Central Counterparty Management of Liquid and Prefunded Resources*†

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Abstract

This paper presents a simple analytical framework for understanding aggregate central counterparty (CCP) resource demands. The framework integrates various dimensions of CCP heterogeneity, including outstanding cleared volume, final settlement mechanism, contract turnover rate, underlying price volatility, market liquidity, market concentration, and certain CCP risk-management parameters, such as the extent of resource mutualization. Where available, we present empirical counterparts to these parameters using data from the CPMI-IOSCO Public Quantitative Disclosures (PQDs). Our framework extends previous literature by explicitly considering liquid as well as capital resources and we conclude with two reflections on CCP liquidity management. First, CCPs with a high turnover of physically settled contracts, such as securities or repo, may use liquid resources to help share funding risks associated with default between members. This helps explain the greater degree of resource mutualization at such CCPs and may even provide a motive for common ownership. Second, without sufficient liquid resources to weather large price dislocations, CCPs may be unable to commit to putting members into default in such circumstances. This may limit market discipline for appropriate ex-ante liquidity management by clearing members.

Keywords: central counterparty, default management, liquid and capital resources

JEL Codes: G01, G13, G23

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1 Introduction

Central counterparties (CCPs) are market infrastructures that manage counterparty credit risk in various securities, funding, and derivatives markets. If a clearing member (CM) defaults on a cleared contract prior to final settlement, the CCP fulfills that member's obligations, and so shields its original counterparty from default losses.

During the financial crisis of 2007-2008, CCPs facilitated relatively orderly settlement of defaulted derivatives contracts, particularly after the failure of Lehman Brothers. Since the crisis, regulators have promoted the use of central clearing with both mandates for clearing of OTC swaps contracts and incentives in bank capital regimes for the clearing of other products. These measures aim to reduce systemic risks by promoting transparency and rapid, orderly loss allocation proceedings in the event of default by a major market participant.

CCPs have therefore grown considerably in recent decades and the largest have become systemically important in their own right. **Figure 1** documents the growth of CCP clearing funds, i.e. resources set aside to cover potential losses in the event of clearing member default. In the U.S., pronounced increases have occurred after the global financial crisis in 2009, during the mid 2010s with the onset of clearing rules, and in 2020 with the onset of the Covid-19 pandemic (see **Figure 1a**). Globally, regular data are available since late 2015 and show increases in 2020 with the onset of the Covid-19 pandemic, after Russia's invasion of the Ukraine in 2022, and during the Yen carry trade unwind in Q3 2024 (see **Figure 1b**). Both in the U.S. and globally, the growth in clearing as measured by aggregate prefunded resources has outpaced GDP growth.

This paper introduces an analytical framework to aid in interpreting the size of CCPs' aggregate prefunded and liquid resources. The framework assumes a simple and highly stylized market structure for a generic futures transaction and derives the quantities of liquid and prefunded resources required by a CCP for risk management of the cleared transaction. The determinants of these resources include various market characteristics, settlement characteristics, and risk-management parameters. In practice, CCPs exhibit a high degree of heterogeneity across these characteristics and our framework is therefore helpful in facilitating a comparison.

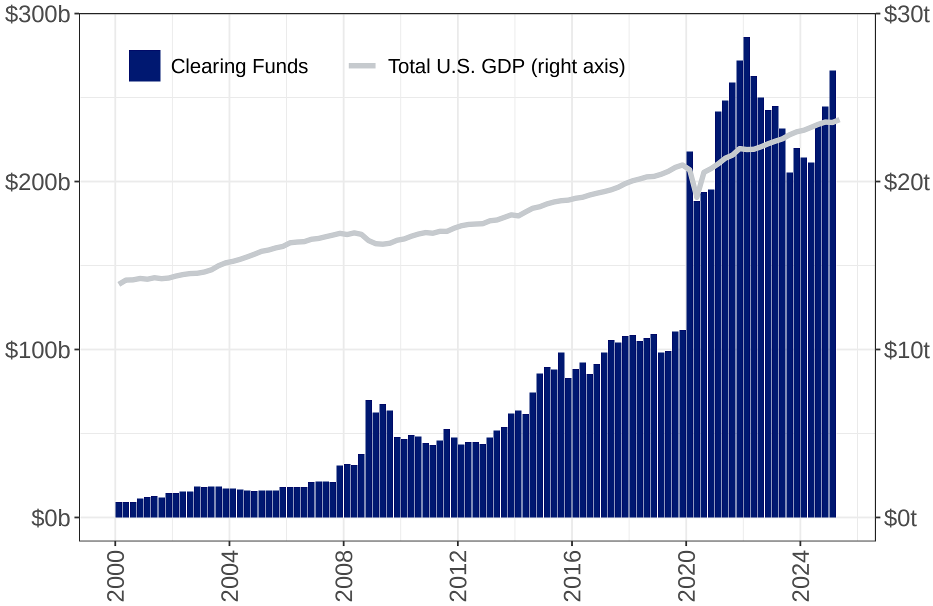
We supplement the analytical description of CCPs with a detailed empirical overview of the major global CCPs. In particular, we present empirical counterparts to the parameters in the framework, where available. We obtain data from the public quantitative disclosures (PQDs) that many large CCPs make in line with the CPMI-IOSCO standards. These institutions vary considerably. Among other attributes, we document differences in the contract markets for which they perform clearing, their degree of loss mutualization, and the intensity of their reliance on liquid resources.

