Central Clearing and Systemic Liquidity Risk*

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By stepping between bilateral counterparties, central counterparties (CCPs) transform credit exposure, thereby improving financial stability. But large CCPs are concentrated and interconnected with major global banks. Moreover, although they mitigate credit risk, CCPs create liquidity risks, because they require participants to provide cash. Such requirements increase with market volatility; consequently, CCP liquidity needs are inherently procyclical. This procyclicality makes it more challenging to assess CCPs' resilience in the rare event that one or more large financial institutions default. Liquidity-focused macroprudential stress tests could help to assess and manage this systemic liquidity risk.

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1. Introduction

Central counterparties (CCPs) play a critical role in the financial system. By inserting itself between the two participants in a securities or derivatives transaction, a central counterparty guarantees payments that could otherwise be jeopardized by the default of either participant. CCPs' importance has grown significantly since the 2008 financial crisis, in part as a result of new regulatory mandates requiring central clearing of over-the-counter (OTC) derivatives. By the first half of 2018, over 75 percent of the notional value of interest rate swaps (IRS) and credit default swaps (CDS)—the two largest categories of OTC derivatives affected by clearing mandates—was centrally cleared.[1] The risks managed and posed by CCPs are a subject of intense interest for financial regulators and policymakers, particularly as certain large CCPs have been designated to be systemically important.

We review the central clearing landscape and highlight some financial stability issues, focusing on the large CCPs that are the most critical for the U.S. financial system. A robust literature discusses CCPs, and we synthesize some of this work in our overview. We also make three novel contributions. First and most importantly, we highlight a potential risk of central clearing: CCPs may place significant liquidity strains on the banking system precisely in the moments when the banking system is least able to bear such strains. This risk stemming from CCPs' procyclical need for liquidity was arguably under-appreciated when an earlier version of this paper circulated, but became more widely recognized following the severe market volatility resulting from the COVID-19 pandemic.[2] The increased attention has focused on the procyclicality of margin—for example, see Futures Industry Association (FIA) (2020) and ISDA Clearing Member Committee (2021) for industry responses and Financial Stability Board (FSB) (2021) and BCBS-CPMI-IOSCO (2022) for the global regulatory response—which is only part of the potential risk. CCPs are connected to and dependent

[1] Clearing percentages calculated from Bank for International Settlements (BIS) data at https://www.bis.org/statistics/derstats.htm.

[2] King et al. (2020) was published just prior to the market volatility in early 2020.

upon globally systemically important banks (G-SIBs) through a variety of channels in addition to direct clearing relationships. These connections include banks' obligations to post margin to CCPs; their required contributions to CCP default funds; and their provision of lines of credit to CCPs. The liquid resources that CCPs demand through each of these and other channels are inherently *procyclical* with respect to market conditions. The materiality of this risk may have been under-appreciated partly due to a focus in the literature on OTC derivatives clearing in isolation. Despite the impact of COVID-19 on market volatility, the full scope of the potential liquidity risk has not received as much attention because there were no defaults requiring CCPs to use liquidity resources beyond margin. Second, given this procyclical liquidity risk, we discuss the potential for macroprudential liquidity stress tests to improve the preparedness of CCPs, G-SIBs, and other actors by looking at potential liquidity needs across the system. Third, we exploit "quantitative disclosure" data on CCPs in combination with market volatility data. The quarterly disclosure data, which most large CCPs began reporting publicly in 2015, present a rich source of potential information for researchers and policymakers.[3] Although the length of the data limits analysis, it is long enough to at least indicate relationships between clearing and market volatility.

At the outset, it is important to recognize that in most circumstances CCPs improve financial stability relative to a world in which trades are bilateral.[4] There are a variety of ways in which they do so, including by insulating members from each others' defaults; by simplifying and reducing members' gross exposures through the netting of positions; by centralizing risk management within a small number of relatively transparent entities; by pooling financial resources to address extreme tail risks; and by increasing the transparency and predictability of market operations. De Bandt and Hartmann (2019) create a typology of systemic risk and identify the first mechanism that can lead to widespread instability within the financial

[3]See Alfranseder et al. (2018) for further discussion of this data and its usefulness for monitoring CCPs. We access the data through Clarus CCPView.

[4]For example, Kiff et al. (2010) argue that well-run CCPs reduce systemic risk, in principle, and FSB (2017b, p. 1) concludes that reforms have mitigated systemic risk in OTC derivatives largely because of increased central clearing.

system as *contagion*—the potential transfer of distress "horizontally" from one financial intermediary or market to another.[5] CCPs are exactly targeted at mitigating such contagion, by serving as a "fire break" to contain defaults. Indeed, several recent studies—Duffie and Zhu (2011) and Amini, Cont, and Minca (2016), among others—find that CCPs reduce contagion stemming from potential counterparty defaults. Arguably, CCPs performed well during the COVID-19 crisis (CCP12, 2020).

However, De Bandt and Hartmann (2019) also identify *interconnectedness* as a potential driver of financial instability. Large CCPs are, virtually by definition, highly concentrated and interconnected. It is thus worth exploring channels through which CCPs could amplify systemic risk through interconnectedness, even as they dampen contagion risk.[6] Some previous papers (e.g., Faruqui, Huang, and Takáts 2018) have noted the interconnectedness risk associated with CCPs being unable to meet their obligations following member default. We highlight a different problem: the ability of CCPs to fulfill their obligations in stressful periods involves their accessing contingent liquidity from members; such procyclical liquidity risk can be a source of systemic risk that could limit how effective CCPs are at reducing systemic risk overall. Our discussion recalls Bernanke (1990), who, in the wake of the 1987 stock market crash, expressed concerns both about the limits to CCPs' ability to address systematic risks on their own and about the potential for CCPs to be a source of risk.

The potential for CCPs to produce procyclical liquidity strains was recently illustrated by the large increases in margin requirements during the extraordinary market volatility in early 2020 brought on by the COVID-19 pandemic; BCBS-CPMI-IOSCO (2022) reports that daily variation margin calls, which cover already realized losses on cleared portfolios, increased around $115 billion from early 2020

[5]De Bandt and Hartmann (2019) divide systemic risk into horizontal risks that remain in the financial system and vertical risks where financial system risks create risks in the real economy.

[6]FSB (2017a, 2018a) details the high interconnectedness between the largest CCPs and 11 to 20 large financial institutions. Barker et al. (2017) argue that banks need to model their interconnected exposures to CCPs and that the modeling is extremely complex.

to the peak in aggregate. At the same time, initial margin requirements, which cover CCPs against potential losses if a clearing member defaults, increased $300 billion in aggregate. These requirements were met, but the potential stress could have been worse, as it was attenuated by the strong liquidity position of banks. Critically, there were no major concurrent defaults, like Lehman during the 2009 financial crisis.

Defaults can create additional liquidity draws, as was seen in the September 2018 default of a large clearing member at the Swedish CCP, Nasdaq Clearing. The default originated due to the member's inability to meet the CCPs' liquidity demands, which were in turn generated by extremely large market movements (in this case, in the spread between Nordic and German Power futures). Losses stemming from the default quickly ate through much of the CCP's prefunded buffer, and surviving members found themselves required to replenish €107 million of that buffer within a few days.[7] While some elements of this event were idiosyncratic—and it fortunately occurred amid otherwise benign market conditions—the difficulties in liquidating the portfolio and the resulting impact on other clearing members show the potential for liquidity problems at a CCP to amplify systemic risk. The implication is that the observed liquidity strains at CCPs during COVID-19 did not fully reflect the systemic risk that could have materialized if there had been a significant default.

Procyclicality of margin requirements has been studied by Murphy, Vasios, and Vause (2014) and Glasserman and Wu (2018), among others. Regulatory bodies have also highlighted margin procyclicality as a concern prior to March 2020 (e.g., CPMI-IOSCO 2012, 2016). But this issue has not been explicitly tied to systemic risk, and we are not aware of any studies that focus on the impact of this procyclicality on bank condition.[8]

[7]Based on materials downloaded from NASDAQ Nordic's website on August 4, 2020.

[8]Duffie (2014) studies how collateral demands shift with the introduction of mandatory margin and central clearing. Similarly, Heller and Vause (2012) show that the current set of rules can place significant liquidity burdens on clearing members, potentially contributing to their failure, and Gibson and Murawski (2013) study banks' trading behavior and welfare under different margin regimes.

Moreover, we emphasize the additional demands that CCPs may place on banks during stressful periods, beyond margin requirements. Most large banks, particularly G-SIBs, have multiple types of obligations toward multiple CCPs simultaneously. Some of these obligations are more likely to come due or to be larger during times of heightened market volatility. These obligations have received little attention in the literature even though, during severe crises, they could be substantial.[9] Liquidity obligations to CCPs could concentrate at banks during an already stressful period and could strain a bank's ability to manage their liquidity, either by making it challenging to maintain regulatory liquidity requirements or in extremis by exceeding a bank's funding capacity.[10] In either case, CCPs' liquidity demands could increase systemic risk, either by decreasing the liquidity available to support other market functions or by increasing the likelihood that payments are missed or even that institutions default.

To be clear, we do not argue that the potential for procyclical liquidity demand outweighs the systemic benefits provided by CCPs, or that the world would be better off if CCPs did not make such demands. Both prudence and regulatory directives lead CCPs to build stronger defenses during periods of greater realized and anticipated stress, and some amount of procyclicality is an unavoidable consequence of the dynamic risk management required of CCPs. Nevertheless, CCPs are most critical precisely when systemic stress occurs, heightening concerns over whether CCPs' dynamic risk management sufficiently anticipates systemic stress. Although individual CCPs regularly stress-test the sufficiency of their own liquid resources, that "micro" approach is not designed to estimate the potential liquidity impacts across multiple CCPs at a time of

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However, the analyses in these papers are static; they do not consider how liquidity demands vary over time with financial market conditions. Sidanius and Zikes (2012) estimate that collateral demand from margin requirements (both in and out of CCPs) would be approximately twice as large under "stressed" market conditions as it is under "normal" conditions.

[9]Maruyama and Cerezetti (2019) also study the inherent procyclicality of CCP risk management, including some of the additional demands that banks could face, but do not focus as much on financial stability.

[10]Under extreme market stress, regulatory requirements may be relaxed, increasing the amount of availability liquidity, but not completely forestalling the possibility that liquidity demands could exceed capacity.

financial stress.[11] This observation motivates the call for macroprudential liquidity stress tests that look across multiple institutions simultaneously with a focus on the systemic impact. (See CPMI-IOSCO 2017 and Anderson, Cerezetti, and Manning 2020.) Such macroprudential stress tests could provide insights into potential aggregate liquidity demands in response to an extreme but plausible market event. At the end of this paper, we discuss some proposals for incorporating CCP liquidity into a macroprudential stress-testing framework. Insights from such tests could be crucial in more accurately assessing whether CCPs and the broader financial system could weather any procyclical demands for liquidity emanating from central clearing. In addition, most bank stress-testing implementations (e.g., those surveyed in Borio, Drehmann, and Tsatsaronis 2014 and Schuermann 2014) have not incorporated liquidity exposures to CCPs. After CCP macroprudential stress testing matures, integrating bank and CCP macroprudential stress testing should be considered.

Our discussion of the procyclicality of CCP demands fits into a broader literature showing how synchronized liquidity needs in the financial sector can be destabilizing and lead to systemic risk.[12] Adrian and Shin (2008, 2010) show that intermediaries broadly decrease leverage during periods of financial stress, and they argue that this behavior is indicative of procyclical liquidity in the financial system as a whole. Allen, Carletti, and Gale (2009), Acharya, Shin, and Yorulmazer (2011), and Heider, Hoerova, and Holthausen (2015) present models in which bank demand for liquidity is inefficiently high during crises, contributing to instability of the interbank market. Ashcraft, McAndrews, and Skeie (2011), Acharya and Merrouche (2012), and Berrospide (2021) document that banks did

[11] In addition to CCPs' own liquidity stress tests, the U.S. Commodity Futures Trading Commission (CFTC) and the European Securities and Markets Authority (ESMA) both have conducted liquidity stress testing using their own scenarios applied jointly to sets of CCPs, but the objective has remained focused on the micro objective of assessing individual CCPs' resilience (see CFTC 2017 and ESMA 2018a, respectively).

[12] The contingent obligations of banks to CCPs also have implications for system-wide liquidity measurement. For example, though potentially large, these commitments do not generally factor into measures of aggregate liquidity conditions that have been proposed in the academic literature (Berger and Bouwman 2009, 2017; Bai, Krishnamurthy, and Weymuller 2018).

indeed hoard liquidity during the 2008 financial crisis.[13] These shifts in the demand for safe and liquid assets can cause financial institutions to fire-sale securities (Shleifer and Vishny 2011, Greenwood, Landier, and Thesmar 2015) and reduce lending (Cornett et al. 2011, Iyer et al. 2014). The increasing contingent obligations of banks to CCPs constitute an additional source of liquidity pressure—likely correlated with both asset and liability draws during stressful periods—adding to the funding pressures faced by banks during stress.[14]

Section 2 of this paper provides a brief overview of the U.S. CCP landscape and discusses how CCPs fit into the broader financial system. Section 3 reviews the basics of CCP operation and risk management. Section 4 discusses various ways that CCP risk management can extract liquidity from the rest of the financial system during times of financial stress. Section 5 describes the role of liquidity stress tests at both the CCP and the macro level. Section 6 concludes.

2. The U.S. CCP Landscape

As cataloged by Kroszner (1999, 2000), CCPs developed in the United States to address counterparty risks in response to financial crises. Indeed, the essential function of a CCP is transforming counterparty exposure. A CCP steps into each trade between its clearing members. By design, a CCP is a very restricted counterparty, as it

[13] Cornett et al. (2011) and Ippolito et al. (2016) emphasize that bank exposure to liquidity risk during stressful periods can come both from creditor demands and from off-balance-sheet commitments, such as lines of credit. While the ability of banks to provide liquidity on both sides of their balance sheets has traditionally been seen as a stabilizing force (Kashyap, Rajan, and Stein 2002), this is only true to the extent that liquidity outflows are imperfectly correlated. Ivashina and Scharfstein (2010) show that draws on lines of credit occurred during the crisis at precisely the time that banks also faced difficulty rolling over their liabilities.

