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Measuring Systemwide Resilience of Central Counterparties

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Central clearing can improve transparency and risk management across the financial system. It also creates new dependencies between firms. Stress tests are now a common tool that central counterparties (CCPs) use to evaluate their resilience in the face of losses due to defaults of their clearing members, which include the largest and most systemically important banks. But determining the resilience of the entire system of CCPs and clearing members requires a combined supervisory stress test across CCPs and their clearing members. This brief proposes a framework that would use existing stress test results at individual CCPs to create a U.S. systemwide stress test.

After the 2007-09 financial crisis, several regulatory initiatives sought to avoid a repeat of the large losses in over-the-counter derivatives transactions. One initiative requires derivatives transactions to be centrally cleared. Other post-crisis initiatives require many financial firms, including many banks, bank holding companies, insurance companies, and qualified hedge funds, to undergo regular stress tests. These initiatives aim to improve risk management. A financial firm that carries out central clearing, called a central counterparty, or CCP, might also be required to undergo regular stress tests.

A CCP assumes the credit risk associated with the default of either of the two parties in a financial transaction. Most over-the-counter derivatives transactions were not centrally cleared before 2008.[2] Although central clearing increases transparency and may improve risk management, it also concentrates risk. The CCP becomes a single point of failure that can promote contagion. Losses from the default of a large clearing member at a CCP may spread to other clearing members. Losses can also spread across markets if the defaulting clearing member belongs to multiple CCPs for different asset classes, or if losses at one CCP lead to the default of clearing members that participate in other markets. The potential risks to the financial system are obvious. Clearing members include the largest and most systemically important banks.

CCPs are required to hold liquid resources to protect themselves against defaults of clearing members. Losses large enough to create ripple effects across the financial system are likely to be rare. But the growing role of CCPs in derivatives markets suggests the need to monitor the potential effects of these rare events on the system as a whole.

Systemwide Stress Test Components for Clearing Members and CCPs

1. Set of scenarios
2. Estimation of the profits and losses each clearing member would have under each scenario
3. Analysis of the probability of default of clearing members under each scenario

This brief proposes a framework for conducting such a systemwide stress test using information already available to supervisors. Reusing information already reported would avoid an additional burden on the CCPs and their clearing members. Three components are needed to evaluate simultaneously stress testing on clearing members and CCPs across markets: (1) testing scenarios, (2) evaluation of the profits and losses (P/L) for each clearing member in each scenario, and (3) analysis of the probability of default of each clearing member. For each component, this brief identifies alternatives, discusses their benefits and limitations, and makes a recommendation.

The brief makes three recommendations. First, use a common set of underlying factors, such as interest rates or equity prices, to generate stress scenarios. This approach offers flexibility and ease in generating a large number of scenarios. Second, individual CCPs already report to their supervisors the results of individual stress tests against clearing member default. Regulators could use the results from those stress tests to calculate P/L impacts on clearing members.[3] Third, use default models that are consistent with the stress scenarios. This consistency implies that the same market conditions can be applied to defaults.

U.S. regulators already have the information needed to build a systemwide stress test. However, carrying it out would require further cooperation among U.S. regulators, including the Commodity Futures Trading Commission (CFTC), Securities and Exchange Commission, and Federal Reserve Board.

The Current Stress Testing Landscape

Representatives from international regulators agreed in 2012 on guidelines for stress testing individual CCPs, known as the Principles for Financial Market Infrastructures (see **Figure 1**).[4] In 2016, the European Securities and Markets Authority (ESMA) and CFTC separately reported the results of their first systemwide supervisory stress tests in their markets (see **Figure 2**).

Individual CCPs

Individual CCPs carry out and report stress tests daily to their supervisors. The goal of these tests is to ensure that CCPs are able to continue operating in times of market stress. Stress scenarios include peak historic price volatilities, shifts in market factors that determine the price of contracts cleared by the CCPs, and forward-looking stress scenarios in a variety of extreme but plausible market conditions.

