publ/bcbs155.htm, accessed January 31, 2018, p. 10.

Consequently, the Proof of Concept approach's results can be validated by DCOs with little risk of a shared source of error. By contrast, the November 2016 Stress Test approach relies upon DCOs for model input data such as delta ladders that are dependent on the valuation assumptions made by the DCOs. Therefore, the validation of the November 2016 Stress Test's results by DCOs could in theory fail to identify some errors if the errors are due to DCO valuation assumptions incorporated as inputs into the November 2016 Stress Test approach.

## E. Sophistication, Accuracy, and Robustness of Models

The stress testing literature recommends the use of full valuation models where time and computational resource constraints allow, but acknowledges the potential for less computationally intensive methods, such as parametric first order approximations, to serve a useful role in stress tests as well. For example, BIS and IOSCO's Consultative Report advises that nonparametric, full valuation models are preferred:

> [E]ach product would be fully revalued under the proposed set of stress scenarios. Specifically, under such an approach, stress scenarios would be applied to risk factor exposures to derive shocked risk factor values, which would subsequently be applied within closed pricing formulas to generate new prices for the products. Although potentially computationally intensive, this technique may be expected to generate sound estimates of the potential changes in value of each product; it can also capture higher-order effects and incorporate interactions between risk factors.[98]

In the same document, BIS and IOSCO recognize that parametric approximations using factors like duration and convexity can be relied upon as reasonable approximations for some products, albeit not for others:

> The approach of approximating the potential changes in value of a cleared product using the change in the value of its underlying risk factors, for example, by using delta or delta-gamma approximations may be relatively simple and may help to reduce the dimensionality of the problem. However, an important drawback of this approach is that it may provide misleading results when applied to non-linear financial products, or when used to approximate the risk from large shocks.[99]

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[98] Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissioners, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)." June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, p. 34.

[99] Committee on Payments and Market Infrastructures, Board of the International Organization of Securities Commissioners, "Consultative Report, Framework for Supervisory Stress Testing of Central Counterparties (CCPs)." June 2017, available at https://www.bis.org/cpmi/publ/d161.pdf, p. 34.

While delta ladders, often called duration-convexity approximations in the literature, can be useful for accurately estimating the value of many products, they are less reliable for products with non-linear payoffs, and they generally ignore curve risks arising from changes in the shape of the forward curve or yield curve.[100]

All of the valuation models and/or approximations used by both approaches are applied widely by industry participants and regulators to value appropriate product groups, and are thus believed to be both reliable and validated. However, the decision to use particular valuation methodologies has implications for the overall robustness, scalability, and flexibility of a stress test approach.

The November 2016 Stress Test approach used a full valuation model for CDS, a commercially-used model for futures and options on futures, and a "delta ladder" approximation for interest rate swaps. The Proof of Concept approach used the same full valuation model for CDS, and also used full valuation models rather than approximations for the other products. Because the Proof of Concept approach used full valuation models for more products, it was capable of including a range of products that were excluded from the November 2016 Stress Test approach, such as interest rate swaptions.

Moreover, as part of the validation of the Proof of Concept approach, it was used to replicate the stress test scenarios and product coverage of the November 2016 Stress Test approach and arrived at extremely similar results. Due to the limitations of duration-convexity approximations, the November 2016 Stress Test approach cannot fully replicate the stress test scenarios and product coverage of the Proof of Concept approach. Moreover, because the November 2016 Stress Test approach relies on delta ladders provided by DCOs to value IRS, the November 2016 Stress Test approach would need an additional data source to value uncleared IRS. While stress testing uncleared IRS does not have a direct impact on CCP financial resources, it does provide useful insight into the broader risks of clearing member derivatives portfolios.

In general, stress test approaches using duration-convexity approximations to value products are less robust with respect to incorporating curve risk and will often be limited to "vanilla" interest rate swaps. By contrast, stress test approaches utilizing more sophisticated, full valuation models, such as the Proof of Concept approach, can easily incorporate curve risk and can cover more exotic products, and are thus more robust, scalable, and flexible than duration-convexity approximations.

[100] Frank J. Fabozzi, Steven V. Mann, and Moorad Choudhry, *Measuring and Controlling Interest Rate and Credit Risk (2nd Edition)*, 2003, published by John Wiley & Sons, Inc. of Hoboken New Jersey, pp. 3-4.

# IV. Summary

While both the November 2016 Stress Test approach and the Proof of Concept approach represent valuable tools for regulatory preparedness and are largely consistent with stress testing literature guidance, the Proof of Concept approach provides value-added regulatory oversight capability. In the context of regular innovations in financial products and market structures, as well as constantly evolving market conditions, the ability to more easily include a wide range of products and additional sources of risk represents a real advantage.

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