[14] Similar effects extend outside of the commercial banking sector. In particular, liquidity shortages may affect broker-dealers' willingness to provide securities financing to clients. Breach and King (2018) demonstrate this relationship empirically. In Brunnermeier (2009), increases in the collateral demanded by dealers for securities financing leads to asset-price volatility that feeds back into funding conditions in a destabilizing spiral. To the extent that dealers experience or anticipate extraordinary liquidity demands from CCPs, they may respond by making funding conditions more restrictive, increasing the likelihood of such a spiral.

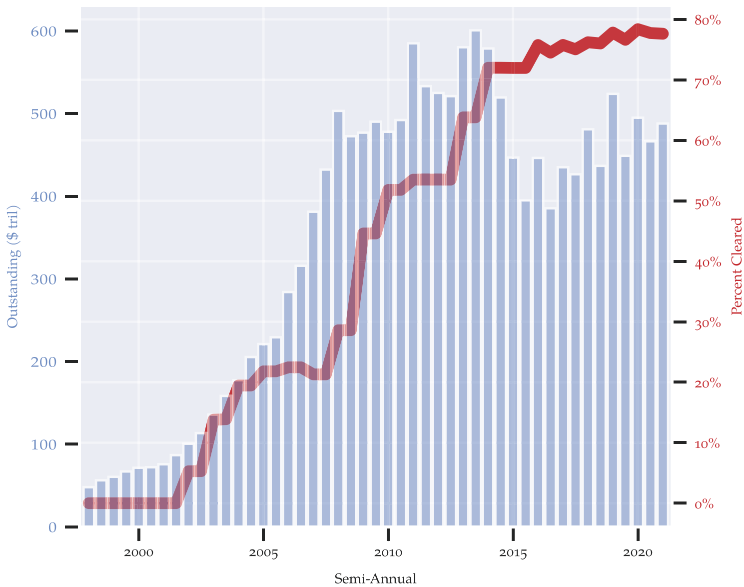
does not take any positions on its own behalf. By being the "buyer to every seller and seller to every buyer," a CCP always maintains a perfectly matched book and therefore takes no direct market risk in the markets it clears. However, counterparty risk is concentrated at the CCP, and the CCP is exposed to contingent market risk upon the default of a clearing member, because it acquires the defaulting member's positions. A CCP then has to take steps to return itself to a matched book and flat market-risk position. (We discuss CCP risk management in the next section.)

CCPs fared well, and served their role as a buffer against defaults, during the 2008 financial crisis. For example, from Valukas (2010), the Chicago Mercantile Exchange (CME) closed out the cleared derivatives portfolio of Lehman Brothers, which had a net value around \$21 billion in May 2008, within a few days; Lehman's margin was sufficient to cover auction-related losses amounting to \$1.2 billion. Similarly, at LCH SwapClear, Lehman's interest rate swap portfolio, with a notional value of \$9 trillion spread over 66,390 trades across five currencies, was closed out by early October (LCH.Clearnet 2008). As discussed in Fleming and Sarkar (2014) and Wiggins and Metrick (2019), central clearing did face some challenges and consequent criticism. Yet, despite this stress, as shown in Figure 1, the percentage of cleared IRS trades (the red line) jumped from less than 25 percent in 2007 to nearly 50 percent by 2009, as traders sought the safety of CCPs during the crisis. In 2009, the G-20 leaders committed to clearing all standardized OTC derivatives contracts through CCPs. The goal was to address risks in the bilateral OTC derivatives' markets, including large concentrations of counterparty exposures, inconsistent risk management, a scarcity of prefunded resources to cover realized losses, a lack of transparency, and adverse feedback loops (e.g., margin spirals). Subsequently, as shown in the figure, clearing of IRS rose to 75 percent.

In the years since the 2008 crisis, a variety of factors have led to further increases in clearing volumes for both exchange-traded and OTC derivatives. The most direct impetus was the establishment of central clearing mandates for OTC derivatives noted above.[15]

[15] Culp (2010) reviews the regulatory history of OTC derivatives' clearing through the Dodd-Frank legislation. FSB (2018b) analyzed the incentives to centrally clear created by various reforms beyond just clearing mandates.

Figure 1. Interest Rate Swaps Outstanding



Note: The blue bars, associated with the left-hand scale, represent IRS notional outstanding; the red line, associated with the right-hand scale, shows the percentage centrally cleared.
Source: Bank for International Settlements.

In Figure 1, for example, the jump in cleared interest rate swaps from about 50 percent in 2012 to near 75 percent by 2014 is coincident with mandates coming into force. Similarly, CDS clearing, which began at ICC (formerly ICE Trust) in March 2009 and at ICE Clear Europe (ICEU) in July 2009, steadily climbed to nearly 40 percent by 2017 according to BIS data (not shown in the figure).[16] This increase came despite delays in implementing clearing mandates. For both IRS and CDS, over 80 percent of new dollar-denominated trades are now centrally cleared. Some of the growth in central clearing likely reflects an increased appreciation for the risk-mitigating function of CCPs following the crisis. It also likely reflects market moves away from more exotic and bespoke trades

[16] CME also started clearing CDS in 2009, but terminated the service in early 2018.

to more standardized ones. The increased clearing rate means that clearing volumes have held roughly steady even as notional amounts fell by a third in the last few years. More recent support for central clearing has been provided by bilateral margin requirements; FSB (2018b) found that OTC derivative clearing dramatically accelerated in terms of notional cleared upon the implementation of bilateral margin requirements, even for trades where central clearing was not required. These developments helped to contribute to a more resilient financial system that was able to weather the COVID-19 market stress (FSB 2021).

In the United States six CCPs clear the most important financial markets; these are listed in Table 1. Five of these CCPs are designated as systemically important in the United States. The sixth, London Clearing House SwapClear (LCH), is a U.K. CCP but clears a substantial amount of U.S. dollar-denominated interest rate swaps. These six CCPs can be classified as clearing securities and derivatives, respectively. The securities CCPs include the Fixed Income Clearing Corporation (FICC), which operates two separate clearing services: one for U.S. Treasuries and repurchase agreements (repos), and one for mortgage-backed securities (MBS). The National Securities Clearing Corporation (NSCC) also clears securities; it is the primary clearer for U.S. equity markets, and also clears corporate and municipal bonds. These securities CCPs are all part of the Depository Trust Clearing Corporation. Derivatives CCPs include: the Options Clearing Corporation (OCC), which is the primary clearer for U.S. equity options; the Chicago Mercantile Exchange Inc. (CME), which operates two separate clearing services, one for futures and options (Base), and one for interest rate swaps and swaptions; ICE Clear Credit (ICC), which clears credit default swap indexes and single names; and, LCH SwapClear, which also clears IRS. Derivatives CCPs can further be divided by whether the cleared derivatives are exchange traded or OTC. OCC and CME's Base service clear exchange-traded derivatives. The remainder—CME's IRS service, ICC, and LCH SwapClear—clear OTC derivatives.[17]

[17]Under the Dodd-Frank legislation, the Securities and Exchange Commission (SEC) is the supervisory agency for FICC, NSCC, and OCC while the CFTC is the supervisory agency for CME and ICC. Because ICC is registered with

Table 1. Six Major CCPs Clearing U.S. Markets

CCP	Main Products	Approx. Prefunded Resources ($ Bil.)		Max. Daily Margin Call Since 2015 ($ Bil. Est.)	
		2019	2020:Q1	Pre-2020	2020:Q1
	Securities				
FICC		39.7	66.6	16.2	34.2
GSD	U.S. Treasuries and Repos				
MBSD	Mortgage-Backed Securities				
NSCC	U.S. Equities, Corps., and Munis	12.5	36.7	8.6	24.5
	Derivatives				
OCC	U.S. Equity Options and Futures	57.2	103.0	17.3	31.8
CME		139.4	239.8	16.0	21.3
Base	Commodity and Financial Futures and Options				
IRS	Interest Rate Swaps and Swaptions				
ICC	Credit Default Swaps	36.7	53.3	2.4	9.1
LCH SwapClear	Interest Rate Swaps	170.7	206.9	24.9	32.9

Note: Maximum daily margin call estimated by adding the peak VM and IM calls during each quarter.
Source: Quantitative disclosures via Clarus CCPView. Data through 2021:Q3.

Measuring the size of CCPs is not entirely straightforward, but Table 1 provides some context. The first numeric column presents approximate total prefunded resources in 2019; although substantial, the resources also jumped significantly—for NSCC, nearly tripling—in the first quarter of 2020, as shown in the second numeric column. The last two columns present the maximum daily call for margin since 2015 prior to 2020 and during the first quarter of 2020, respectively. Again, the pre-2020 peaks were large but were dwarfed by the calls during the COVID-19 market stress. Note that the measures of size used here likely understate the economic impact of securities clearing houses, because they do not capture the total cash that flows through securities CCPs, which is substantial due to the settlement demands for cash. Despite measurement challenges, clearly, all the CCPs have significant resources available, but also all have made significant calls for additional funds from the market, both before the market shock in early 2020 and even more so during it. This pattern is consistent with the analysis in BCBS-CPMI-IOSCO (2022).

3. CCP Function and Risk Management

The concentration of counterparty exposure at a CCP means that the success, or failure, of its risk management controls could have profound implications for the markets it clears. Success means defaults are not amplified with potential systemic implications; failure, although designed to be an extremely remote possibility, potentially creates contagion effects between clearing members that would not otherwise have been exposed to the default. CCPs manage their credit and liquidity risks differently than banks, partly reflecting that CCPs do not actively trade financial contracts, but rather manage the risks generated by participants' trading activity.[18]

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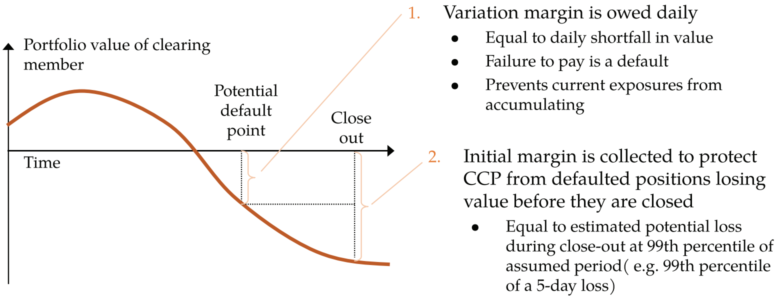
the SEC as a clearing agency, the SEC also has authority over all of its clearing services. The Federal Reserve has authority to participate in the designated supervisor's examinations and reviews of material changes at the designated CCPs. LCH SwapClear is registered with, and supervised by, the CFTC for the clearing of U.S. dollar-denominated positions; the Federal Reserve also participates in international oversight of LCH SwapClear under the auspices of the Bank of England.

[18]In the event of a clearing member default, a CCP may trade in order to hedge and liquidate the defaulter's portfolio, but usually needs to second traders from

Figure 2. Variation and Initial Margin



CCP risk management generally includes membership eligibility requirements, the netting of exposures, margin requirements, mutualized financial resources (usually in a default or guaranty fund), and default-management procedures. See Murphy (2013) for a fuller discussion. CCPs may also have additional tools to employ in recovery scenarios, such as assessment powers, variation margin haircutting, contract tear-ups, or loss allocation powers (CPMI-IOSCO 2014, Section 4). In addition to the management of credit risk, CCPs also manage liquidity risk, and have a variety of tools to address liquidity needs, such as access to collateral markets and pre-arranged repo lines. With an eye towards the subsequent discussion of procyclicality, we review two of the most important elements of CCP risk management: margin and mutualized financial resources, which represent prefunded resources held by the CCP. Both resources are critical to managing and mitigating a CCP's contingent risk exposures and are two major drivers of procyclicality in CCPs' resource demands.

Margin is a critical component of CCP risk management. It can be divided into variation margin (VM) and initial margin (IM); Figure 2 illustrates how VM extinguishes a CCP's current exposure and IM covers potential future exposure. We discuss each type of margin in turn.

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its clearing members to do so. For further discussion of the differences between banks and CCPs, particularly the different roles played by capital and collateral in their respective risk-management approaches, see Manning and Hughes (2016) and Cox and Steigerwald (2018).

Variation margin covers the realized change in a cleared position. Regulations generally require CCPs to collect and pay out in cash the daily change in value that each member's portfolio experiences as VM.[19] In the stylized example in Figure 2, the change in value of the portfolio at the end of the day is negative. The clearing member must pay this amount to the CCP. The total value of the payments of VM exactly equals the amount owed to clearing members whose portfolios gained in value. By marking every portfolio to market daily and exchanging cash to cover the changes, the CCP resets its current exposure to zero every day and prevents exposures from accumulating.[20] The requirement to pay VM, however, also creates a point of failure; if a clearing member fails to make a VM payment for itself or its clients in the time required, the CCP can, and likely will, declare the clearing member to be in default.[21] As emphasized by Maruyama and Cerezetti (2019), VM is the main driver of CCP margin calls. The requirement to meet VM effectively tests each clearing member's performance at least daily, which in some sense transforms the credit exposure it faced with its original counterparty to a liquidity exposure to the CCP (Cont 2017). Though not without its own risks (as we discuss in detail below), the liquidity exposure has the virtue of transparency, since it depends directly on observable market movements, rather than on difficult to observe counterparty actions.

Initial margin is designed to cover the potential future exposure of a clearing member's portfolio from the time of the last VM payment until the portfolio could be liquidated in a default. Because the loss that could be realized on a portfolio is uncertain, IM targets a high quantile—at least the 99th percentile—of market moves over the specified close-out period (also sometimes called the margin period of risk). In Figure 2, IM covers both the VM that was not

[19]There are exceptions. In particular, FICC's clearing structure for mortgage-backed securities collects VM, but does not pass it through. OCC collects little VM, because the covered options positions it clears are generally hedged by the underlying securities.