Figure 1. Principles for Financial Market Infrastructures – CCP Stress Testing Guidelines

Scenario Requirements	• Peak historical price volatilities • Shifts in market factors • Forward-looking in variety of extreme but plausible market conditions • Reverse stress tests to identify scenarios that would cause the largest exposures
Default Requirements	• Systemically important CCPs must withstand default by the largest two participants and their affiliates, by exposure (Cover 2) • Other CCPs must withstand default by the largest participant and its affiliates, by exposure (Cover 1)
Liquidity Requirements	• A CCP must have sufficient liquid resources to withstand losses due to the default of its largest participant and affiliates, by exposure

Note: The Principles for Financial Market Infrastructures apply to systemically important entities in the clearing, settlement, and recording of financial transactions. These include central counterparties, trade repositories, swap data repositories, central securities depositories, and securities settlement systems.

Sources: Committee on Payments and Market Infrastructures, International Organization of Securities Commissions

The international guidelines divide CCPs into two groups. The first group contains CCPs involved in activities with complex risk profiles and CCPs that are systemically important in multiple jurisdictions. All other CCPs are in the second group.

CCPs in the first group are subject to a Cover 2 standard. That means their stress tests include the default of at least the two largest CCP participants and their affiliates, by exposure. CCPs in the second group are subject to a Cover 1 standard. CCPs are expected to have adequate financial resources to cover the losses projected in these stress tests using prefunded resources. These resources include contributions by the CCP itself, known as the CCP's "skin-in-the-game." They also include contributions of clearing members to a mutualized fund, known as the guarantee fund.

In addition to requiring sufficient resources generally, the international guidelines require sufficient liquid resources. Stress scenarios for liquidity risk include all the scenarios used for credit stress testing and also customized scenarios. Stress scenarios for liquidity risk consider the default of at least the largest participant and its affiliates.

ESMA and CFTC supervisory stress tests

In April 2016, ESMA reported the results of its first stress test of CCPs based in the European Union.[5] To construct four extreme but plausible scenarios, ESMA used extreme values for variables that influence the value of contracts cleared at each CCP. ESMA relied on CCPs to calculate and report the P/L for each clearing member.

Given the P/L of each clearing member, ESMA considered the default of an increasing number of clearing members. Losses were resolved according to each CCP's default waterfall or hierarchy of payments. In its report, ESMA estimated the shortfall across the entire system. For example, ESMA found that a default of the

Figure 2. U.S. and European Supervisory Stress Tests: The Current Landscape

	U.S. Commodity Futures Trading Commission	European Securities and Markets Authority
Who tested?	Five CCPs supervised by the CFTC 15 clearing members per CCP	17 CCPs supervised by ESMA All clearing members at each CCP
When tested?	One date - April 29, 2016 Results released November 16, 2016	October 31, November 30, December 31, 2014 Results released April 29, 2016
General scenarios tested?	11 scenarios: all hypothetical across CCPs Respects observed correlations	Four scenarios: three hypothetical, one historical Represents extreme, but plausible, conditions at each CCP
Default scenarios tested?	Considers the effect of successive defaults of one, two, and eventually all clearing members Prefunded resources used to determine a CCP's financial shortfall	Considers the default of a CCP's: • Two largest clearing members by exposure • Two largest corporate groups by exposure • Two largest corporate groups by default-probability-weighted exposure Prefunded and unfunded resources used to determine a CCP's financial shortfall Reverse stress test considers how many defaults required to exhaust prefunded and total financial resources
Test limits	Small number of scenarios Consider only credit risk, not other risks such as liquidity, operational, investment, funding	

Sources: Commodity Futures Trading Commission, European Securities and Markets Authority two clearing members with the largest losses at each CCP would exhaust the CCPs' prefunded resources and result in an additional systemwide shortfall of 10 billion euros.

ESMA's stress test had advantages and limitations. Because ESMA used factors already considered by CCPs for their individual stress tests, the broader test placed a relatively modest additional burden on CCPs. A limitation was that the losses were calculated on only a handful of trading days. Another drawback was the sole focus on credit risk. ESMA's stress tests did not consider liquidity risks, operational risks, and other risks.

In November 2016, the CFTC reported the results of a joint stress test of the five largest CCPs registered with the agency:

1. CME Clearing
2. ICE Clear Credit
3. ICE Clear Europe
4. ICE Clear U.S.
5. LCH Clearnet Limited[6]

Focusing on the largest clearing members, the CFTC developed a set of 11 stress scenarios based on price changes and correlations across markets that occurred on dates with extreme volatility. The results showed each CCP had sufficient prefunded resources to cover losses of its two largest clearing members. The results also showed that clearing members are diversified among CCPs.