Our framework considers both a CCP's liquidity needs during its management of a defaulted member's portfolio as well as its capital needs for allocating losses afterwards. Having provided this context, we offer two reflections on CCP liquidity management. First, CCPs that oversee physical settlement of contracts share not only losses but also funding shocks associated with default across CMs. This service may provide a motive to increase the extent of resource mutualization or even common ownership. We provide suggestive evidence consistent with these observations. Second, we consider how price dislocation can exhaust CCP liquid resources. In circumstances like short squeezes, as at the LME in March 2022, the exhaustion of liquid resources may limit the ability of CCPs to put members into default. This may reduce market discipline on CMs for poor liquidity management of their own.

The remainder of the paper is as follows. **Section 2** describes related literature on CCP resource management. **Section 3** describes the process by which CCPs manage the technical default of a CM. **Section 4** provides an overview of our data sources and our sample of CCPs. **Section 5** introduces an analytical framework to clarify CCP demand for prefunded and liquid resources. Throughout, we present data on our sample of large global CCPs to provide a sense of magnitude. **Section 6** details our reflections on CCP liquid resource management. **Section 7** concludes.

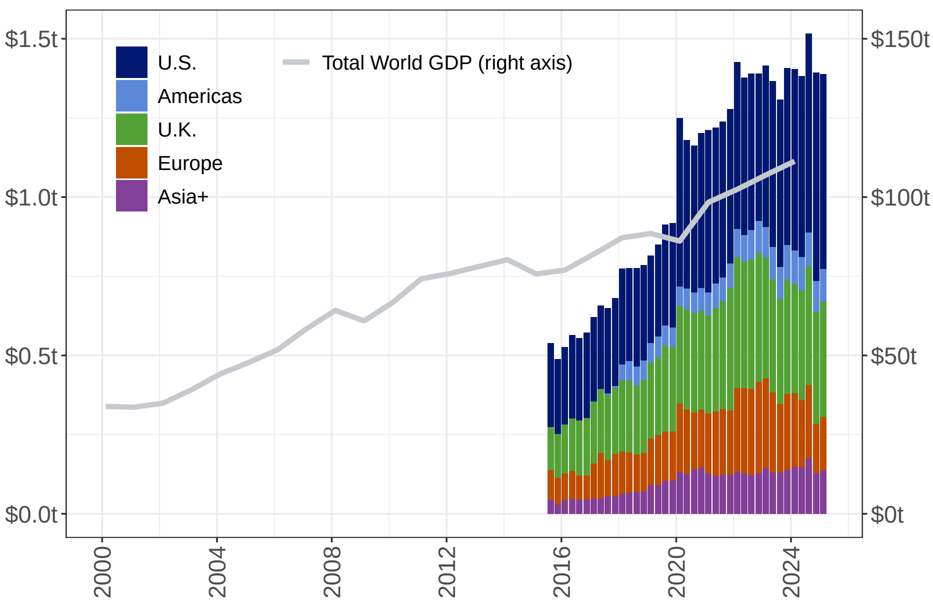
Figure 1: CCP Aggregate Prefunded Resources

(a) Large U.S. CCPs



Sources: *Financial Accounts of the United States, U.S. Bureau of Economic Analysis, Authors' analysis.*

(b) Large Global CCPs by Region



Sources: *World Bank, ClarusFT CCPView, Authors' analysis.*

2 Related literature

The literature on CCPs describes several determinants for the level of prefunded resources. Rising asset market volatility increases demand for these resources (King et al. 2022). Additionally, it may be appropriate for CCPs to collect more prefunded resources when market participants have taken concentrated positions (Glasserman, Moallemi, and Yuan 2015; Albert J Menkveld 2017). By contrast, the netting benefits associated with clearing positions that represent hedges can reduce the need for prefunded resources at CCPs (Baer et al. 2005; Duffie and Zhu 2011; Duffie, Scheicher, and Vuillemey 2015; Cont and Kokholm 2012). Cross-margining across different CCPs may achieve the same result (Magerle and Nellen 2011). There is also evidence suggesting that available prefunded resources are better calibrated to needs when CCP skin-in-the-game capital is higher (Huang and Takats 2020). This paper does not add additional dimensions to CCP demand for prefunded resources, per se. Instead, it provides an exposition of the CCP's margin demand problem and begins to integrate some of the various parameters into a common framework for ease of interpretation.

Because of their margining activities, CCPs play a key role in managing flows of liquid resources between market participants. Some existing work describes and documents how CCPs manage liquid resources that have been prefunded. Liquid resources may be contributed as initial margin (IM) or to the default fund (DF) and are subsequently invested, lent in the repo market, or stored with central banks (Benos, Ferrara, and Ranaldo 2023; Aldasoro, Avalos, and Huang 2023; Guse, Hoops, and Perozek 2024). Other work, most often in the form of case studies, documents how CCP variation margin (VM) practices may impose large and rapidly changing liquid obligations on CMs when market prices move rapidly (Heilbron 2024; Bignon and Vuillemey 2018; Kress 2009). A literature on pro-cyclicality considers how CCP initial margin top-ups also impose liquid resource demands on members (King et al. 2022). Finally, in the event that a CM defaults, CCP netting of positions at close-out helps to prevent liquid resources from being absorbed by the defaulting member's bankruptcy estate. This can preserve available aggregate liquidity in times of system-wide distress (Squire 2014). Despite the importance of liquidity concerns for financial stability, the topic has not been given a systematic treatment in the context of CCPs. We aim to fill this gap.