[20]In addition, VM is sometimes exchanged intra-daily to more actively limit the buildup of current exposures that might occur more rapidly, for example, in more volatile markets.

[21]Armakolla and Laurent (2017) show the importance of members' abilities to meet their obligations for the resilience of a CCP.

paid during a default plus additional losses on the position that could be realized during the close-out. At their core, CCPs' IM estimates for a portfolio bear similarities to standard market risk calculations, like value-at-risk or expected shortfall. However, regulatory requirements also specify that IM covers other exposures that are more difficult to quantify, like estimates of portfolio transaction costs, jump-to-default exposures, and concentration risks. Heckinger, Cox, and Marshall (2017) review both historical and current IM practices. Looking across certain derivatives CCPs for futures and swaps, as shown in Figure 3, the size of IM requirements more than doubled from less than \$194 billion at the end of 2013 to over \$425 billion in August 2019; that steady increase was matched by roughly an additional \$200 billion in March 2020 alone, and at the end of 2021 IM is more than triple that held in 2013 at these CCPs.[22] This growth in IM implies growth in the amount of risk CCPs are managing, although not in direct lockstep.

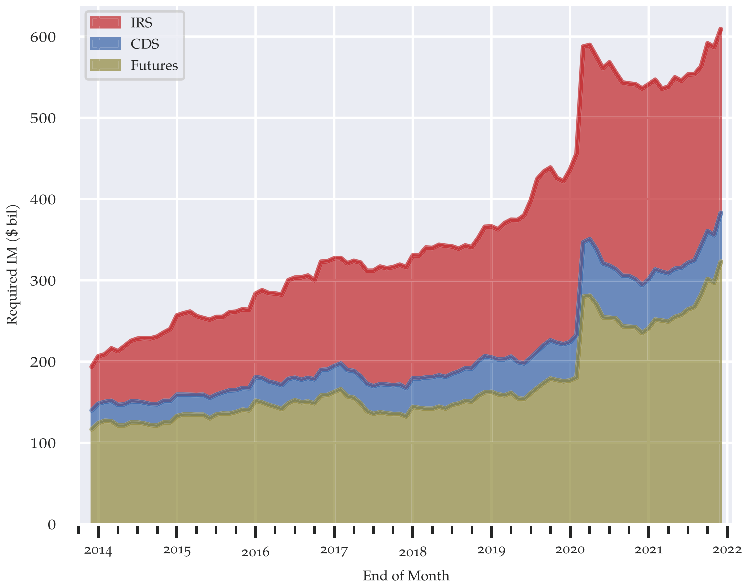
To cover potential losses beyond margin in the event of a default, CCPs require clearing members to provide mutualized financial resources sufficient to meet a specific coverage target in a wide range of extreme but plausible stress scenarios. The mutualized resources are sized so that the CCP has sufficient financial resources to cover the default of either any single or any pair of clearing members in stressed market conditions.[23] At most CCPs, mutualized resources are maintained in a separate fund, called a default or guaranty fund. The U.S. securities CCPs instead mutualize all IM. In either case, the adequacy of these resources is tested daily by the CCP through its stress-testing program, which is required to apply a variety of extreme but plausible scenarios: both historically observed market stresses and hypothetical scenarios.

To cover any losses from a default, a CCP would use prefunded resources in a prescribed sequence, often called the CCP "waterfall." The defaulter's margin absorbs losses first. If the defaulter's margin

[22]The data include requirements from more than the systemically important CCPs. Besides ICEU, which clears energy futures and options in addition to CDS, and other parts of LCH Ltd. besides SwapClear, requirements from ICE US, which clears a variety of futures and options, and LCH SA, which is the European sited counterpart to LCH Ltd. in the United Kingdom are included.

[23]Specifically, in the United States, FICC, NSCC, and OCC are required to cover the single largest default loss, while CME and ICC are required to cover the largest two default losses, as is LCH SwapClear.

Figure 3. IM for IRS, Futures, and CDS



Note: Total requirements held by clearinghouses from clearing members, including add-ons. IRS data include CME and LCH Ltd. Futures data include CME, ICEU, and ICE US. CDS data include CME, ICC, ICEU, and LCH SA. Data are month-end through December 2021.
Source: CFTC.

is exhausted, any additional resources provided by the defaulting party, such as its contributions to a default fund, are applied. If the defaulter's resources are exhausted, before mutualizing losses to surviving clearing members, CCPs typically apply a portion of their own capital—known as "skin in the game"—to cover remaining losses. Mutualized resources would be applied to any remaining losses. CCPs are required to have explicit rules and procedures that address how potentially uncovered credit losses would be allocated. They may also have additional prescribed assessment powers to seek further resources from non-defaulting members.

The strong and consistent risk-management practices adopted by CCPs have been enhanced by stronger regulatory expectations promulgated in the wake of the 2008 financial crisis. This strengthening was facilitated by the development of internationally agreed risk-management standards set out in the Principles for Financial Market Infrastructures (PFMI).[24] The principles in the PFMI set several expectations for CCPs, including effectively managing all dimensions of the CCP's credit and liquidity risks, employing a robust margining system, and maintaining a minimum level of financial resources to cover potential losses and honor payment obligations, both in extreme market conditions. The principles are designed to ensure that CCPs will halt contagion among their members and mitigate systemic risk across the interconnections.

4. Potential Procyclical Resource Demand

Any reduction in systemic risk afforded by central clearing depends on CCPs performing as designed in stressed markets. As noted above, CCPs have grown both in size and in the scope of the products they clear. Furthermore, individual systemically important banks tend to participate in multiple CCPs, in order to access different markets across different jurisdictions. For example, the recent analysis in FSB (2018a) shows that out of a set of 26 major global CCPs, the 11 largest clearing members in terms of aggregate resources are members of at least 16 of the 26, with a median participation of 22. Many of these same large financial institutions also provide other services to CCPs, such as settlement and investment services and lines of credit. This interconnectedness, together with CCPs' critical functions supporting markets, naturally raises the need to monitor their impact on financial stability.

CCPs' risk-management controls can affect the other financial institutions expected to meet one or more resource demands, particularly if CCP resource demands come at times of heightened financial stress. These demands include (i) variation margin; (ii) initial margin; (iii) settlement requirements; (iv) default fund contributions and assessments; (v) lines of credit and other liquidity arrangements; and (vi) capital and liquidity to absorb the positions of members and their clients in the event of default. In this section, we review each of these potential resource demands in turn.

From a systemic risk perspective, there is a trade-off between rigorously managing the risk of positions cleared through CCPs and

[24]See CPMI-IOSCO (2012).

minimizing interconnected liquidity strains on the system. The failure of a large CCP would be a devastating event for the global financial system; it would likely be accompanied by massive disruptions in financial markets and the severe distress or failure of many other systemically important institutions. From a financial stability perspective, it is important for CCPs to maintain financial resources sized to cover potential losses in a wide range of stress scenarios. One hypothetical way to achieve this would be for CCPs to prefund all of these financial resources ex ante by holding very large quantities of safe and liquid assets at all times. Such an approach would tie up liquidity and collateral in accounts that, most of the time, would be well in excess of any plausible loss that CCPs might experience. Moreover, the requirement to keep large amounts of assets parked at CCPs continuously would impose costs on clearing members; those costs could well induce banks and their clients to move activity into uncleared positions (eliminating the stability benefits of central clearing) or to exit positions altogether, which could result in less hedging activity and a reduction in overall market liquidity. Rather than holding an extremely large buffer of financial resources all the time, CCPs hold smaller (though still significant) amounts of liquid resources during calm periods and increase these resources during times of high financial market volatility, when their market and counterparty risks increase. The increase must be met by a web of banks and other financial institutions, which implies an increase in the risk associated with the CCPs' interconnectedness.

Importantly, the most common resource draws that come from CCPs, margin calls, are not unique to clearing relationships. Prior to implementation of the Dodd-Frank Act and similar regulatory changes abroad, many bank arrangements with non-bank counterparties included provisions for IM, and for most derivative exposures there was some periodic exchange of VM. However, these arrangements were somewhat ad hoc and flexible. With central clearing, margin requirements are universal for cleared contracts and, to a large degree, standardized due to consistent regulatory expectations.[25]

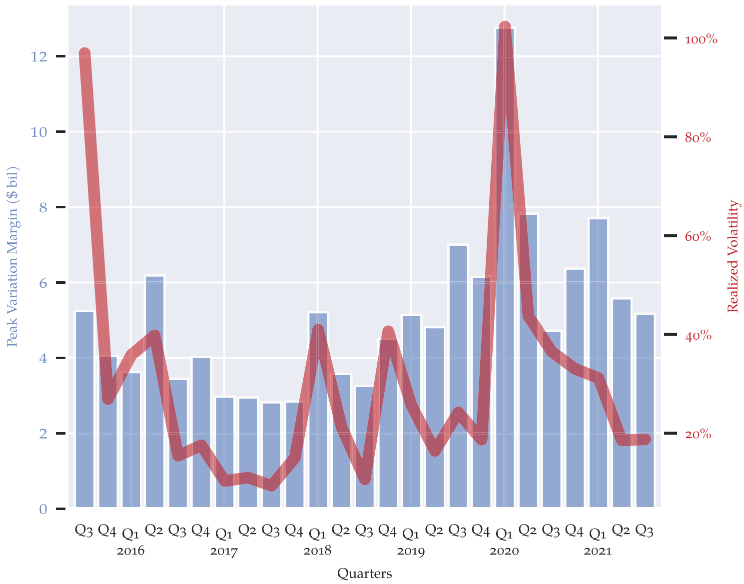
[25] Margin requirements, both for VM and IM, have also been established for bilateral trades (BCBS-IOSCO 2015); for analysis of their impact on the incentives to centrally clear, see FSB (2018b).

Figure 4. Percentage of Client IM Requirements at Five Largest Parent Firms

Note: Futures data include CME, ICEU, and ICE US. Swaps data include both IRS and CDS requirements. IRS data include CME and LCH Ltd. CDS data include CME, ICC, ICEU, and LCH SA. Data are month-end through December 2021. Identity of top five firms can vary from month to month.
Source: CFTC.

Nevertheless, because clearing takes place through a small number of CCPs, the models and rules used by any one CCP can have significant implications for a large number of market participants. In addition, much of the activity at CCPs is concentrated in a few large members. The concentration is illustrated in Figure 4, which shows that the five largest clearing members also account for the majority of IM requirements facing clients for dollar-denominated clearing of both futures and swaps; in fact, at one point the five largest clearing members accounted for nearly three-quarters of clients' swap IM requirements, before declining to around 60 percent. The concentration associated with CCPs and their large members implies that margin calls are likely to come in a more coordinated manner in a world with central clearing, reflecting stronger interconnectedness. Furthermore, as discussed below, CCPs also impose other types

Figure 5. Daily Peak VM Paid versus Realized Volatility



Note: Peak VM, represented by the blue bars associated with the left-hand scale, is the industry average of the maximum paid by/to each CCP in the quarter. Realized volitility is annualized.
Source: Quantitative disclosures accessed via Clarus CCPView and Heber et al. (2009). Data through 2021:Q3.

of obligations on their clearing members—obligations that have no counterparts in bilateral trading—and these are more likely to be triggered in the same states of the world in which margin calls are large.

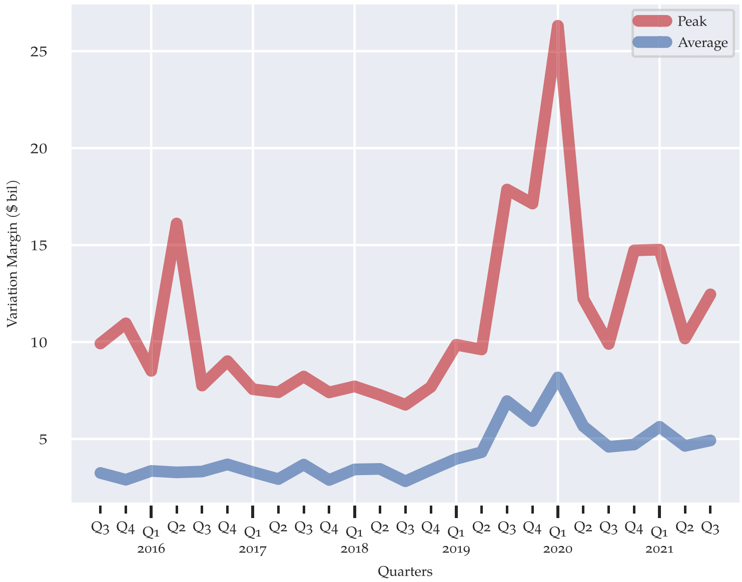
4.1 Variation Margin

As noted earlier, VM is the amount that a clearing member must post to the CCP to cover marked-to-market changes in the value of its portfolio. Maruyama and Cerezetti (2019) illustrate how VM is the margin component that is most sensitive to market volatility. Because changes are greatest on days when market prices move most, the amount of VM paid to CCPs necessarily increases during times of high realized volatility in financial markets. Figure 5 illustrates this relationship by showing the peak amount of VM collected in each quarter by the CCPs through which U.S. banks clear most of their trades. This margin is plotted against the peak in the realized volatility of the stock market in each quarter. (Although the data do not tell us for certain, it is likely that the peaks in the two series occur on the same days of each quarter.) This comparison is crude because some CCPs do not clear products that are directly linked to equity markets. Nevertheless, the tendency of volatility in most markets to move together makes the comparison informative, and the pattern is clear. Not surprisingly, the peak in both is during the first quarter of 2020.

To meet VM calls, clearing members must make payments to the CCP in a short amount of time, often in as little as one hour, and these payments generally are made in cash. Furthermore, although clearing members who clear on behalf of clients pass through VM calls on client positions, this pass-through sometimes does not occur until the following day, and the clearing member is itself responsible for ensuring that the proper amount of margin is posted to cover their clients' losses. Clearing members and their clients expect to make (or receive) VM daily; however, because they reflect changes in asset prices, the size of VM calls are essentially unpredictable. To address this risk, clearing members maintain reserves of cash or have access to funding markets that can be drawn on with very short notice.