The CFTC stress test shared the limitations of the ESMA stress test, but considered a larger number of scenarios. Despite these limitations, ESMA and CFTC supervisory stress tests present a clear advancement in assessing the resilience of CCPs and clearing members.

Supervisory Systemwide Stress Test for CCPs and Clearing Members

A systemwide supervisory stress test for CCPs and clearing members should be able to assess the resilience of multiple CCPs and their clearing members across markets. Designing such a stress test must consider three key components:

1. a set of scenarios;
2. estimation of the profit and loss for each clearing member under each scenario; and,
3. determination of clearing member defaults.

Scenarios

The goal in choosing stress scenarios is to identify extreme but plausible conditions.[7]

For a systemwide stress test, identifying the appropriate scenarios presents a challenge. Predicting which scenarios would be the most stressful for the entire system is difficult. As a result, many scenarios may need to be considered. Fortunately, in the case of CCPs, this concern is not significant. Each CCP already carries out stress tests in which the P/L for the portfolio of each clearing member is calculated for tens, or even thousands, of scenarios. But combining these scenarios in a systemwide supervisory stress test consistent with the scenarios used by individual CCPs could be challenging.

One way to overcome this difficulty and combine scenarios across CCPs and clearing members is to calculate the P/L of every cleared contract using changes on particular calendar dates. The results can then be combined across CCPs. For example, changes over each calendar day during the previous five years could be used.

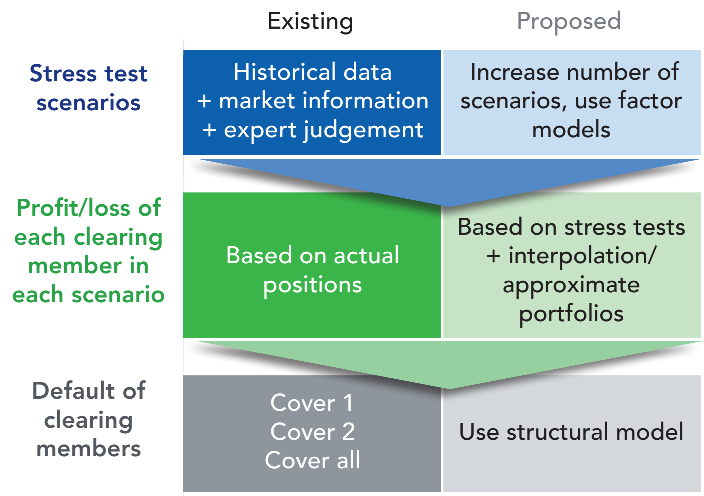
A limitation of this approach is that historical changes may not include conditions that are extreme but plausible. Stress tests by ESMA and the CFTC do not rely solely on historical scenarios. To ensure that extreme but plausible conditions are included, they construct scenarios based on historical information, information implied by the prices of traded instruments, and expert judgment. One limitation is that these tests consider only a small number of scenarios to represent extreme but plausible conditions for cleared contracts. Determining whether such conditions for traded contracts are also extreme but plausible conditions for clearing member portfolios would require the use of many scenarios.

A second way to construct many scenarios is to use a common set of high-level variables, or factors. Factors are closely related to every other variable of interest. For example, factors can be interest rates, prices of equity and commodity indexes, market volatility, or aggregate default rates. They can also be variables identified by statistical analysis. Factor models are useful for two reasons. First, they are flexible and can easily accommodate additional variables. Second, using joint changes in the factors could be a guide in creating a large number of scenarios for all the variables of interest for each CCP. On Feb. 1, 2017, ESMA announced that the methodological framework for the 2017 stress test will use a set of high-level risk factors.[8]

Factor models typically involve only a few variables. To calculate the P/L of individual contracts, a model is needed to link the common factors to contract prices. For example, consider a CCP that clears credit default swap contracts, both for indexes and individual companies.[9] Changes in the price of the credit default swap contracts are expressed by changes in the spread between the risk-free rate and the rate on the corresponding bonds. These changes can be decomposed into one common factor — the spread on the index — and one, additional, residual term for each contract. Given the distribution of the common factor — the spread on the index — and the decomposition into spreads of individual companies, any number of scenarios can be generated.