CCPs facilitate default loss mutualization; when one member defaults, the associated losses are spread across several market participants. As in the case of any insurance market, there is a trade-off between risk-sharing benefits (Biais, Heider, and Hoerova 2012) and moral hazard concerns (Baer et al. 2005; Wang, Capponi, and H. Zhang 2021). More specifically in a payments network, mutualization may reduce propagation of small loss shocks but exacerbate propagation of large shocks (Acemoglu, Ozdaglar, and Tahbaz-Salehi 2015; Paddrik and S. Zhang 2020). This paper adds to the literature on CCP resource mutualization by illustrating two distinct forms of mutualization: funding needs and default losses. Before default losses are allocated according to the default waterfall (as is commonly studied in the literature), the CCP may also need to finance its positions by drawing temporarily on liquid resources from members. This latter form of resource mutualization is important for CCPs clearing physically-settled transactions and is effected by the use of lines-of-credit.

Several studies at the intersection of law and economics offer perspectives on the industrial organization of CCPs. There are some trade-offs associated with CCP size. Trade clearing services can be made less expensive when market participants use a common CCP because offsetting positions with different counter-parties or hedged positions in different contracts can be netted to reduce margin requirements

(Duffie and Zhu 2011). Moreover, "vertical integration" of CCPs, i.e. when CCPs share common ownership with and clear transactions for a single exchange, may inhibit competition in the market for trade execution (Wolkoff and Werner 2010). Still, some scholars express concern that particular CCPs may grow "too big to fail" and so distort risk-management incentives (Chang 2015; Peirce 2016). There are other trade-offs associated with whether a CCP is owned and operated by its members, who are market participants, or by a distinct class of shareholders. The literature has documented a trend toward "demutualization" and considers the resulting conflicts between shareholders and members (R. T. Cox and Steigerwald 2016; Saguato 2017; Albert J. Menkveld and Vuillemey 2021). This paper suggests that ownership structure may vary across CCPs according to the type of cleared contracts. Mutual ownership may be more advantageous when clearing contracts that are physically settled, like securities or repo, because of additional uses for mutualized liquid resources.

There is relatively little cleaned, standardized, publicly-available data on CCPs. The primary source of data are the CPMI-IOSCO Public Quantitative Disclosures (PQDs). These disclosures are published quarterly and, though they contain elements that are conceptually similar, CCPs often differ in their choice of formatting and interpretation. Industry groups and data merchants like CCPGlobal and ClarusFT have helped to standardize and aggregate the information, but it remains difficult to use. The paper closest to ours is Aldasoro, Avalos, and Huang (2023), who clean series on liquid resources for a subset of CCPs publishing these PQDs. Our paper more thoroughly cleans the data, and so provides a more extensive summary of risk-management at a larger cross-section of CCPs. Furthermore, we provide a framework to help interpret the cross-sectional variation in the data.

We follow the literature in taking a value-at-risk (VaR) approach to describing CCP resource management. This approach has been used to explore netting benefits (Baer et al. 2005; Duffie and Zhu 2011), position concentration (Albert J Menkveld 2017), CM heterogeneity (Cont and Ghamami 2023), and portfolio directionality (Kubitza, Pelizzon, and Sherman 2024).[1] We further develop this VaR framework according to the purposes of our analysis. First, we aim to facilitate comparison across different kinds of CCPs, including those with different final settlement mechanisms. We build a stylized setting in which both the underlying and derivatives contracts are priced in order to contrast cash and physical settlement in a common framework. Second, we wish to consider the timing of resource demands on CCP, because of how quickly these demands may arise. To this end, when analyzing an instance of CM default, we keep track not only of ultimate capital losses but also interim liquidity needs.[2]

3 Institutional setting: The function of CCPs and the timing of default loss management

When trading in securities or derivatives markets, market participants face the challenge of counterparty credit risk.[3] There is the possibility that the counterparty to a transaction, i.e. the participant with whom

[1]Notably, Capponi et al. (2022) presents evidence suggesting that margin demands may not be well explained by VaR models in CDS markets.

[2]We rely on the discussion in J. C. Cox and Rubinstein (2002) for exposition on how variation margining takes place relative to financial contracts.

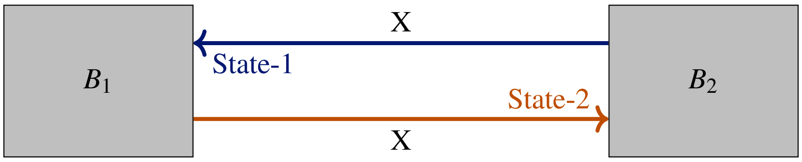
[3]This discussion serves as exposition of how CCPs function. The beginning of the discussion, describing the problem of counterparty credit risk and the default waterfall is based on the discussion in Heilbron (2024) and therefore uses similar language. The discussion has been elaborated to the interim management of defaults as well as the ultimate assignment of default losses.

they are trading, could default on contracted commitments. The counterparty might fail to deliver the contracted security at the contracted date (spot/futures), on exercise (option), or at default (CDS), and so on. Alternatively, the counterparty could fail to make cash payment (spot/futures), or premium payments (CDS/options), or interest payments (IRS).

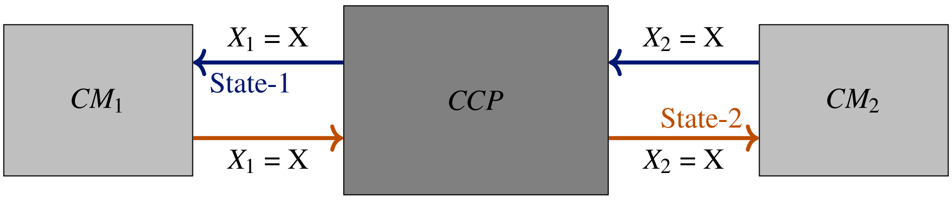
One approach market participants might take is to manage counterparty credit risk bilaterally, i.e. between each pair of transacting entities. In this case, parties to the transaction often set aside collateral.[4] Should one party default on its obligations, the other is then entitled to seize this collateral and use it to offset any losses associated with the default. This is done separately by each pair of parties transacting.