Even in times when financial institutions are not under severe pressure, VM calls due to spikes in volatility can be burdensome. Events surrounding the "Brexit" referendum in the United Kingdom in June 2016 provide an example. The referendum, the result of which surprised many, caused a spate of volatility in financial markets, particularly those involving the British pound, the euro, and associated fixed-income products. LCH, which clears many such instruments, called for large amounts of VM in the wake of this episode. Figure 6 shows that on the peak day during the second quarter of 2016, VM payments to LCH totaled \$16 billion, in contrast to the daily average of about \$3 billion. These calls came simultaneously with smaller VM calls from other CCPs; Commodity Futures Trading Commission (CFTC) (2016) found that LCH together with four other CCPs called for \$27 billion over the two days following the

Figure 6. VM at LCH SwapClear



Note: Peak VM, the higher red line, is the maximum paid by/to LCH SwapClear in the quarter. The blue line shows the corresponding quarterly average.
Source: Quantitative disclosures accessed via Clarus CCPView. Data through 2021:Q3.

referendum.[26] The peak demand caused by Brexit was much higher than the elevated average demand during COVID-19, even though much larger calls were made at LCH in the later period.

Under most circumstances, VM payments to CCPs do not reduce aggregate liquid resources available to market participants, because CCPs run matched books, so that every marked-to-market loss they face is accompanied by an equal marked-to-market gain. Thus, VM ought to be passed through, dollar for dollar, from one set of clearing

[26]LCH was also slower to make payments to members with position gains than it was to collect from members with losses, creating further liquidity pressure; some market participants seemed to find the obligation to post this margin onerous, despite the fact that the financial system itself did not appear to be under a particularly high level of pressure (Madigan, Wood, and Becker 2016).

members (those with net losses) to another (those with net gains).[27] Even so, the transfer of funds can cause stress for those with unanticipated liquidity outflows. Furthermore, particularly in times of stress, disruptions and delays in payment chains can occur, potentially preventing the liquid assets from flowing to their recipients in a timely manner. CCPs and settlement banks themselves may deliberately slow the transfer of liquidity out of a fear that their own liquid resources may prove inadequate. The stock-market crash of 1987, for example, was accompanied by a number of disruptions in the payments system, including the reluctance of settlement banks to provide large amounts of intraday credit. As a result, VM payments to clearing members at CME and OCC were delayed, adding to the stress of market participants on an already volatile day (Presidential Task Force on Market Mechanisms 1988). During the COVID-19 stress, some clients did report needing to conduct repo transactions and assets sales to meet margin calls (BCBS-CPMI-IOSCO 2021), which may have added additional strain on funding markets.

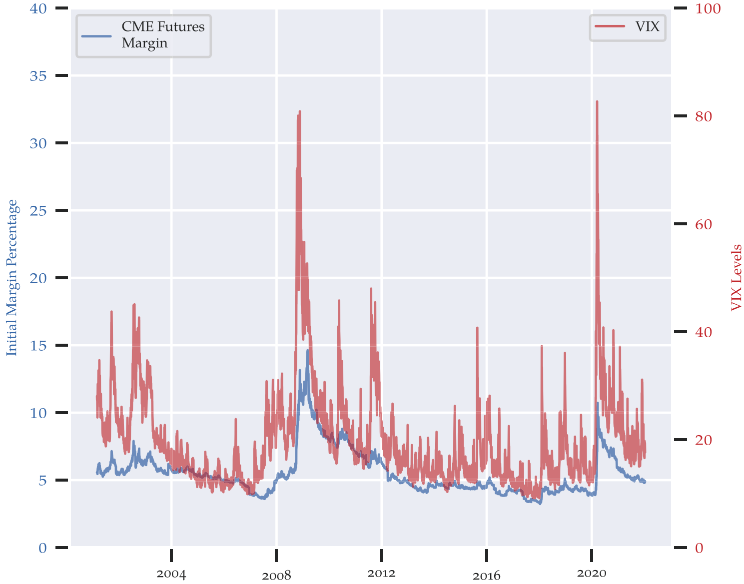
Finally, extreme circumstances may also prevent clearing members from receiving the full VM due to them. In particular, if a CCP's resources should be exhausted by clearing member defaults, one option some CCPs have to manage liquidity is to "haircut" the VM it pays out. In this case, the CCP would absorb, at least temporarily, part of the VM it received on loss positions. As another option in such situations, some CCPs may pay out VM in securities collateral, rather than cash, putting the burden of liquidity transformation onto members.

4.2 Initial Margin

Initial margin is posted to CCPs to account for possible deterioration in the value of clearing member positions that might occur between the time of a default and the time the defaulting member's positions can be liquidated. Like VM, IM generally increases during times of financial-market volatility. As discussed in Murphy, Vasios, and Vause (2014), the requirements to cover a quantile of market moves require IM models to be risk sensitive, and therefore procyclical, to at least some degree. However, while the pass-through

[27] There are some exceptions for intraday variation margin calls.

Figure 7. CME Futures IM Requirements and VIX Index

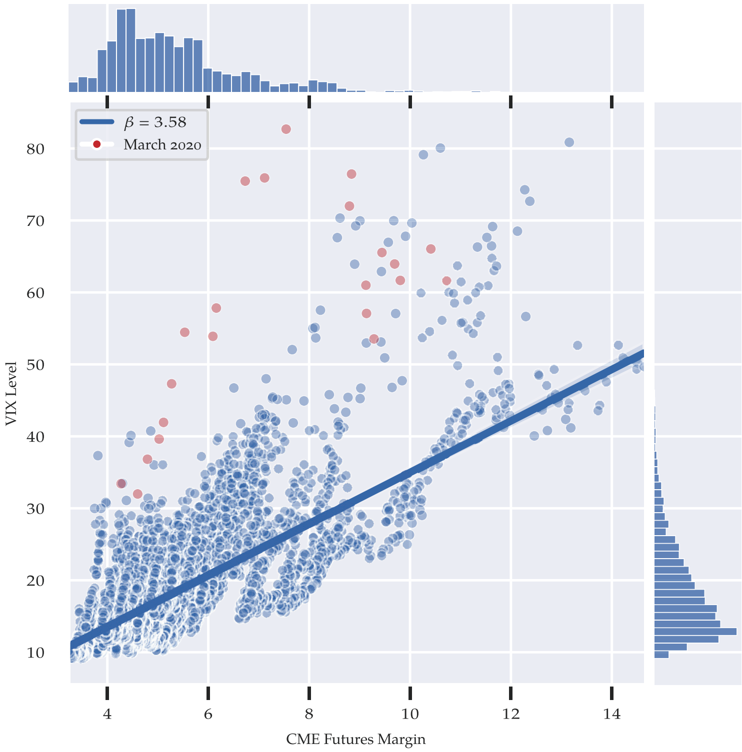


Note: The blue line, associated with the left-hand scale, shows CME's IM requirements on an S&P 500 futures contract as a percentage of the contract value. The red line, associated with the right-hand scale, is the Chicago Board Options Exchange's Volatility Index (VIX), which reflects market expectations of 30-day forward-looking implied volatility. It is calculated from S&P 500 index options.
Source: Daily data 3/1/2001–1/12/2022 from Chicago Board Options Exchange, CME, and Haver Analytics.

of volatility to VM is largely mechanical and out of the CCP's control, the factors determining IM are more complex and depend on the specific practices the CCP follows. These practices are largely spelled out in CCP rule books, but they also involve elements of discretion.

As a baseline, CCPs maintain models of the value that positions could lose with some confidence: typically, 99 percent or 99.5 percent over a specified liquidation period (typically a few days). These tail losses are almost always greater when market volatility is expected to be higher, and consequently IM tends to increase in periods of high realized and implied volatility. As an example, Figure 7 plots the amount of IM that CME has required on an S&P 500 futures

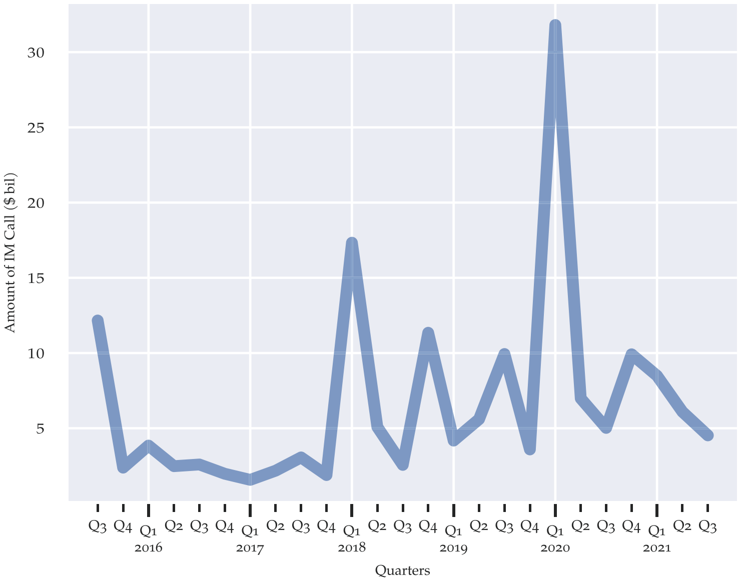
Figure 8. CME: Futures IM Requirement versus VIX Index



Note: The joint plot shows CME's IM requirements on an S&P 500 futures contract as a percentage of the contract value versus VIX; the strong positive relationship is reflected in the upward-sloping regression line; this regression, which is highly significant as shown by the barely visible 99th percent bootstrapped confidence interval, is estimated robustly to reduce the influence of outliers that would increase the slope further. The marginal distributions, plotted above and to the right as histograms, show that both series have a long positive tail, although presumably margin as a percent is capped. The red points highlight values from March 2020 during the COVID-19 induced market shock.
Source: Daily data 3/1/2001–1/12/2022 from Chicago Board Options Exchange, CME, and Haver Analytics.

contract, as a percentage of the contract value, with the VIX index of implied volatility on the S&P. It is clear that these two series move closely together particularly during large spikes in implied volatility. The strength of this relationship is further shown in Figure 8, which

Figure 9. OCC Quarterly Peak IM Calls



Source: Quantitative disclosures accessed via Clarus CCPView. Data through 2021:Q3.

plots the same data against each other; the significant positive relationship can be seen by the slope of the regression line.[28] The red dots show the behavior during March 2020 as the IM level increased as VIX spiked, but continued to do so even as VIX fell back.

As another example of the connection between volatility and IM, Figure 9 shows peak IM calls at the OCC, which primarily clears equity options; the jumps in equity volatility that occurred in February 2018, December 2018, and March 2020 are clearly identified as causing corresponding jumps in IM during those quarters.

Although it is related to volatility, the total amount of IM required of a clearing member is, in most cases, more complicated than the direct relationships suggested by Figures 7 to 9.

[28]The line is calculated by an M-type estimator with Huber's T norm (Huber 1981) to make the regression robust against the large positive outliers.

Figure 10. Quarterly Changes in Required IM and VIX

Note: The blue bars, associated with the left-hand scale, represent quarterly changes in the sum of the largest calls in required IM across the seven CCPs; the red line, associated with the right-hand scale, shows the change in the maximum VIX level in each quarter.
Source: Quantitative disclosures accessed via Clarus CCPView, and Chicago Board Options Exchange. Data through 2021:Q3.

The net positions that clearing members and their clients maintain with CCPs consist of large arrays of financial instruments that are exposed to different types of risk. CCP margin models attempt to account for the co-movement of different assets and employ a variety of modeling techniques to capture the tails of the joint distributions of returns. In addition, the overall level of margin charged often includes certain "add-ons," which tend to be less sensitive (to varying degrees) to market volatility (CPMI-IOSCO 2016). And, of course, the total amount of IM required tends to rise and fall with the size of participants' positions. Figure 10 shows quarterly changes in the total quantity of IM required by the major U.S. CCPs, plotted against contemporaneous changes in the VIX. The positive correlation is clear, despite the introduction of anti-procyclicality tools designed to mute such correlation. European Securities and Markets Authority (ESMA) (2018b) codifies some anti-procyclicality tools, which have also been applied to U.S. CCPs due to their global activity. Examples of tools include a buffer that allows for a proportion of margin to be temporarily exhausted following a significant increase in margin requirements, which lessens the size of any IM calls that result from sudden spikes in volatility, and a floor that limits the amount that margin requirements can decline during tranquil periods, thereby muting increases that result when tranquility gives way to turbulence. Despite the prevalent use of these tools, BCBS-CPMI-IOSCO (2022) finds that market volatility was the major driver of IM requirements during the severe COVID-19 stress.

Another reason that CCP IM requirements may not be direct functions of market volatility is that CCPs may attach margin surcharges to particular clearing members to compensate for concentration or counterparty risk. Though counterparty-risk surcharges are rare, they can result in sudden large increases in the amount of IM margin required from financial institutions that are already in distress. For example, as discussed by Heckinger (2014), amid concerns about the risk associated with its repo positions, the futures commission merchant MF Global was downgraded by Moody's and Standard & Poors on the week of October 24, 2011. Over the following few days, LCH (through which these repo positions were cleared) imposed counterparty-risk surcharges that approximately doubled the IM that MF Global was required to hold. The resulting margin calls, which totaled over $500 million, exceeded MF Global's resources, which led directly to its failure. This sort of example illustrates how margin requirements can contain a procyclical element, even if they are not explicitly tied to asset price volatility.[29] Such unusual charges also received significant attention during the "meme

[29]Standards require IM models to incorporate anti-procyclicality measures (CPMI-IOSCO 2012), but ultimately IM will respond to changing risk exposures. Houllier and Murphy (2017), Wong and Pei (2017), and Glasserman and Wu (2018) study the problem of reducing margin procyclicality. O'Neill and Vause (2018) study how a time-varying "macroprudential buffer" added to IM can address fire-sale externalities. Raykov (2012) examines the trade-offs inherent in reducing the procyclicality of IM and finds that reducing it does not necessarily reduce systemic risk.

stock" episode in U.S. equity markets in January 2021 (Mourselas 2021).