Factor models make assumptions about the joint range of future changes of the factors, rather than simply relying on realized changes. For example, dependence between the factors can be captured by using several statistical models, such as correlated normal distributions, log-normal distributions, or copula models. The parameters of the models are based on historical information, as well as information about future values of the factors implied in current market prices, and expert judgment. Scenarios are generated consistent with the distribution of factors. Once scenarios are generated,

Figure 3. Supervisory Stress Testing: Existing and Proposed Components



Sources: Author's analysis

the proposal described in this brief would identify the scenarios that result in the greatest systemwide stress, and refine the assumptions underlying the distribution of the factors.

Profit and loss

The second component of this systemwide stress testing proposal is to calculate the P/L impacts. To aggregate P/L across CCPs and clearing members, a new systemwide approach would first calculate P/L for the portfolio of each clearing member for each scenario.

In existing supervisory stress tests, ESMA and CFTC use information on trading positions to calculate portfolio P/L. Knowing the portfolio positions in individual contracts, they calculate the P/L of portfolios by first calculating the P/L for individual contracts.[10] ESMA relied on CCPs to perform this calculation. The CFTC performed the calculation and verified the results with CCPs. The calculation requires information on positions of clearing members and can be complicated for some of the cleared contracts.

This brief recommends a different approach: use stress test results reported by individual CCPs to calculate the P/L impacts on clearing members. The advantage of this approach is that it would not require position information. It would not place any additional burden on CCPs or clearing members. The portfolio P/L can be approximated either directly, using numerical interpolation, or indirectly, by constructing portfolios of instruments cleared at each CCP that approximate the portfolio of each clearing member.

Numerical interpolation would allow a supervisor to approximate the change in value of a portfolio for intermediate changes. For example, if the impacts of interest rate increases of 2 basis points and 5 basis points were known, interpolation could be used to estimate the impact of a 3 basis point increase. To reduce interpolation error, many scenarios at individual CCPs are needed. The scenarios should accurately capture changes in portfolio value when multiple variables change simultaneously. For example, in the case of a portfolio that depends on interest rates and implied volatilities, a supervisor would need to know more than how the portfolio value changes when interest rates or implied volatilities vary independently. A supervisor would also need to know how the portfolio value changes when interest rates and implied volatilities change simultaneously.

A way to address this problem is to construct approximate portfolios. To illustrate how CCP stress tests can use an approximate portfolio, consider a CCP that clears a single contract, for example, an index. A 20 percent decrease in the value of an index that would result in a loss of $2 million implies that the portfolio has a $10 million exposure to the index. When a CCP clears multiple contracts, more scenarios are needed, but the idea is the same. In that case, rather than solving for a single unknown in a single equation, one solves for many unknowns in a system of equations.[11]

The possibility of constructing approximate portfolios solves the problem of calculating P/L for a portfolio from stress test information when variables are changed independently. In that case, the P/L for the portfolio is calculated using the approximate portfolio.

The accuracy of either the interpolation or the approximate portfolio approach depends on the number of stress test scenarios available at the CCP: the more the better. Having many scenarios available would also allow for an evaluation of the accuracy of each approach. Borrowing ideas from statistical learning, one can evaluate accuracy using some of the CCP stress tests — the training set — to build the approximation. The remaining stress tests — the validation set — could be used to test whether the approximation matches the reported results.[12]

Default

The last component of a systemwide supervisory stress test for CCPs and clearing members is the determination of clearing member default in each scenario. Determining default is important because CCPs hold balanced portfolios. If clearing members do not default, CCPs do not have losses, no matter how large the movements in contract prices.

The existing approach used by ESMA and the CFTC does not use a model to determine whether default is probable. Rather, the Cover 1 and Cover 2 standards assume default of one or two clearing members based on the size of the exposures of the clearing members. ESMA and the CFTC consider variations for supervisory stress tests. For example, in the ESMA scenarios, the two biggest clearing members in every CCP default. In the CFTC scenarios, the biggest, two biggest, or all clearing members default.