A central counterparty (CCP) is an institution that manages counterparty credit risk for many market participants without taking an outright position in any particular transaction. The CCP takes on the counterparty credit risk through a process of *novation*. It replaces the original contract between market participants with two contracts in which it becomes the buyer to the seller and the seller to the buyer (see **Figure 2**). In doing so, the CCP does not take on market risk, because it signs contracts only in offsetting pairs. If both contracts perform, the CCP does not stand to gain or lose anything because of market movements. However, even if a market participant defaults on one of the novated contracts, the CCP must still honor the other contract. This means the CCP must absorb any default losses and therefore has taken on the counterparty credit risk.

Figure 2: Contract Novation in Central Clearing



(a) Bilateral Contract



(b) Novated Contract

Sources: *Authors' creation.*

CCPs use several techniques to manage counterparty credit risk. They only novate contracts traded between a set of approved market participants, whom they designate as CMs. They conduct *ex-ante* screening and monitoring of the financial health of these entities to ensure that their credit risk remains low and therefore it is unlikely that they will default on their cleared portfolios. They also require members to set aside collateral to cover losses in the event of a default.

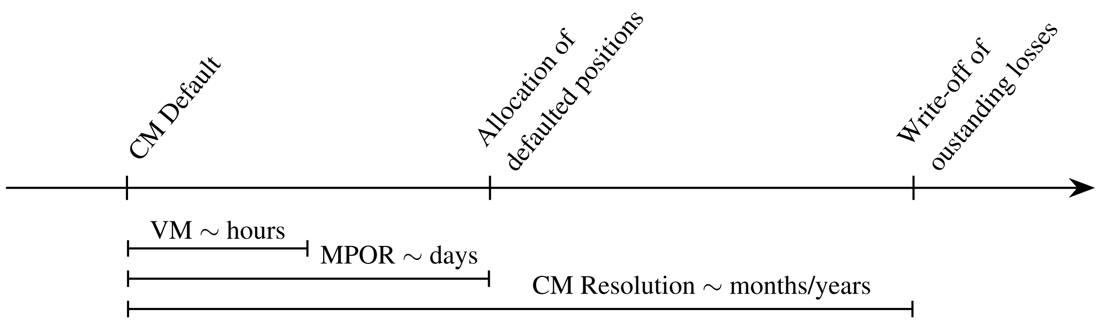
Should a CM default, CCPs then allocate default losses according to a *default waterfall*. A given

[4]This legal process is known as *hypothecation* of collateral.

CCP can specify idiosyncratic terms for its particular default waterfall in its rulebook, but waterfalls at different CCPs have a similar priority structure. Losses are first taken from the IM of the defaulting CM. Next, they are taken from the contributions of the defaulting CM to the DF. Next, a small layer of capital provided by the ownership of the CCP itself, known as the CCP's *skin-in-the-game* (SITG), is used. After this, the contributions of other CMs to the mutualized DF are used. If the DF has ben exhausted and there are still default losses outstanding, the CCP may turn to other techniques including assessments or capital calls on members.

The assignment of default losses, however, is only the outcome of an involved process of default management by the CCP. With the default of a CM, the CCP becomes exposed to various risks. In its default management procedures, it aims to (i) continue performing in its contractual obligations to non-defaulting CMs (ii) allocate the risks it has inherited from the defaulting CM and (iii) minimize losses to itself and to its other CMs due to the default. For a rough schema of its operations, see **Figure 3**.

Figure 3: Timeline for CCP Management of CM Default



Source: *Authors' creation.*

Prior to "CM Default", the CCP is exposed only to the counterparty credit risk of its CMs. When one of its CMs fails to perform on its contractual obligations, it exposes the CCP to two additional types of risk:

(i) The CCP now faces market risk. It has agreed to make good on any promises that the defaulting member fails to pay. In that sense, it takes over the positions of the defaulting member. These include the positions in the house account of the CM but also any non-performing client positions that the CM had guaranteed. In contrast to before default, it now holds risks on its balance sheet. The CCP therefore stands to make or lose money according to movements in market prices.

(ii) If the defaulting CM formerly cleared client positions and those clients are still performing on their obligations despite the member's default, the CCP is now exposed to the counterparty credit risk of those clients. Formerly, the CM stood as a buffer between client default and the CCP. Now, should one of those clients default, the CCP will effectively take over the position and be exposed to market risk. Note that the CCP takes on the counterparty credit risk of CMs with a careful process of screening and monitoring. Though they may have some information about clients, these are accepted primarily because of the risk-tolerance and guarantees of the CM.

A CCP may declare a non-performing CM in default, but, barring additional intervention, standard clearing operations for other CMs are meant to continue. So, for example, the CCP will make standard margin calls, including VM calls that pass gains and losses between winning and losing positions, as well as potential IM calls that require liquid resources from all members to reflect rising volatility. Notably, the CCP itself will have to pay out any VM obligations of the defaulting member. These obligations can arise quickly, within hours, as defaults may take place in the middle of the trading day and margin settlement is required before the next trading day and sometimes intra-day as well.

Meanwhile, to restore standard operations, the CCP must allocate (i) the market risk associated with the non-performing positions, whether house or client, inherited from the defaulted CM and (ii) the counterparty credit risk associated with any performing client positions of the defaulted CM.