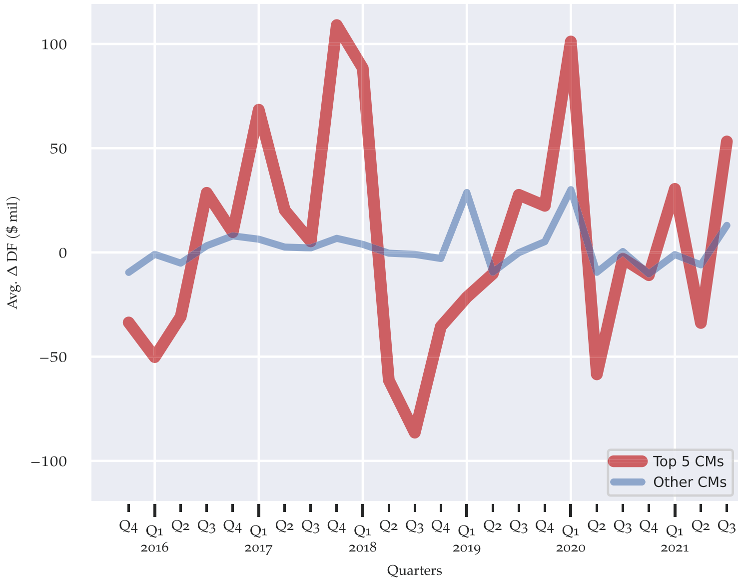
Finally, it is not only the amount of IM required that is likely to rise during times of market stress. According to the quantitative disclosure data, approximately half of IM is in the form of securities, rather than cash, and those securities are subject to haircuts. Lewandowska and Glaser (2017) find that one major CCP does not significantly increase its haircuts during times of market stress. Nevertheless, in principle, rising haircuts and declines in market value that could be associated with episodes of market volatility could lead to changes in haircuts and would require the posting of additional collateral even if the margin requirement were unchanged.

4.3 Settlement Requirements

In discussing how VM and IM can vary with market volatility, there is a tendency to focus on the change in market prices. However, market volatility usually is also associated with increased trading activity. As a result, portfolio valuations can change because both prices and positions fluctuate. Importantly, increases in trading activity directly create liquidity needs at securities CCPs in order to settle the trades. Because the cash needed to settle securities corresponds directly to the full value of the securities trades, the resulting liquidity needs can be simultaneously material and procyclical. In terms of materiality, from the latest quantitative disclosures, the sum of the peak payment obligations in the prior 12 months was just under $194 billion. For derivatives, most trades do not require up-front payments to settle, so the effect there is at most minor.[30] From a systemic view, the liquidity needs generated by the settlement of centrally cleared securities need to be combined with the liquidity needs from VM and IM in assessing the resiliency of the clearing system overall.

[30]Derivatives contracts can have settlement requirements, such as if an option is exercised or a future matures, but such requirements likely are not strongly procyclical. CDS potentially can generate procyclical payments due to the defaults of reference entities, but such payments are difficult to predict or regularly observe.

Figure 11. Change in Average Default Fund Assessments



Note: The thicker red line represents average change at the six CCPs in the default fund assessments of each CCP's five largest clearing memebers. The thinner blue line shows the same average change for the remaining CMs across the CCPs.
Source: Quantitative disclosures accessed via Clarus CCPView. Data through 2021:Q3.

4.4 Default Fund Contributions and Assessments

While VM and IM calls are the most common ways in which CCPs draw in resources from their clearing members, several other contingent relationships can also come into play, particularly in times of financial stress. One important way in which CCPs can require resources from their members is by calling for contributions to the default fund. Figure 11 shows the average quarterly changes in default fund sizes per clearing member split into the five largest versus the rest.[31] Since 2015, average changes in default fund contributions have been small on average, however the average of averages

[31]This figure only includes the derivatives CCPs, as the securities CCPs do not have clearing funds that are distinct from IM.

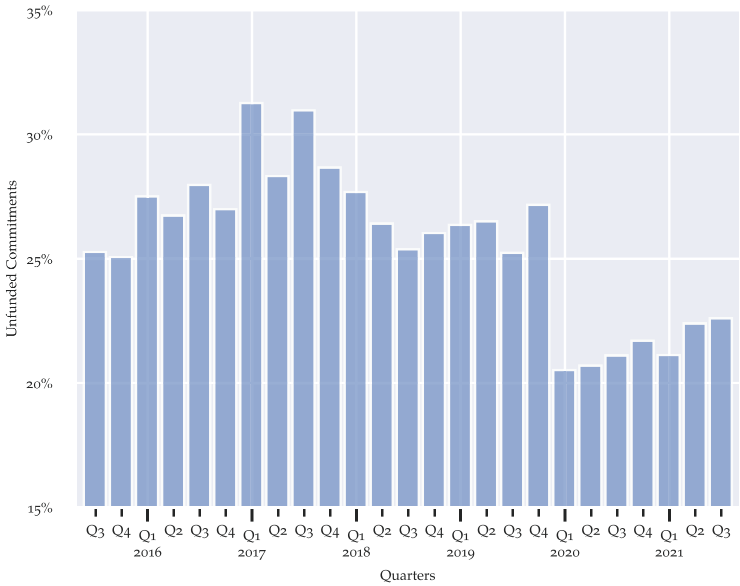
masks volatility, particularly for larger clearing members, where even the quarterly average across the CCPs has been over $100 million. The largest call at an individual CCP was over $540 million, and even clearing members not among the five largest faced a call of nearly $160 million. Although likely less sensitive than margin, default funds can change due to changing portfolios, market risk, and risk-management practices. The fact that the change in default fund assessments was not more pronounced during the first quarter of 2020 likely reflects a lag in updating stress scenarios; such a lag across multiple CCPs may indicate a correlated weakness in CCP stress testing and therefore a higher level of systemic risk.

There are three distinct circumstances under which CCPs may call on clearing members to add resources to the default fund. The first is intra-month calls for contributions in response to changes in risk that the CCP perceives. Typically, CCPs levy default fund assessments monthly to reflect changes in market conditions and concentration that occur over the course of any given month. In times of market stress, however, CCPs may not wait for the end of the month. Intra-month default fund calls may be issued following sudden changes in market volatility.[32]

The second situation in which unscheduled payments to the default fund may occur is when a clearing member defaults and that member's IM and own default fund contribution is insufficient to cover the liquidation value of its position. An example occurred in 2013 when a topping-up of the default fund was required at the Korean CCP KRX following a trading error that resulted in a clearing member losing $45 million before a margin call could be issued. A more recent example is the previously mentioned 2018 default of a large clearing member at Nasdaq Clearing, which ultimately consumed approximately two-thirds of the mutualized default fund resources. Although both of these defaults were idiosyncratic and occurred during times of relative market calm, the obligation to replenish the default fund is a source of procyclicality, because both the likelihood of defaults and the potential impact of a realized default increase during times of market stress, when the necessary capital may be scarce. Because clearing member defaults that are

[32]Increased default fund needs could alternatively be addressed by issuing margin calls.

Figure 12. Unfunded CM Commitments as a Percent of Total Default Resources Excluding IM



Source: Quantitative. disclosures accessed via Clarus CCPView. Data through 2021:Q3.

large enough to breach a CCP's mutualized default resources are quite uncommon and fortunately did not occur during the pandemic, there is also a risk that market participants may not be attuned to or prepared for the resource demands such defaults could generate. In addition, and from the perspective of a given clearing member, there is a distinction between the risks posed by VM and IM calls relative to calls for additional mutualized default fund resources, regardless of either the frequency or size of the associated calls, since the former two relate entirely to the portfolio that a given clearing member (CM) brings to the clearing house, while the latter, to a degree, depends upon the portfolios brought by other CMs, which are outside of the given CM's immediate control.

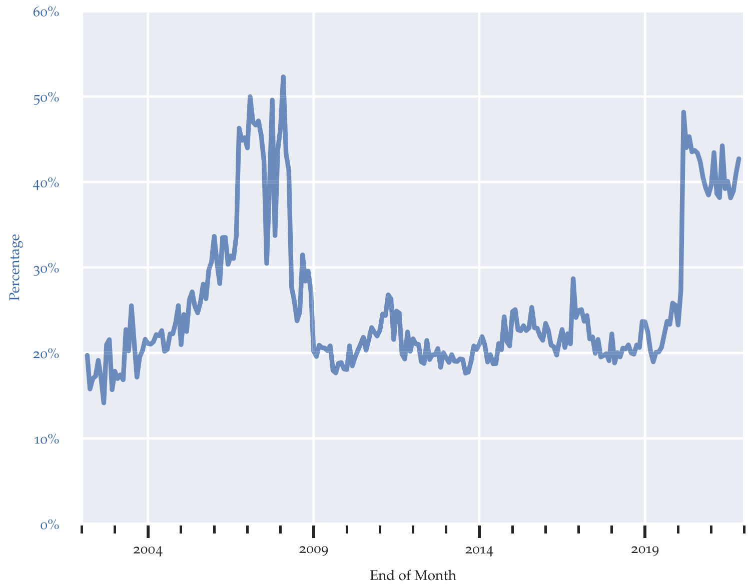
Finally, CCPs have powers of assessment in the event that the prefunded portion of the default fund is exhausted. Figure 12 shows the unfunded commitments that clearing members could have to pay CCPs in such circumstances as a percentage of total default resources excluding IM. The exercise by a CCP of its unfunded commitments is a very rare situation, since prefunded resources are calibrated to cover the losses of a CCP's single or two largest clearing members. Thus, in principle, CCPs should only need to draw on unfunded commitments in cases in which three or more members default nearly simultaneously and have insufficient margin to make up for the loss associated with their positions. The caveat "in principle" reflects that one or two member defaults also could exhaust prefunded resources if the CCP's models are inaccurate or if liquidation of defaulted positions proves unexpectedly challenging. Clearly, an environment in which those defaults occurred would be associated with very high levels of market stress and liquidity demand and could strain clearing members' ability to meet their payment obligations. Notably, the increase in prefunded resources held following March 2020 has reduced the unfunded commitments as a percentage. However, this indicates that assessment powers have not necessarily expanded even as CCPs seem to view risk as being higher, as reflected in their increased holding of prefunded resources.

4.5 Absorbing Defaulting Member Positions

In the event of a clearing member default, the remaining clearing members may also have other obligations. In particular, they may acquire some or all of the defaulting member's positions and may also become responsible for the positions of the defaulting member's clients. As part of its default-management procedures, an OTC derivatives CCP would typically auction part or all of the defaulting member's house portfolio. Depending on the rules of the CCP, surviving clearing members may be obligated to participate in the auction. In addition, the positions of the defaulting member's clients must be transferred to remaining clearing members or be liquidated. Many market participants who clear indirectly have established backup relationships with one or more direct clearing members that they could activate in the event of the default of their primary clearer.

Absorbing this additional business places an added burden on clearing members' resources. In particular, clearing members that are banks or broker-dealers are required to hold capital against both

Figure 13. Largest Total Client Position of CM as a Percentage of Other CMs' Excess Capital



Source: End-of-month data March 2002–November 2021 from CFTC.

their own positions and those of their clients. Although institution-level data on house positions are not available, Figure 13 shows the size of the largest client positions at any clearing member, relative to the excess capital at the remaining clearing members. (The data are from the CFTC and only cover the derivatives CCPs.) "Excess Capital" represents the amount of capital that clearing members have available to support additional positions. Thus, the ratio in the graph is a measure of members' ability to absorb the client business of another member. The ratio was subdued in the years leading up to the COVID-19 crisis, partly reflecting the high levels of capital in the banking sector, but it rose quickly when volatility spiked, which is also when the probability of a default and the possible need to port client positions likely increased.

We note that, unlike many of the other procyclical resource demands noted in this paper, the need for banks to absorb house and client positions of defaulting members is largely an issue of capital. However, during stressful periods, capital and liquidity adequacy can become intertwined. Moreover, the absorption of new positions also requires bank liquidity, because it requires posting additional contributions to CCP default funds and reserving additional liquidity buffers to meet future margin calls. Again, given that at least one member has defaulted, these commitments are likely to occur in a time when the capital and liquidity of other members are already stretched thin. Furthermore, adding new positions and posting new collateral can affect regulatory liquidity ratio requirements. Even if not binding, a bank's willingness to absorb positions could be influenced by concerns over negatively affecting its liquidity ratio, which could be reflected in its valuation of the defaulted portfolio.[33]

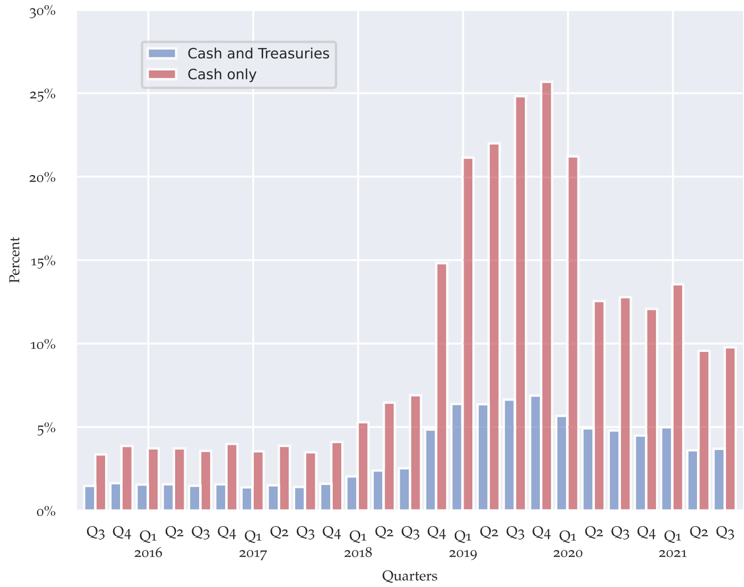
4.6 Liquidity Provision

Finally, CCPs maintain liquidity arrangements with many large banks. These arrangements include committed lines of credit, repo facilities, and foreign-exchange swap agreements. Ideally, the counterparties on the other side of these contracts are liquidity providers that do not face the CCP in other types of transactions. In practice, most of the institutions that are in a position to commit to providing significant liquidity are large banks that also participate directly in CCPs, clearing high volumes of derivatives and securities transactions. Consequently, since large banks tend to be members of multiple CCPs and offer liquidity services to each, the supply of these services to the overall system of CCPs tends to be concentrated. FSB (2018a) reported that 27 percent of clearing members surveyed across 26 CCPs also provide credit lines that provide liquidity to the CCP. Many of these clearing members provide such lines to multiple CCPs.[34]

[33] These concerns motivated in part the recent announcement of a revision to the treatment of client margin in calculating the liquidity coverage ratio (BCBS 2019).