A model-free approach may be attractive, but has a drawback in the difficulty of determining if defaults are extreme but plausible. CCP clearing members have bilateral exposures with other financial and nonfinancial entities outside CCPs. Clearing members also have assets and liabilities whose values fluctuate. In many cases, those outside influences might mean that a clearing member may face large losses in its cleared portfolio but not default. Given that clearing members are similar in many dimensions, multiple simultaneous defaults would likely occur in some scenarios.[13] To determine whether a particular combination of defaults is extreme but plausible, a default model is needed that is consistent with the stress scenarios used.

If assets, liabilities, and all bilateral exposures between clearing members in each asset class are available, they can be used to determine whether a clearing member would default in a particular scenario. However, such a complete picture of the financial system will probably not be available. An alternative way to determine simultaneous defaults is based on structural models of firm value.

In a structural model, the default of a company is determined based on information on liabilities and changes in equity value. Similar to the discussion on factor analysis for building scenarios, changes in the value of a clearing member company are decomposed into factors. For example, in the case of a large bank, a structural model could determine how the bank's stock price depends on interest rates, index credit default swap spreads, mortgage default rates, and the S&P 500. When these factors change in a stress scenario, one could determine whether the bank defaults by comparing the resulting company value to the face value of the liabilities.[14] Determining defaults this way is compatible with factor analysis for scenario building.[15]

The proposal here uses a structural model to determine multiple defaults, not because it is more or less strict than the model-free approach, but because it is consistent with the stress scenarios. Supervisors may have difficulty determining whether defaulting the two largest members by exposure in every CCP is extreme but plausible in a given scenario. With a structural model, defaults are consistent with each scenario. In some cases, this approach would mean more firms would default. In other cases, fewer would default; but defaults would be consistent with each stress scenario.

Reverse stress testing

The proposal in this brief can serve to identify conditions that would lead to the largest systemwide losses — a systemwide reverse stress test. Losses depend on clearing member defaults and changes in market prices. If many scenarios are available, the scenarios with the largest losses may be a reasonable approximation. An alternative is to search for conditions that lead to the largest losses iteratively, using information from the existing scenarios. However, searching for the worst scenarios iteratively, with the help of CCPs, could alert CCPs to the focus areas of supervisors. This concern provides an additional reason to calculate the P/L of the portfolios of clearing members using stress test results, rather than rely on CCPs to calculate or verify P/L estimates using clearing-member positions.

Accounting for reduced liquidity and auction failure

A systemwide stress test should also include adjustments for market liquidity when a clearing member holds a very large portfolio. To illustrate this problem, consider a situation when a clearing member defaults while holding 30 percent of the outstanding positions in a particular market. The size of such a portfolio may be many times the average daily, or even weekly, market trading volume. Although CCPs use auctions to avoid liquidating large positions of defaulting members in the open market at times of stress, transferring a position of this size is likely to have an additional price impact beyond that reflected in historical experience. Liquidity adjustments must reflect consideration of the size of the portfolio of the defaulting member relative to the market volume and to the exposures of surviving clearing members.

Liquidity adjustments must also reflect consideration of whether the transfer auction after a clearing member default may fail. For example, if winning the auction results in the violation of a requirement that clearing members must fulfill, clearing members may not participate in the auction. If the auction fails, the position may need to be liquidated in a stressed marketplace, and a larger adjustment may be needed.

Conclusion

This brief proposes a framework for supervisors to carry out a systemwide stress test of CCPs and clearing members. It requires three changes to the current tests: (1) generating a large number of scenarios using a factor analysis technique, (2) using existing stress test results to calculate P/L for a clearing member's portfolio for each scenario, and (3) using a structural default model to determine defaults consistent with the stress scenarios. These changes do not require additional information beyond what is already available to CCP supervisors. The framework can turn the results of existing, CCP-specific stress tests into a systemwide stress test if supervisors of different CCPs collaborate and share the data provided by the CCPs they supervise.

Endnotes

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[2] For a comprehensive history of central clearing see Peter Norman, *The Risk Controllers: Central Counterparty Clearing in Globalized Financial Markets,* Hoboken, N.J.: John Wiley & Sons Inc., May 2011. The Dodd-Frank Wall Street Reform and Consumer Protection Act required clearing certain standardized swap transactions through a CCP. Subsequent changes — such as the Basel Committee on Banking Supervision and the International Organization of Securities Commissions policy framework that establishes minimum margins for bilateral, non-centrally cleared, derivatives — provide incentives to clear additional transactions.