(i) A CCP may take several approaches to assigning market risks associated with default:[5]

- It may go to the open market to purchase (or sell) an offsetting position. For example, if the defaulting CM had written a call option on the S&P 500, having inherited the position, the CCP is now short this exposure. If it can purchase such a call option, payment from the writer of the replacement contract will now cover any obligations associated with the original default contract, which the CCP inherited, and so the CCP's exposure to market risk will have again been neutralized.
- Another option is for the CCP to "auction the defaulting member's positions" among the surviving CMs. In this case, it is one of the surviving CMs who will take responsibility for the defaulting member's obligations associated with a position or set of positions. The surviving CMs may demand some form of compensation if such positions have lost value or are costly for them to hedge, which would be reflected in the bids they submit to the auction.[6]
- Finally, the risks associated with defaulted positions could be allocated through contract tear-up. In this case, the obligations of the defaulting CM are essentially assigned to the original counterparty. They had originally entered a contract to lay off those risks (potentially for the purpose of hedging them) and this contract has been canceled. Assuming it is done under the appropriate authority, the counterparty is not guaranteed any compensation for having the risks re-assigned to them.[7]

(ii) Additional counterparty credit risk is resolved through the process of "porting". Performing client accounts are transferred to non-defaulting CMs who agree to take on the client's business as well as credit risks.

The process of assigning defaulted positions and porting performing client positions is estimated by the CCP to take on the order of days. The "margin period of risk" (MPOR) refers to the length of

[5]Upon inheriting a portfolio of non-performing positions immediately after a CM default, the CCP will place hedges on constituent components of these positions' pricing, where liquid markets permit it to trade quickly and inexpensively. For example, it might offset interest rate risk or the performance of the S&P 500. The market risk it faces is then the residual between the defaulted portfolio and the offsetting hedges. For simplicity of exposition, in this paper, we elide this distinction. Qualitatively, it makes little difference to the analysis – statements about changing market values can simply refer to hedged rather than unhedged positions. Quantitatively, the efficacy and reliability of rapid position hedging could have important consequences for the amount of losses CCPs sustain during default.

[6]See Ferrara, Li, and Marszalec (2017) and Huang and Zhu (2021) for analysis of CCP auctions.

[7]In the rulebooks of most CCPs, contract tear-ups are not permitted in this early phase of reestablishing a matched book. Rather it is only in the event that default losses accumulate during the process that CCPs can turn to the use of contract tear-ups. Nevertheless, during the March 2022 Nickel Market Stress, the LME authorized contract tear-ups that helped the associated CCP, LME Clear, avoid having to put CMs in default. See Heilbron (2024) for more details.

time over which this process is anticipated to take place. The length of time may affect the severity of losses that the CCP may incur in the process, and so it is a basis for determining the quantity of prefunded resources to be made available to absorb such losses, particularly the IM. At the conclusion of this period, the CCP will have incurred losses in order to assign the risks inherited from the defaulting CM. These losses will be absorbed according to the rules of the default waterfall, described above.

It is possible that CCPs are unable to recover all the losses associated with a default through its management of the portfolio and margin resources of the defaulter. It is common that the CCP rulebooks maintain recourse and can recover outstanding losses from the estate of the defaulted CMs. Assuming this CM entered bankruptcy, however, it is possible that such recovery would take months or years. In the meantime, the losses are assigned according to the default waterfall. Should resources be recovered, they are rebated to CMs at that later date.

This rough sketch of the CM default timeline emphasizes two distinct aspects of default management. In the immediate aftermath of a default, the CCP inherits market risk from defaulted positions and counterparty credit risk from performing positions of clients with whom it may not be familiar. The CCP faces a liquidity management problem in meeting any associated payment obligations. Subsequently, the CCP lays off these various inherited risks from other members of the market ecosystem. It may incur losses when doing so, and faces a problem of absorbing and allocating those losses. This is a problem of ensuring the adequacy of default loss resources.

The kinds of resources that a CCP requires to serve these two functions differ. Meeting inherited obligations requires that CCPs maintain liquid resources, i.e., resources that can be expended on short notice. Contracts often require cash payment, so to be liquid requires that the resource can be quickly converted to cash. In some cases, it is necessary that this is done quickly, within a few hours or less. Default loss management requires that CCPs maintain capital resources. These are resources that are capable of absorbing losses after successful conversion of risks to losses. Liquid resources do not necessarily need to be loss absorbing. Provided that payment can be made according to the timing of CCP's obligations, if such payment represented a loss, it is possible for the CCP to absorb that loss at a later date. Capital (or loss absorbing) resources do not necessarily need to be liquid. Default losses arise through the process of allocating positions, and this process may take a few days.

In what follows, we present the problem of CCP resource management. This describes how a CCP prepares *ex-ante* based on its resource needs *ex-post*, after a CM has defaulted. Following the intuition sketched here, we keep track of the distinct liquid and capital needs of the CCP.

4 Data sources

There is relatively little publicly available data on the activities of CCPs. What is available comes from voluntary disclosures made by CCPs who aim to meet industry-wide minimum reporting standards. These standards are based on a disclosure framework, known as the *Principles for financial market infrastructures* (PFMI), that was first articulated by the BIS Committee on Payment and Settlement Systems (CPSS) and the Technical Committee of the International Organization of Securities Commissions (IOSCO) (CPSS-IOSCO 2012). Subsequently, the BIS Committee on Payments and Market Infrastructures (CPMI) and the Board of IOSCO supplemented the framework with specific recommended quantitative disclosures for CCPs (CPMI-IOSCO 2015).