[34] In the event of default, liquidity demands may be particularly large at the two securities CCPs, because such CCPs guarantee settlement of the full purchase price of securities. (The settlement value of derivatives contracts is typically a small fraction of their notional value.) For example, in the few days following the bankruptcy of Lehman Brothers in 2008, NSCC and FICC settled (without loss) over $300 billion of securities transactions that Lehman had executed with its customers and other counterparties. In contrast, the market value of Lehman's obligations under derivative contracts was about $45 billion (Valukas 2010).

Figure 14. Committed Lines of Credit as a Percent of Large Bank Liquid Assets



Note: Large banks are domestic banks with more than $250 billion in assets. Liquid assets includes cash and other highly liquid assets.
Source: Quantitative disclosures accessed via Clarus CCPView, and Federal Reserve H.8 release. Data through 2021:Q3.

Figure 14 shows total committed lines of credit and repo arrangements at CCPs as a fraction of the holdings of cash and cash plus liquid securities at large U.S. banks.[35] Although not all of the CCP liquidity providers are large U.S. banks, the comparison nonetheless shows that if these facilities were suddenly and significantly drawn upon, the cash demand could be material. Interestingly, starting in 2018, the significance rose particularly relative to cash holdings, both because CCPs worked to improve their access to liquidity and because banks reduced cash holdings. Fortunately, CCPs did not have to draw on these resources during the COVID-19 crisis, and the size exposures have declined somewhat as banks have maintained

[35] Large banks includes those with over $250 billion in assets.

higher cash holdings. But if needed, even if banks were able to meet this demand, doing so could well put pressure on short-term funding markets, including the interbank market and the repo market for high-quality collateral. Again, the CCPs are only likely to need to access their liquidity arrangements following the default of a very large clearing member, so it is probable that funding markets would already be under some pressure. For example, CCPs would also most likely be withdrawing large sums from their cash deposit accounts at banks in such a situation.

4.7 The Scale of CCP Resources

Tables 2–5 show how the main resources absorbed and potentially demanded by CCPs compare with various measures of the financial sector's capacity to handle those demands. In particular, we scale CCP resource draws by two measures of intermediary capital and four measures of intermediary liquidity. The measures of capital are the total Tier 1 capital at commercial banks and the capital in excess of required at the clearing members of U.S. futures commission merchants. The liquidity measures are the liquid assets (cash and Treasury securities) of U.S. broker-dealers, the cash held by large domestically chartered commercial banks, the total amount of high-quality liquid assets (HQLA) held by the six largest bank holding companies, and the amount of HQLA in excess of the liquidity coverage ratio (LCR) requirement.[36]

Table 2 compares the stock of resources held by CCPs as of 2021:Q1 with the levels of the balance sheet measures at intermediaries at that time. The six CCPs collectively held $700 billion in IM and default funds, an amount equal to several times the excess capital of clearing members' or dealers' holdings of liquid assets.

Tables 3 and 4 consider the situation in terms of flows, rather than stocks. Table 3 reports the largest daily variation and initial

[36]Total bank capital comes from the FDIC Quarterly Banking Profile. Clearing member capital comes from the monthly CFTC report on Financial Data for FCMs. Broker-dealer liquid assets comes from the Financial Accounts of the United States. Large-bank liquid assets comes from the Federal Reserve H.8 Report. Information about HQLA and LCR requirements is taken from the individual regulatory filings of JP Morgan Chase, Bank of America, Citibank, Wells Fargo, Goldman Sachs, and Morgan Stanley.

Table 2. Stock of Resources Absorbed by CCPs

		Relative to Financial Intermediary Balance Sheet Quantities, 3/31/21					
Resources at Six CCPs	**Total Value 3/31/21 ($ Bil.)**	**Tier 1 Capital (All Banks)**	**Excess Capital (FCMs)**	**Liquid Assets (Dealers)**	**Cash (Large Banks)**	**HQLA (Large Banks)**	**HQLA Above Min. LCR (Large Banks)**
Initial Margin	$572	30%	426%	247%	30%	22%	141%
Default Fund	$128	7%	95%	55%	7%	5%	32%
Total	$700	36%	521%	302%	37%	27%	173%

Source: Quantitative disclosures via Clarus CCPView; FDIC Quarterly Banking Profile; CFTC Financial Data for FCMs; Financial Accounts of the United States; Federal Reserve H.8 Report; regulatory filings of JP Morgan Chase, Bank of America, Citibank, Wells Fargo, Goldman Sachs, and Morgan Stanley. Data as of 2022:Q1.

Table 3. Flow of Resources to CCPs — Maximum Daily

Resources Demanded by Six CCPs	Total Value 3/31/21 ($ Bil.)	Relative to Daily Std. Dev. of Intermediary Balance Sheet Quantities, 2015–21					
		Tier 1 Capital (All Banks)	Excess Capital (FCMs)	Liquid Assets (Dealers)	Cash (Large Banks)	HQLA (Large Banks)	HQLA Above Min. LCR (Large Banks)
Max. Daily VM Call at a Single CCP	$26	1644%	2070%	431%	328%	227%	440%
Max. Daily IM Call at a Single CCP	$32	1984%	2498%	520%	396%	274%	532%

Source: Quantitative disclosures via Clarus CCPView; FDIC Quarterly Banking Profile; CFTC Financial Data for FCMs; Financial Accounts of the United States; Federal Reserve H.8 Report; regulatory filings of JP Morgan Chase, Bank of America, Citibank, Wells Fargo, Goldman Sachs, and Morgan Stanley. Data through 2021:Q3.

Table 4. Flow of Resources to CCPs — Maximum Quarterly

Resources Demanded by Six CCPs	Total Value 3/31/21 ($ Bil.)	Relative to Quarterly Std. Dev. of Intermediary Balance Sheet Quantities, 2015–21					
		Tier 1 Capital (All Banks)	Excess Capital (FCMs)	Liquid Assets (Dealers)	Cash (Large Banks)	HQLA (Large Banks)	HQLA Above Min. LCR (Large Banks)
Max. Qtrly. IM Call	$199	1538%	1938%	403%	307%	213%	412%
Max. Qtrly. Def. Fund Call	$22	170%	214%	45%	34%	24%	46%

Source: Quantitative disclosures via Clarus CCPView; FDIC Quarterly Banking Profile; CFTC Financial Data for FCMs; Financial Accounts of the United States; Federal Reserve H.8 Report; regulatory filings of JP Morgan Chase, Bank of America, Citibank, Wells Fargo, Goldman Sachs, and Morgan Stanley. Data as of 2022:Q1.

margin calls reported at any of the six CCPs over the sample period, relative to estimates of the standard deviation of daily changes in the balance sheet categories.[37] These margin calls represented changes of several daily standard deviations in each of our capital and liquidity measures. Note that these are calls at *individual* CCPs. The data do not allow us to measure the maximum aggregate daily margin calls, but they were necessarily larger and likely significantly so.

Table 4 shows the maximum quarterly changes in initial margin and default funds, compared with the quarterly standard deviation of changes in the balance sheet measures. Again, the maximum aggregate IM call in our sample was equal to a change of several standard deviations in intermediary cash and liquidity positions at the quarterly frequency. The maximum default fund call over this sample was smaller, but it still represented a large flow relative to typical quarterly changes in intermediary capital.

Finally, Table 5 reports the explicit claims that CCPs had on financial institutions as of 2021:Q1. These include lines of credit, deposits (both the CCPs' own house accounts and the portion of initial margin held as bank deposits), and unfunded commitments that the CCPs can call from members in the event of a depletion of the default fund. Because these items all represent potential flows, we again scale them by the quarterly standard deviation of intermediary balance sheet changes. Again, it is clear that these potential resource draws could be large relative to the typical fluctuations banks and dealers see in their balance sheets. To take the extreme case, if all of these CCP commitments were drawn at once, the result could be equal to a 7-standard-deviation move in excess HQLA at large banks and a 32-standard-deviation move in CM excess capital. This would be on top of the VM, IM, and default fund calls that would likely occur at the same time.

The upshot of this discussion is that the demand by CCPs for liquid resources that has been observed over the last several years has been quantitatively large relative to market participants' capital and liquidity cushions, and it has the potential to be even larger in future periods of stress. Because such periods are also associated with other

[37]The estimates are constructed by calculating the variance of *quarterly* balance sheet changes and assuming independence of changes at the business-day frequency within quarters.

Table 5. Claims on Intermediaries, as of 3/31/21

Resources Demanded by Six CCPs	Total Value 3/31/21 ($ Bil.)	Relative to Quarterly Std. Dev. of Intermediary Balance Sheet Quantities, 2015–21					
		Tier 1 Capital (All Banks)	Excess Capital (FCMs)	Liquid Assets (Dealers)	Cash (Large Banks)	HQLA (Large Banks)	HQLA Above Min. LCR (Large Banks)
Lines of Credit	$232	1797%	2263%	471%	359%	248%	482%
Bank Deposits (CCP Acct. + IM Held)	$70	539%	678%	141%	108%	4%	144%
Unfunded Commitments	$30	232%	292%	61%	46%	32%	62%

Source: Quantitative disclosures via Clarus CCPView; FDIC Quarterly Banking Profile; CFTC Financial Data for FCMs; Financial Accounts of the United States; Federal Reserve H.8 Report; regulatory filings of JP Morgan Chase, Bank of America, Citibank, Wells Fargo, Goldman Sachs, and Morgan Stanley. Data as of 2022:Q1.

pressures on financial institutions' balance sheets, CCP procyclicality could be material in inducing systemic liquidity shortfalls.

4.8 The Importance of CCP Incentives

Although their procedures are governed by detailed rule books, CCPs retain some discretion in the extent and timing of their calls for resources. Two examples will illustrate this point.

Bignon and Vuillemey (2020) describe one of the very few failures of a CCP, the Caisse de Liquidation des Affairesen Marchandises in Paris. In 1974, following a collapse of sugar prices, the CCP faced the default of a clearing member that had cleared a large volume of sugar futures. Because the CCP's margining practices were inadequate, the default would have created a loss for the CCP's members, but would have allowed it to continue operating. But the CCP engaged in risk-shifting: it delayed declaring the underwater member in default, apparently in the hopes that its position would right itself. Instead, further losses accrued, eventually resulting in a shortfall so large that the CCP was forced to shut down.

More recently, as Heckinger (2014) describes, prior to the failure of MF Global in 2011, at least two CCPs (ICE Clear US and FICC) refused to release margin, totaling about $100 million, that was due to the teetering broker-dealer. The CCPs may have feared that MF Global might subsequently take losses on positions cleared through them and not be able to make up the shortfall. Although these actions afforded the CCPs an additional layer of protection, they contributed to MF Global's liquidity shortfalls and ultimate demise.

As illustrated by these episodes and others noted above, CCPs can bend or circumvent rules, at least for a time, when it is in their interest to do so. Moreover, there is no guarantee that the interests of CCP owners will align with the advancement of financial stability. Some CCPs are owned by their members or exchanges, while others are owned by publicly traded companies. The ability of these owners to exercise discretion makes it important to consider the incentives that CCPs might face in stress situations. The CCPs discussed herein all have their own capital exposed in their default waterfalls. Being exposed to loss provides CCPs an incentive to manage risks, but could also incentivize defensive moves—like choosing to withhold MF Global's margin—during a stressful default. For CCPs that are member owned, the potential that clearing members might need to replenish lost capital can be an additional procyclical liquidity risk that could affect incentives even if a loss is not actually realized. The broader point is that, when facing the possibility of a severe liquidity or solvency threat, CCPs may have the ability and incentive to hoard even more resources than their normal practice suggests.[38]

5. Liquidity Stress Tests: Individual and Macroprudential

One of the main ways that the PFMI raised standards for CCPs was the explicit requirements around managing their liquidity risk. A CCP must be able to make all of its payment obligations on time in all relevant currencies with a high degree of confidence. The PFMI established the expectation that CCPs establish a robust framework to identify, measure, monitor, and manage liquidity risk from participants, settlement and custodian banks, liquidity providers, and any other relevant entities. The PFMI specified that CCPs had to be able to make their payments under the default of the clearing member that would generate the largest aggregate liquidity obligation for the CCP in extreme but plausible market conditions. Furthermore, the PFMI defined what resources should qualify for the purposes of meeting such requirements. The ability of the CCP to meet its potential liquidity demands with its liquid resources must be tested daily through rigorous stress testing similar to how the total financial resources are stress-tested daily.[39]

[38] CCP discretion can also go the other way, providing market participants more time to meet payment requirements, or even overriding margin requirements. Such exercises of discretion can result in smaller burdens on clearing members than would otherwise have occurred, but potentially expose the CCP to higher risk during a period of market stress. More generally, CCP discretion means that it may be difficult to predict CCP actions.

[39] In addition to CCPs' own liquidity stress tests, the U.S. Commodity Futures Trading Commission (CFTC) and the European Securities and Markets Authority (ESMA) both have conducted liquidity stress testing using their own scenarios applied jointly to sets of CCPs (see CFTC 2017 and ESMA 2018a, respectively).

The requirement to stress-test liquidity, in addition to being newer, adds new complexities. First, the number of relevant parties goes beyond just the clearing member function and includes those entities who generate a liquidity exposure. Second, multiple roles played by a clearing member—for example, if they were also a liquidity provider—need to be considered. Third, the ability to make payments, often in cash, in different currencies must be tested and met. Fourth, the time dimension matters, because it is not enough to have sufficient cash or other liquid resources in aggregate over a close-out period, but rather the CCP needs to be able to make payments on time when due.