[3] Stress tests are used in many industries to evaluate such things as the strength of materials for earthquake-resistant buildings, the performance of firearms, and cardiovascular health. Stress testing for financial institutions goes back at least to 1992, when the U.S. Office of Federal Housing Enterprise Oversight was charged with developing a stress test for Fannie Mae and Freddie Mac. Regulatory stress testing expanded after the financial crisis of 2007-09 to banks, insurance companies, hedge funds, and central counterparties.

[4] See Committee on Payment and Settlement Systems and International Organization of Securities Commissions, *Principles for Financial Market Infrastructures,* April 2012 (available at www.bis.org/cpmi/publ/d101a.pdf, accessed Feb. 8, 2017).

[5] See European Securities and Markets Authority, "EU-wide CCP Stress Test 2015," April 29, 2016 (available at www.esma.europa.eu/press-news/esma-news/esma-publishes-results-eu-central-counterparties-stress-test, accessed Jan. 26, 2017).

[6] See Commodity Futures Trading Commission, "CFTC Staff Issues Results of Supervisory Stress Test of Clearinghouses," press release, Nov. 16, 2016 (available at www.cftc.gov/PressRoom/PressReleases/pr7483-16, accessed Jan. 26, 2017). CME Clearing is part of CME Group, formerly known as the Chicago Mercantile Exchange. ICE Clear Credit, ICE Clear Europe, and ICE Clear U.S. are part of the Intercontinental Exchange. LCH Clearnet Limited was formed following the merger of the London Clearing House and Clearnet SA.

[7] The literature focuses on choosing scenarios judiciously, that is, using only a small number of scenarios. One reason to limit the number of scenarios is the difficulty in calculating the P/L profile of large portfolios under each scenario. See Matthew Pritsker, "Enhanced Stress Testing and Financial Stability," Federal Reserve Bank of Boston working paper, July 30, 2012 (available at www.frbsf.org/economic-research/files/pritsker.pdf, accessed Feb. 8, 2017); Paul Glasserman, Chulmin Kang, and Wanmo Kang, "Stress Scenario Selection by Empirical Likelihood," *Quantitative Finance* (2015) 15, 25-41. Also see references by Rick Bookstaber, Jill Cetina, Greg Feldberg, Mark Flood, and Paul Glasserman, "Stress Tests to Promote Financial Stability: Assessing Progress and Looking to the Future," OFR Working Paper no. 13-10, July 18, 2013 (available at www.financialresearch.gov/working-papers/files/OFRwp0010_BookstaberCetinaFeldbergFloodGlasserman_StressTeststoPromoteFinancialStability.pdf, accessed Jan. 26, 2017).

[8] See European Securities and Markets Authority, *Methodological Framework: 2017 EU-wide CCP Stress Test Exercise,* Feb. 1, 2017 (available at www.esma.europa.eu/file/21270/download?token=EmSs2Ank, accessed Feb. 9, 2017).

[9] A credit default swap (CDS) contract on an individual company provides protection against losses to the value of the company's bonds, due to the default of the company. A CDS contract on an index provides protection against losses to the value of a basket of bonds of several companies.

[10] See Sean Campbell and Ivan Ivanov, "Empirically Evaluating Systemic Risks in CCPs: The Case of Two CDS CCPs," Sept. 19, 2016 (available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2841076, accessed Feb. 8, 2017). In this working paper, the authors propose using the actual portfolios of clearing members to evaluate P/L across CCPs using models built by supervisors.

[11] It is not necessary to build portfolios that reflect the entire range of contracts cleared by the CCP. Using fewer contracts may result in a worse approximation, but has the benefit of needing fewer scenarios.

[12] See Trevor Hastie, Robert Tibshirani, and Jerome Friedman, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction,* 2nd edition, New York: Springer, 2009.

[13] In one default scenario, the European Securities and Markets Authority considered the probability of default of clearing members based on current credit default swap spreads. One limit of this approach is the reliance on current conditions. Instead, one needs to consider whether default is likely based on conditions consistent with each stress scenario.

[14] The value of a company is the value of its liabilities plus the value of its equity.

[15] It is possible to use different factors to determine default compared with the factors used to generate scenarios for valuing cleared contracts. In that case, we would augment the information in the scenarios to include both sets of factors.