These public quantitative disclosures (PQDs) are made by major CCPs internationally. PQDs are released quarterly, usually with two months lag, and a few weeks' additional lag for aggregators to ingest the data. While there is no required format for the presentation of information, a template has been made available by the industry organization, CCPGlobal, since 2020. Information in the disclosures is collected and compiled by Clarus Financial Technology (ClarusFT). Despite these improvements, the raw data remain difficult to work with because of non-standardized CCP responses. Even where available, the data are infrequent and show limited and inconsistent granularity.

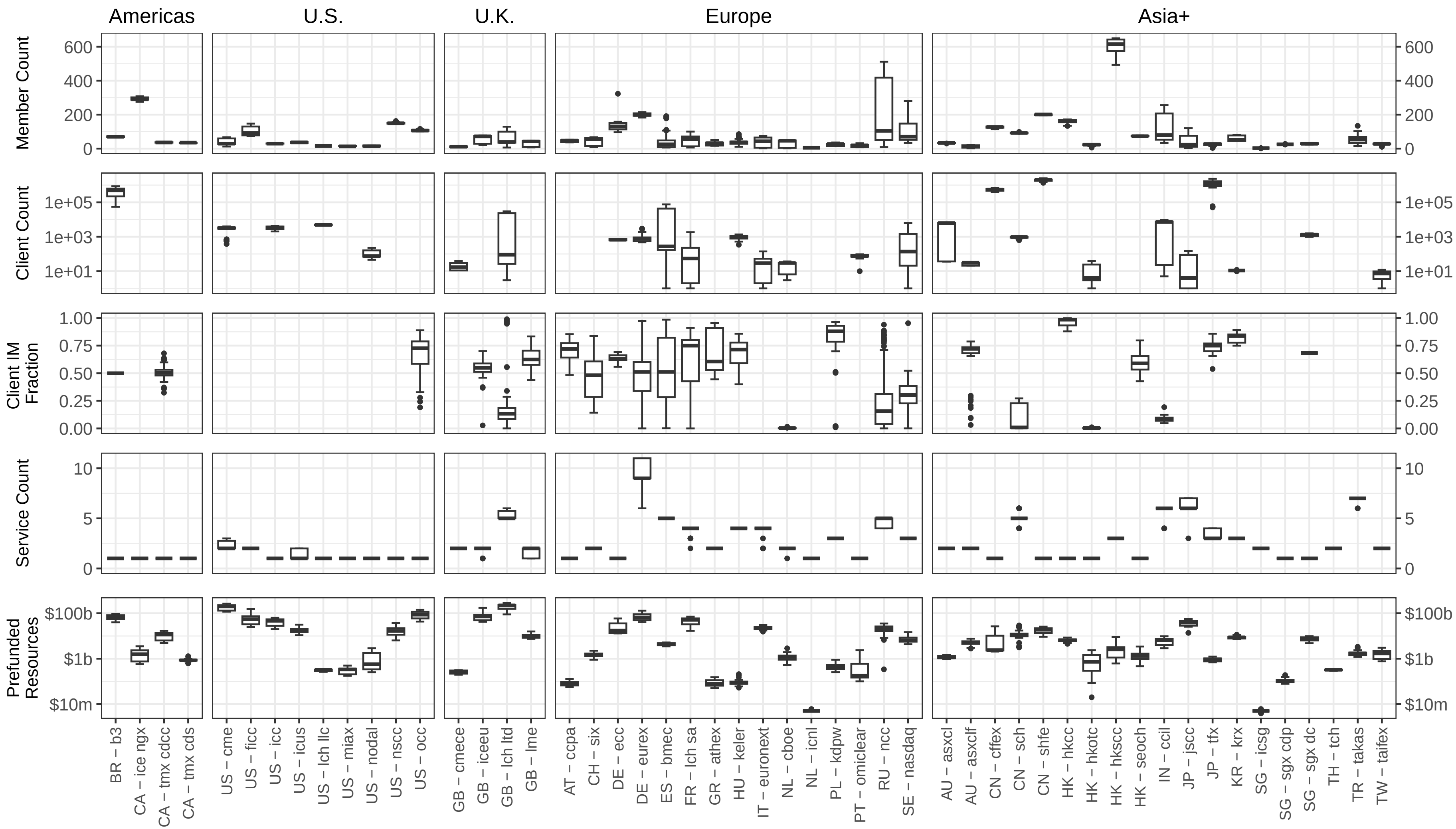
We use the CPMI-IOSCO PQDs to provide a snapshot of the cross-section of major international CCPs. Our sample includes 50 international CCPs, some no longer in operation, represented in data collected by ClarusFT. As in Aldasoro, Avalos, and Huang (2023), we clean the data to construct time-series of key variables for each of these CCPs. Many of these CCPs contain multiple clearing services (e.g. CME Base and CME OTC), but not all CCPs clearly distinguish between these services in their reporting, so we aggregate our level of observation across services to the level of the CCP. To aid in understanding this snapshot of CCPs, we also enhanced the data by merging information about the location (country and continent) of the CCP as well as the asset classes cleared by its various services. We also merge, as available, data collected by ClarusFT on trade activity at each CCP, which is published by many CCPs at a higher degree of frequency than the PQDs (e.g. monthly).

Our sample is summarized in **Table 4**. The table presents cross-sectional characteristics, where, as necessary, the average for each CCP is taken across all available quarters in the sample. All but five of the 50 CCPs are still in operation as of Q4 2024. There is considerable range in the size of these CCPs, from <\$0.1b to $\sim$\$200b. Most of the CCPs are located in Asia+, although most of the prefunded resources are devoted to CCPs located in the U.S., with the second most in the U.K. Finally, CCPs devote on average 18% of resources to clearing cash transactions, 7.7% to repo, 9.3% to a combination of cash and derivatives products, 27% to a combination of derivatives products, and the remainder to distinct kinds of derivatives products.