The PFMI significantly enhanced expectations for liquidity risk management at CCPs and advanced the stress testing of each CCP's particular liquidity needs. By their nature, however, these micro-level stress tests cannot measure liquidity demands that may arise across the financial system in a market-stress event. While particular payment obligations are isolated within individual CCPs, the resources available to make such payments extend beyond the CCPs' boundaries. The resulting interdependencies are difficult if not impossible for an individual CCP to disentangle, evaluate, and stress-test.

The simplest relationship illustrating dependencies across CCPs is the committed lines of credit extended to CCPs by liquidity providers. As noted above, a few of the largest clearing members provide such lines of credit, often to multiple CCPs. As shown in FSB (2018a, Figure 11 on p. 21), apart from a few outliers, there is a positive correlation between the amount of prefunded resources a clearing member provides in aggregate and the amount of aggregate resources it provides as a liquidity backstop. The implication is that larger CCP members also provide significant liquid resources to the same CCPs. Individual CCPs do not necessarily have a view to the obligations its clearing members have to other CCPs. The default of a large clearing member likely would entail a simultaneous default across multiple CCPs, and therefore multiple CCPs activating liquidity relationships. Stress testing at individual CCPs cannot capture this interdependency.

A coordinated, macroprudential supervisory stress test across multiple CCPs can complement the micro-oriented stress tests conducted by individual CCPs. The goal would be to evaluate the collective impact the participating CCPs have on the broader financial system during such a default. The results would inform regulators and participants on potential liquidity demands and perhaps avoid the liquidity hoarding that increased systemic risk during the 2008 crisis (Ashcraft, McAndrews, and Skeie 2011, Acharya and Merrouche 2012, Berrospide 2021). This objective stands in contrast to the CCPs' own stress tests, which look at their individual resiliency. The test would provide a sense of the size of the systemic liquidity risk that a central bank could face in extreme circumstances either in its role as the lender of last resort to the banking system or potentially through direct lending to CCPs.[40]

The testing would be designed in a manner consistent with the international framework for supervisory stress testing published by CPMI-IOSCO in 2017.[41] But we are more focused than the framework in explicitly calling for stressing liquidity needs and focusing on the overall impact on the system. The results would greatly enhance market participants' and regulators' understanding of how liquidity risks could arise in the CCP network and potentially affect the rest of the financial system, going beyond prior analysis, such as Heath et al. (2016). Such tests may require iterative defaults to trace the potential for stress to spread through the network of liquidity need and provision. Such iteration would be different than supervisory stress testing for banks, which is a firmly established regulatory tool after the 2008 crisis, and generally is viewed as effective.[42] Testing the resiliency of the clearing system likely would similarly improve our understanding of the feedback loops discussed in Faruqui, Huang,

[40]Central banks' ability and willingness to lend directly to CCPs varies widely. The Federal Reserve has a constrained ability to lend directly to CCPs that have been designated to be systemically important, but only in unusual or exigent circumstances and if other provisions are met (Baker 2012). In contrast, the Bank of England explicitly includes CCPs in its regular lender-of-last-resort function.

[41]See CPMI-IOSCO (2017). Anderson, Cerezetti, and Manning (2020) discuss such macroprudential CCP stress tests further, including discussing their rationale and objectives; see also Tompaidis (2012).

[42]See Drehman (2008), Petrella and Resti (2013), Borio, Drehmann, and Tsatsaronis (2014), Schuermann (2014), Flannery, Hirtle, and Kovner (2017), and Fernandes, Igan, and Pinheiro (2020). Although the generation of such tests could create incentives for CCPs to adjust their risk and liquidity management, their macroprudential nature and the fact that CCPs do not trade into their own positions likely eliminates the "window-dressing" effect observed by Cornett et al. (2020) in bank stress testing by supervisors.

and Takáts (2018). It would expand on the recent supervisory stress tests conducted by the CFTC on CCPs it regulates (CFTC 2016, 2017), particularly by including in the analysis securities CCPs, which, as noted above, require large amounts of liquidity to effect settlement.

Although macroprudential stress testing of CCPs' liquidity risk would be an important step, it is likely not sufficient to fully identify the scope of risks associated with their interconnectedness. To do so, regulators should work to integrate macroprudential stress testing of CCPs with more established bank stress testing, which has generally ignored banks' large exposures to CCPs (Borio, Drehmann, and Tsatsaronis 2014, Schuermann 2014). Such an integrated approach goes beyond the CPMI-IOSCO framework for CCPs.

6. Conclusion

By taking both sides of derivatives and securities trades, CCPs absorb counterparty credit risk. In so doing, they generally improve financial stability through multilateral netting, risk mutualization, and margining. Following the success of CCPs in managing risk and preventing contagion during the 2008 financial crisis, regulatory reforms have moved even more activity to central clearing, in particular through clearing mandates for the most common OTC derivatives.

Despite their roles in promoting financial stability, and particularly in reducing contagion, large CCPs are concentrated and interconnected and pose risks of their own. While attention has generally focused on the potentially disastrous consequences of a failure or severe disruption of a CCP, we have highlighted a difficulty that may occur in a much less remote state of the world. Namely, to protect themselves, CCPs necessarily require liquidity from large banks and other market participants. From the perspective of clearing members, the counterparty risk that is mitigated with central clearing is, in a sense, replaced with liquidity risk. The demand for resources can take the form of VM and IM calls, default fund assessments, draws on liquidity lines, the transfer of positions associated with defaulting members, and other obligations. This liquidity risk spans banks and funding markets, creating risks due to interconnectedness. Furthermore, the strength of the interconnectedness increases under market stress. From a systemic perspective, the trade-off between reducing counterparty credit exposure while potentially increasing interconnected liquidity needs is expected to reduce systemic risk. Nevertheless, because resources are most likely to be called for by a CCP at times when bank liquidity positions are already under stress, they are inherently procyclical with respect to market conditions. The procyclicality of liquidity risk must be managed. Although CCPs, banks, and other financial institutions successfully managed the unprecedented margin calls during the market stress driven by COVID-19, not all the potential liquidity risk was realized, as the few defaults that occurred were relatively non-impactful. Consequently, the systemic risk may yet remain under-estimated.

The expansion of central clearing at well-managed CCPs strengthens market function and resiliency. But, as more activity becomes concentrated in CCPs, the possibility that CCP liquidity demands could strain banks and other market participants looms larger. On the policy front, as we have discussed, liquidity-focused macroprudential stress tests could help to assess the impact of shocks to CCPs on systemwide liquidity. Such tests also would be a step towards integrating supervisory stress testing of banks and CCPs. From a research perspective, more work is needed to understand how the liquidity risks posed by CCPs fit into the broader context of demand for safe and liquid assets. The answer to that question has implications for the measurement of system-wide liquidity, for the modeling of funding markets, and for our understanding of the propagation of financial crises.

References

Acharya, V. V., and O. Merrouche. 2012. "Precautionary Hoarding of Liquidity and Interbank Markets: Evidence from the Subprime Crisis." *European Finance Review* 17 (1): 107–60. doi:10.1093/rof/rfs022.

Acharya, V. V., H. S. Shin, and T. Yorulmazer. 2011. "Crisis Resolution and Bank Liquidity." *Review of Financial Studies* 24 (6): 2166–2205. doi:10.1093/rfs/hhq073.

Adrian, T., and H. S. Shin. 2008. "Liquidity, Monetary Policy, and Financial Cycles." *Current Issues in Economics and Finance*

14 (1): 1–7. https://www.newyorkfed.org/research/current_issues/ci14-1.html.

———. 2010. "Liquidity and Leverage." *Journal of Financial Intermediation* 19 (3): 418–37. doi:10.1016/j.jfi.2008.12.002.

Alfranseder, E., P. Fiedor, S. Lapschies, L. Orszaghova, and P. Sobolewski. 2018. "Indicators for the Monitoring of Central Counterparties in the EU." Occasional Paper No. 14, European Systemic Risk Board, European System of Financial Supervision. https://www.esrb.europa.eu/pub/pdf/occasional/esrb.op14.en.pdf.

Allen, F., E. Carletti, and D. Gale. 2009. "Interbank Market Liquidity and Central Bank Intervention." *Journal of Monetary Economics* 56 (5): 639–52. doi:10.1016/j.jmoneco.2009.04.003.

Amini, H., R. Cont, and A. Minca. 2016. "Resilience to Contagion in Financial Networks." *Mathematical Finance* 26 (2): 329–65. doi:10.1111/mafi.12051.

Anderson, E., F. Cerezetti, and M. Manning. 2020. "Supervisory Stress Testing for CCPs: A Macro-prudential, Two-Tier Approach." *Journal of Financial Market Infrastructures* 8 (1): 1–25. doi:10.21314/JFMI.2019.115.

Armakolla, A., and J. P. Laurent. 2017. "CCP Resilience and Clearing Membership." doi:10.2139/ssrn.2625579.

Ashcraft, A., J. McAndrews, and D. Skeie. 2011. "Precautionary Reserves and the Interbank Market." *Journal of Money, Credit and Banking* 43 (s2): 311–48. doi:10.1111/j.1538-4616.2011.00438.x.

Bai, J., A. Krishnamurthy, and C.-H. Weymuller. 2018. "Measuring Liquidity Mismatch in the Banking Sector." *Journal of Finance* 73 (1): 51–93. doi:10.1111/jofi.12591.

Baker, C. 2012. "The Federal Reserve as Last Resort." *University of Michigan Journal of Law Reform* 46 (1): 69–133. https://repository.law.umich.edu/mjlr/vol46/iss1/2.

Barker, R., A. Dickinson, A. Lipton, and R. Virmani. 2017. "Systemic Risks in CCP Networks." Risk.net, January 5. http://www.risk.net/cutting-edge/banking/2479766/systemic-risks-in-ccp-networks.

Basel Committee on Banking Supervision (BCBS). 2019. "Leverage Ratio Treatment of Client Cleared Derivatives." https://www.bis.org/bcbs/publ/d467.htm.

BCBS-CPMI-IOSCO. 2022. "Review of Margining Practices." https://www.bis.org/bcbs/publ/d537.htm.

BCBS-IOSCO. 2015. "Margin Requirements for Non-centrally Cleared Derivatives." https://www.bis.org/bcbs/publ/d317.pdf.

Berger, A. N., and C. H. S. Bouwman. 2009. "Bank Liquidity Creation." *Review of Financial Studies* 22 (9): 3779–3837. doi:10.1093/rfs/hhn104.

———. 2017. "Bank Liquidity Creation, Monetary Policy, and Financial Crises." *Journal of Financial Stability* 30 (June): 139–55. doi:10.1016/j.jfs.2017.05.001.

Bernanke, B. S. 1990. "Clearing and Settlement During the Crash." *Review of Financial Studies* 3 (1): 133–51. http://www.jstor.org/stable/2961962.

Berrospide, J. 2021. "Bank Liquidity Hoarding and the Financial Crisis: An Empirical Evaluation." *Quarterly Journal of Finance* 11 (4): 1–35. doi: 10.1142/S2010139221500208.

Bignon, V., and G. Vuillemey. 2020. "The Failure of a Clearinghouse: Empirical Evidence." *Review of Finance* 24 (1): 99–128. doi:10.1093/rof/rfy039.

Borio, C., M. Drehmann, and K. Tsatsaronis. 2014. "Stress-testing Macro Stress Testing: Does It Live up to Expectations?" *Journal of Financial Stability* 12 (June): 3–15. doi:10.1016/j.jfs.2013.06.001.

Breach, T., and T. King. 2018. "Securities Financing and Asset Markets: New Evidence." Working Paper No. 2018-22, Federal Reserve Bank of Chicago. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3301242.

Brunnermeier, M. K. 2009. "Deciphering the Liquidity and Credit Crunch 2007–2008." *Journal of Economic Perspectives* 23 (1): 77–100. doi:10.1257/jep.23.1.77.

CCP12. 2020. "CCPs Again Demonstrate Strong Resilience in Times of Crisis." Technical Report. https://ccp12.org/papers/.

Chicago Board Options Exchange. "CBOE Volatility Index: VIX [VIXCLS]." Retrieved from FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/VIXCLS.

Clarus CCPView. Clarus Financial Technology Ltd. https://ccpview.clarusft.com.

Commodity Futures Trading Commission (CFTC). 2016. "Supervisory Stress Test of Clearinghouses." https://www.cftc.gov/sites/

default/files/idc/groups/public/@newsroom/documents/file/cftcstresstest111516.pdf.

———. 2017. "Evaluation of Clearinghouse Liquidity." https://www.cftc.gov/sites/default/files/idc/groups/public/@newsroom/documents/file/dcr_ecl1017.pdf.

Cont, R. 2017. "Central Clearing and Risk Transformation." *Financial Stability Review* (Banque de France) 21: 127–38. https://publications.banque-france.fr/en/april-2017.

Cornett, M. M., J. J. McNutt, P. E. Strahan, and H. Tehranian. 2011. "Liquidity Risk Management and Credit Supply in the Financial Crisis." *Journal of Financial Economics* 101 (2): 297–312. doi:10.1016/j.jfineco.2011.03.001.

Cornett, M. M., K. Minnick, P. J. Schorno, and H. Tehranian. 2020. "An Examination of Bank Behavior around Federal Reserve Stress Tests." *Journal of Financial Intermediation* 41 (January): Article 100789. doi:10.1016/j.jfi.2018.05.001.

Cox, R. T., and R. S. Steigerwald. 2018. "A CCP is a CCP is a CCP." *Journal of Financial Market Infrastructures* 6 (4): 1–18. doi:10.21314/JFMI.2018.085.

CPMI-IOSCO. 2012. "Principles for Financial Market Infrastructures." http://www.bis.org/cpmi/publ/d101.htm.

———. 2014. "Recovery of Financial Market Infrastructures." https://www.bis.org/cpmi/publ/d121.htm.

———. 2016. "Resilience and Recovery of Central Counterparties (CCPs): Further Guidance on the PFMI." http://www.bis.org/cpmi/publ/d149.htm.