In **Figure 4**, we present information on the size and structure of the CCPs in the sample, much of which later discussions abstract away from. The bottom-most panel describes the total prefunded resources at the CCP, a risk-weighted measure of activity. Above this, we tabulate the number of services reported in the PQDs. The upper-most panels describe the number of CMs and number of clients at each CCP, as well as the fraction of IM in client, rather than house, accounts. This is roughly a risk-weighted measure of the extent to which CMs facilitate clearing on behalf of end users rather than on their own behalf.

Our empirical work is largely descriptive. In the following sections, we build an analytical framework for interpreting aggregate prefunded and liquid resources at different CCPs. Throughout, we accompany the parameters of the framework with their empirical counterparts, where available (see **Table 5**). Because the sample of CCPs is not commonly known, in many figures we provide contextual information to orient the reader. In particular, we organize the CCPs into five regions: the Americas (other than the U.S.), the U.S., the U.K., Europe (other than the U.K.), and Asia+ (including Oceania). We provide country codes for each reported CCP. We also provide information on the total prefunded resources of the CCP.

Figure 4: CCP Size (4.1,6.1) and Structure (4.3,6.2; 18.2.3; 19.1.1) Measures, Q3 2015-Q4 2024



Sources: *ClarusFT CCPView, Authors' analysis.*

5 An analytical framework for the determinants of CCP resource demands

This section describes CCP resource demands analytically. In a highly stylized setting, we characterize aggregate CCP prefunded resource needs, *PRF*, and liquid resource needs, *LQD*, in terms of parameters describing market activity and CCP risk-management decisions. The derivation provides an exposition of the mechanics of default management at CCPs. The resulting expressions help facilitate comparisons across different types of CCPs despite the institutions' idiosyncrasies.[8]

We build to a discussion of CCP resource requirements in three stages. We begin, in **Section 5.1**, by describing how margining and settlement take place for a specific contract. This clarifies how resources change hands in the absence of default and how these resource transfers effect the terms of the contract. Next, in **Section 5.2**, we aggregate over positions to consider the resource needs associated with default by a single participant. The portfolio of trades is highly stylized; trades are identical but placed at different points in time, so that some may reach final settlement during the episode of default. Finally, in **Section 5.3**, we aggregate over multiple market participants to determine the resource demands of a CCP. These aggregate resource demands reflect both decisions about what default scenarios to plan for as well as decisions about how to mutualize losses across members in the event of default.

We make an array of simplifying assumptions about trading activity to facilitate the exposition. We assume trade in a single futures contract that is in zero net supply. This contract references a single underlying instrument and is available at a single tenor, T. The demand of each market participant for the contract is constant period-by-period, N. Trade, then, consists of pairs of market participants who take opposite sides of identically sized trades.

We also make simplifying assumptions about the price process of the underlying security, P_t. We assume this is a random walk characterized by $\Delta P_{t+1} \equiv P_{t+1} - P_t \sim \mathcal{N}(0, \sigma^2)$. From this, we derive a price process for futures contract $F_{t,T}$, a contract signed at date t and specifying the price at which the buyer will obtain the underlying security at a later date, T periods in the future, i.e. $t+T$. For simplicity, we assume a null risk-free rate and, for simplicity, that the underlying is uncorrelated with the market. Futures pricing is then given by $F_{t,T} = E_t[P_{t+T}] = P_t$ and is also a random walk.

Finally, we assume that margining takes place according to standard industry practice. VM is computed by marking-to-market the portfolio of contracts. We assume "worst-case scenario" defaults, in that members with identical rather than offsetting positions are the ones to default. Moreover, we assume that the defaulters are cash-payers, to illustrate points about CCP liquidity needs. In the event of default, we assume that CCPs are responsible for interim cash obligations prior to replacing defaulted positions. These obligations consist of VM obligations as well as cash payments in final settlement. We assume that CCPs face some delay in their ability to go to market to replace positions, the MPOR, τ. We suppose that, in going to market or conducting an auction, CCPs incur some price impact, $\lambda(.)$. CCPs must absorb losses resulting from replacing defaulted positions.

These assumptions abstract away from several key features of CCPs. First, we do not describe the margining for options, forwards, or swaps contracts, which comprise a significant component of cleared activity. Second, these assumptions abstract away from the netting benefits that CCPs provide for market

[8] Despite the analytical notation, the discussion is not intended as a "model", in the sense that it does not endogenize agent behavior or resource allocation in an optimization problem.

participants. CCPs may provide netting benefits to participants who take on and subsequently lay off risk in the form of a single contract. They may also provide margin offsets to participants who trade multiple kinds of contracts with hedged payoffs (Duffie and Zhu 2011). Finally, these assumptions abstract away from key features of CCP institutional design. CCPs often host multiple clearing services at which different contracts trade. Additionally, trade at CCPs is often conducted through clearing "access models", in which a CM enables their client to trade in cleared markets by guaranteeing the performance of the client to the CCP.

5.1 Margining and settlement

In this section, we describe the mechanics of CCP margining and settlement, that is, the kinds of resources they pass through between members both during and at the end of the life of the contract. We discuss only cash- and physically-settled futures. We do so because they are relatively simple and because the distinction between them is central to CCP liquidity needs. Nevertheless, the analysis is useful somewhat more broadly. Spot contracts are a special case of physically-settled futures contracts. And repo contracts, discussed further in **Appendix A**, can be considered the simultaneous transaction of a spot and offsetting physically-settled futures contract.