———. 2017. "Framework for Supervisory Stress Testing of Central Counterparties (CCPs)." http://www.bis.org/cpmi/publ/d161.htm.

Culp, C. L. 2010. "OTC-Cleared Derivatives: Benefits, Costs, and Implications of the 'Dodd-Frank Wall Street Reform and Consumer Protection Act'." *Journal of Applied Finance* 20 (2): 1–27. https://ssrn.com/abstract=2693059.

De Bandt, O., and P. Hartmann. 2019. "Systemic Risk in Banking After the Great Financial Crisis." In *Oxford Handbook of Banking*, 3rd edition, ed. A. N. Berger, Philip Molyneux, and J. O. S. Wilson, 847–89 (chapter 26). Oxford University Press. doi:10.1093/oxfordhb/9780198824633.013.27.

Drehmann, M. 2008. "Stress Tests: Objectives, Challenges and Modelling Choices." *Economic Review* (Sveriges Riksbank) (2): 60–92. http://archive.riksbank.se/Upload/Dokument_riksbank/Kat_publicerat/PoV_sve/eng/2008/er2008_2_ny.pdf.

Duffie, D. 2014. "Financial Market Infrastructure: Too Important to Fail." In *Across the Great Divide: New Perspectives on the Financial Crisis*, ed. J. B. Taylor and M. N. Baily, 251–57 (chapter 11). Hoover Institution Press. https://www.hoover.org/sites/default/files/across-the-great-divide-ch11.pdf.

Duffie, D., and H. Zhu. 2011. "Does a Central Clearing Counterparty Reduce Counterparty Risk?" *Review of Asset Pricing Studies* 1 (1): 74–95. doi:10.1093/rapstu/rar001.

European Securities and Markets Authority (ESMA). 2018a. "EU-wide CCP Stress Test 2017." http://firds.esma.europa.eu/webst/ESMA70-151-1154%20EU-wide%20CCP%20Stress%20Test%202017%20Report.pdf.

———. 2018b. "Guidelines on EMIR Anti-Procyclicality Margin Measures for Central Counterparties." https://www.esma.europa.eu/sites/default/files/library/esma70-151-1293_final_report_on_guidelines_on_ccp_apc_margin_measures.pdf.

Faruqui, U., W. Huang, and E. Takáts. 2018. "Clearing Risks in OTC and Derivatives Markets: The CCP-Bank Nexus." *BIS Quarterly Review* (December 16): 73–90. https://www.bis.org/publ/qtrpdf/r_qt1812h.htm.

Fernandes, M., D. Igan, and M. Pinheiro. 2020. "March Madness in Wall Street: (What) Does the Market Learn from Stress Tests?" *Journal of Banking and Finance* 112 (March): Article 105250. doi:10.1016/j.jbankfin.2017.11.005.

Financial Stability Board. 2017a. "Analysis of Central Clearing Interdependencies." http://www.fsb.org/wp-content/uploads/P050717-2.pdf.

———. 2017b. "Review of OTC Derivatives Market Reforms: Effectiveness and Broader Effects of the Reforms." http://www.fsb.org/wp-content/uploads/P290617-1.pdf.

———. 2018a. "Analysis of Central Clearing Interdependencies." http://www.fsb.org/wp-content/uploads/P090818.pdf.

———. 2018b. "Incentives to Centrally Clear Over-the-Counter (OTC) Derivatives: A Post-Implementation Evaluation of the Effects of the G20 Financial Regulatory Reforms." http://www.

fsb.org/2018/11/incentives-to-centrally-clear-over-the-counter-otc-derivatives-2/.
———. 2021. "Lessons Learnt from the COVID-19 Pandemic from a Financial Stability Perspective: Final Report." https://www.fsb.org/2021/10/lessons-learnt-from-the-covid-19-pandemic-from-a-financial-stability-perspective-final-report/.
Flannery, M., B. Hirtle, and A. Kovner. 2017. "Evaluating the Information in the Federal Reserve Stress Tests." *Journal of Financial Intermediation* 29 (January): 1–18. doi:10.1016/j.jfi.2016.08.001.
Fleming, M. J., and A. Sarkar. 2014. "The Failure Resolution of Lehman Brothers." *Economic Policy Review* (Federal Reserve Bank of New York) 20 (2): 175–206. https://www.newyorkfed.org/research/epr/2014/1412flem.html.
Futures Industry Association (FIA). 2020. "Revisiting Procyclicality: The Impact of the COVID Crisis on CCP Margin Requirements." Technical Report. https://www.fia.org/resources/fia-issues-white-paper-impact-pandemic-volatility-ccp-margin-requirements.
Gibson, R., and C. Murawski. 2013. "Margining in Derivatives Markets and the Stability of the Banking Sector." *Journal of Banking and Finance* 37 (4): 1119–32. doi:10.1016/j.jbankfin.2012.10.005.
Glasserman, P., and Q. Wu. 2018. "Persistence and Procyclicality in Margin Requirements." *Management Science* 64 (12): 5705–24. doi:10.1287/mnsc.2017.2915.
Greenwood, R., A. Landier, and D. Thesmar. 2015. "Vulnerable Banks." *Journal of Financial Economics* 115 (3): 471–85. doi:10.1016/j.jfineco.2014.11.006.
Haver Analytics. http://www.haver.com/our_data.html.
Heath, A., G. Kelly, M. Manning, S. Markose, and A. R. Shaghaghi. 2016. "CCPs and Network Stability in OTC Derivatives Markets." *Journal of Financial Stability* 27 (December): 217–33. doi:10.1016/j.jfs.2015.12.004.
Heber, G., A. Lunde, N. Shephard, and K. K. Sheppard. 2009. "Oxford-Man Institute's Realized Library." Version No. 0.3. University of Oxford. https://realized.oxfordman.ox.ac.uk/.
Heckinger, R. 2014. "MF Global: A Case Study of Liquidity Risks." *Journal of Financial Market Infrastructures* 3 (2): 79–96. doi:10.21314/JFMI.2014.037.

Heckinger, R., R. T. Cox, and D Marshall. 2017. “Cleared Margin Setting at Selected Central Counterparties.” *Journal of Financial Market Infrastructures* 5 (4): 1–21. doi:10.21314/JFMI.2017.075.

Heider, F., M. Hoerova, and C. Holthausen. 2015. “Liquidity Hoarding and Interbank Market Rates: The Role of Counterparty Risk.” *Journal of Financial Economics* 118 (2): 336–54. doi:10.1016/j.jfineco.2015.07.002.

Heller, D., and N. Vause. 2012. “Collateral Requirements for Mandatory Central Clearing of Over-the-Counter Derivatives.” BIS Working Paper No. 373. http://www.bis.org/publ/work373.pdf.

Houllier, M., and D. Murphy. 2017. “Initial Margin Model Sensitivity Analysis and Volatility Estimation.” *Journal of Financial Market Infrastructures* 5 (4): 77–103. doi:10.21314/JFMI.2017.078.

Huber, P. J. 1981. *Robust Statistics*. Wiley Series in Probability and Mathematical Statistics. Hoboken, NJ: John Wiley & Sons.

Ippolito, F., J.-L. Peydró, A. Polo, and E. Sette. 2016. “Double Bank Runs and Liquidity Risk Management.” *Journal of Financial Economics* 122 (1): 135–54. doi:10.1016/j.jfineco.2015.11.004.

ISDA Clearing Member Committee. 2021. “COVID-19 and CCP Risk Management Frameworks.” Technical Report. https://www.isda.org/2021/01/06/covid-19-and-ccp-risk-management-frameworks/.

Ivashina, V., and D. Scharfstein. 2010. “Bank Lending during the Financial Crisis of 2008.” *Journal of Financial Economics* 97 (3): 319–38. doi:10.1016/j.jfineco.2009.12.001.

Iyer, R., J.-L. Peydró, S. da Rocha-Lopes, and A. Schoar. 2014. “Interbank Liquidity Crunch and the Firm Credit Crunch: Evidence from the 2007–2009 Crisis.” *Review of Financial Studies* 27 (1): 347–72. doi:10.1093/rfs/hht056.

Kashyap, A. K., R. Rajan, and J. C. Stein. 2002. “Banks as Liquidity Providers: An Explanation for the Coexistence of Lending and Deposit-taking.” *Journal of Finance* 57 (1): 33–73. doi:10.1111/1540-6261.00415.

Kiff, J., R. Dodd, A. Gullo, E. Kazarian, I. Lustgarten, C. Sampic, and M. Singh. 2010. “Making Over-the-Counter Derivatives Safer: The Role of Central Counterparties.” In *Global*

Financial Stability Report: Meeting New Challenges to Stability and Building a Safer System, 1–27 (chapter 3). International Monetary Fund. https://www.imf.org/external/pubs/ft/gfsr/2010/01/pdf/chap3.pdf.

King, T., T. D. Nesmith, A. Paulson, and T. Prono. 2020. "Central Clearing and Systemic Liquidity Risk." Finance and Economics Discussion Series No. 2020-009, Board of Governors of the Federal Reserve System. doi:0.17016/FEDS.2020.009.

Kroszner, R. S. 1999. "Can the Financial Markets Privately Regulate Risk? The Development of Derivatives Clearinghouses and Recent Over-the-Counter Innovations." *Journal of Money, Credit and Banking* 31 (3): 596–618. doi:10.2307/2601077.

———. 2000. "Lessons from Financial Crises: The Role of Clearinghouses." *Journal of Financial Services Research* 18 (2): 157–71. doi:10.1023/A:1026534619637.

LCH.Clearnet. 2008. "$9 Trillion Lehman OTC Interest Rate Swap Default Successfully Resolved." Press Release, October 8. http://secure-area.lchclearnet.com/media_centre/press_releases/2008-10-08.asp.

Lewandowska, O., and F. Glaser. 2017. "The Recent Crises and Central Counterparty Risk Practices in the Light of Procyclicality: Empirical Evidence." *Journal of Financial Market Infrastructures* 5 (3): 1–24. doi:10.21314/JFMI.2017.072.

Madigan, P., D. Wood, and L. Becker. 2016. "LCH under Scrutiny after Outsized Brexit Margin Calls." Risk.net, October 19. https://www.risk.net/risk-management/2474560/lch-under-scrutiny-after-outsized-brexit-margin-calls.

Manning, M. J., and D. Hughes. 2016. "Central Counterparties and Banks: Vive La Difference." *Journal of Financial Market Infrastructures* 4 (3): 1–24. doi:10.21314/JFMI.2016.058.

Maruyama, A., and F. Cerezetti. 2019. "Central Counterparty Antiprocyclicality Tools: A Closer Assessment." *Journal of Financial Market Infrastructures* 7 (4): 1–25. doi:10.21314/JFMI.2018.110.

Mourselas, C. 2021. "Hero or Villain? NSCC Draws Fire for Robinhood Margin Waiver." Risk.net, March 31. https://www.risk.net/risk-management/7817001/hero-or-villain-nscc-draws-fire-for-robinhood-margin-waiver.

Murphy, D. 2013. *OTC Derivatives: Bilateral Trading and Central Clearing*. Palgrave Macmillan. doi:10.1057/9781137293862.

Murphy, D., M. Vasios, and N. Vause. 2014. "An Investigation into the Procyclicality of Risk-Based Initial Margin Models." Financial Stability Paper No. 29, Bank of England. https://www.bankofengland.co.uk/-/media/boe/files/financial-stability-paper/2014/an-investigation-into-the-procyclicality-of-risk-based-initial-margin-models.pdf.

O'Neill, C., and N. Vause. 2018. "Macroprudential Margins: A New Countercyclical Tool?" Staff Working Paper No. 765, Bank of England. https://www.bankofengland.co.uk/working-paper/2018/macroprudential-margins-a-new-countercyclical-tool.

Petrella, G., and A. Resti. 2013. "Supervisors as Information Producers: Do Stress Tests Reduce Bank Opaqueness?" *Journal of Banking and Finance* 37 (12): 5406–20. doi:10.1016/j.jbankfin.2013.01.005.

Presidential Task Force on Market Mechanisms. 1988. "Report of the Presidential Task Force on Market Mechanisms." Nicholas Brady (Chairman).

Raykov, R. 2012. "Reducing Margin Procyclicality at Central Counterparties." *Journal of Financial Market Infrastructures* 7 (2): 43–59. doi:10.21314/JFMI.2018.106.

Schuermann, T. 2014. "Stress Testing Banks." *International Journal of Forecasting* 30 (3): 717–28. doi:10.1016/j.ijforecast.2013.10.003.

Shleifer, A., and R. W. Vishny. 2011. "Fire Sales in Finance and Macroeconomics." *Journal of Economic Perspectives* 25 (1): 29–48. doi:10.1257/jep.25.1.29.

Sidanius, C., and F. Zikes. 2012. "OTC Derivatives Reform and Collateral Demand Impact." Financial Stability Paper No. 18, Bank of England. https://www.bankofengland.co.uk/financial-stability-paper/2012/otc-derivatives-reform-and-collateral-demand-impact.

Tompaidis, S. 2012. "Measuring System-wide Resilience of Central Counterparties." *Journal of Financial Market Infrastructures* 6 (4): 41–54. doi:10.21314/JFMI.2018.098.

Valukas, A. R. 2010. "Report of Examiner, United States Bankruptcy Court, Southern District of New York, in re. Lehman Brothers Holdings, Inc., et al., Chapter 11 case no. 08-13555."

Jenner & Block LLP. https://web.stanford.edu/~jbulow/Lehmandocs/menu.html.

Wiggins, R. Z., and A. Metrick. 2019. "The Lehman Brothers Bankruptcy G: The Special Case of Derivatives." *Journal of Financial Crises* 1 (1): 151–71. https://elischolar.library.yale.edu/journal-of-financial-crises/vol1/iss1/8.

Wong, M., and P. Ge Pei. 2017. "Performance Testing of Margin Models Using Time Series Similarity." *Journal of Financial Market Infrastructures* 5 (4): 51–75. doi:10.21314/JFMI.2017.076.