The insights from the analysis in **Section 5.1** are summarized in **Table 1**. The table depicts the contract terms for a futures transaction for security S, signed at date t, and terminating at date $t+T$. Whether the contract stipulates cash or physical settlement, the contracted futures price, $F_{t,t+T}$, is the prevailing market price. The VM that is exchanged over the life of the contract is equal to the change in the futures price. Under physical settlement, the buyer returns VM and pays the contracted futures price in exchange for the security. Under cash settlement, by contrast, there VM transfers are simply made permanent and there is no exchange of cash or securities between the counterparties at the settlement date. We include a subsequent potential instance of trade, $Trade'$, to emphasize that the buyer could make a subsequent purchase at prevailing prices in the spot market to obtain the security after cash settlement. In our simplified setting, it is straightforward to show that each settlement mechanism is equivalent and affects the original terms of the the contract.

Table 1: Margining of Cash vs. Physically Settled Futures

	Cash Settlement	**Physical Settlement**
Price	$F_{t,t+T} = P_t$	
Total VM	$\sum_{j=1}^{T} vm_{t+j} \equiv \sum_{j=1}^{T} \Delta F_{t+j,t+T} = P_T - P_t$	
Settlement	$0 \leftrightarrow 0$	$\sum_{j=1}^{T} vm_{t+j} + F_{t,t+T} \leftrightarrow S$
Trade'	$P_{t+T} \leftrightarrow S$	

Source: *Authors' creation.*

5.1.1 Cash-settled futures

We consider a single futures contract of maturity T with a price $F_{t,t+T}$. The contract is "cash-settled" which means that at the maturity of the contract, $t+T$, VM is exchanged and accumulated VM transfers are made permanent, but a transaction of the underlying security for cash does not actually take place.

The buyer contracts at date t to pay F in cash to the seller at date $t+T$, in exchange for a unit of the underlying security. This contract is marked to market daily. If a participant purchases one unit of the futures contract at date t, they do not make any margin payments at the date of purchase. On subsequent dates, they exchange VM:

$$vm_{t+j} \equiv \Delta F_{t+j,t+T} = F_{t+j,t+T} - F_{t+j-1,t+T} = \Delta P_{t+j}$$

This is the change in the value of the futures contract expiring at date $t+T$. If this is positive, the seller of the contract pays the buyer and vice versa if it is negative. With the simplifying assumptions we use in our exposition, this equals the change in value of the underlying price.

Consider what happens in the absence of default. The total VM exchanged over the life of the contract is given by:

$$\sum_{j=1}^{T} vm_{t+j} = \sum_{j=1}^{T} \Delta P_{t+j} = P_{t+T} - P_t = P_{t+T} - F_{t,t+T}$$

When this margin transfer is made permanent, it can be used to defray the costs of purchase or to supplement the proceeds of sale of the underlying elsewhere in the market. For example, if the price has increased, $P_{t+T} - F_{t,t+T} > 0$, the margin transfer has been made from seller to buyer. The buyer could go to market and purchase the underlying using this margin transfer of $P_{t+T} - F_{t,t+T}$ and supplementing it with $F_{t,t+T}$ of its own funds. Thus, when originally signing the contract, it has locked in the price indicated in the futures contract.

5.1.2 Physically-settled futures

We consider a single futures contract of tenor T with a price $F_{t,t+T}$. The contract is "physically settled" in that, at the maturity date, an exchange of the underlying security is made for cash according to the originally contracted futures price, and in addition, the total VM exchanged to date is returned. The process of physical settlement takes place over ϕ days subsequent to the maturity of the contract.

The buyer contracts at date t to pay F in cash to the seller at date $t+T$, in exchange for a unit of the underlying security. This contract is marked to market daily. If a participant purchases one unit of the futures contract at date t, they do not make any margin payments at the date of purchase. On subsequent dates during the tenor of the futures contract, they exchange VM:

$$vm_{t+j} \equiv \Delta F_{t+j,t+T} = \Delta P_{t+j} \qquad j \in \{1,...,T\}$$

After the contract has expired, prior to the final physical settlement of the contract, the buyer and seller continue to exchange VM through the CCP. At this time, the exchanged VM is defined by the change in value of the underlying:

$$vm_{t+T+j} \equiv \Delta P_{t+T+j} \qquad j \in \{1,...,\phi\}$$

Consider what happens in the absence of default. The total VM exchanged over the life of the contract, including the duration of the settlement period, is given by:

$$\sum_{j=1}^{T+\phi} vm_{t+j} = \sum_{j=1}^{T} \Delta P_{t+j} = P_{t+T+\phi} - P_t = P_{t+T+\phi} - F_{t,t+T}$$

At $t+T+\phi$, the buyer pays $F_{t,t+T}$ in cash as well as returning $P_{t+T+\phi} - F_{t,t+T}$, and receives the security in exchange. In total, then, the buyer hands over $P_{t+T+\phi}$ in cash to receive the security, but the cost to the buyer is defrayed by the VM it has received over the life of the contract.

5.1.3 Data

Figure 5 shows the footprint of each CCP in the sample across the different kinds of markets for which it clears products. The product markets are divided between cash and derivatives transactions. Derivatives transactions are further divided by contract style into futures and options, on the one hand, and swaps and forwards on the other. In general, futures and options tend to be more standardized contracts that are exchange traded products (ETP). By contrast, swaps and forwards tend to be more customized, idiosyncratic, and therefore trade in over-the-counter (OTC) markets.

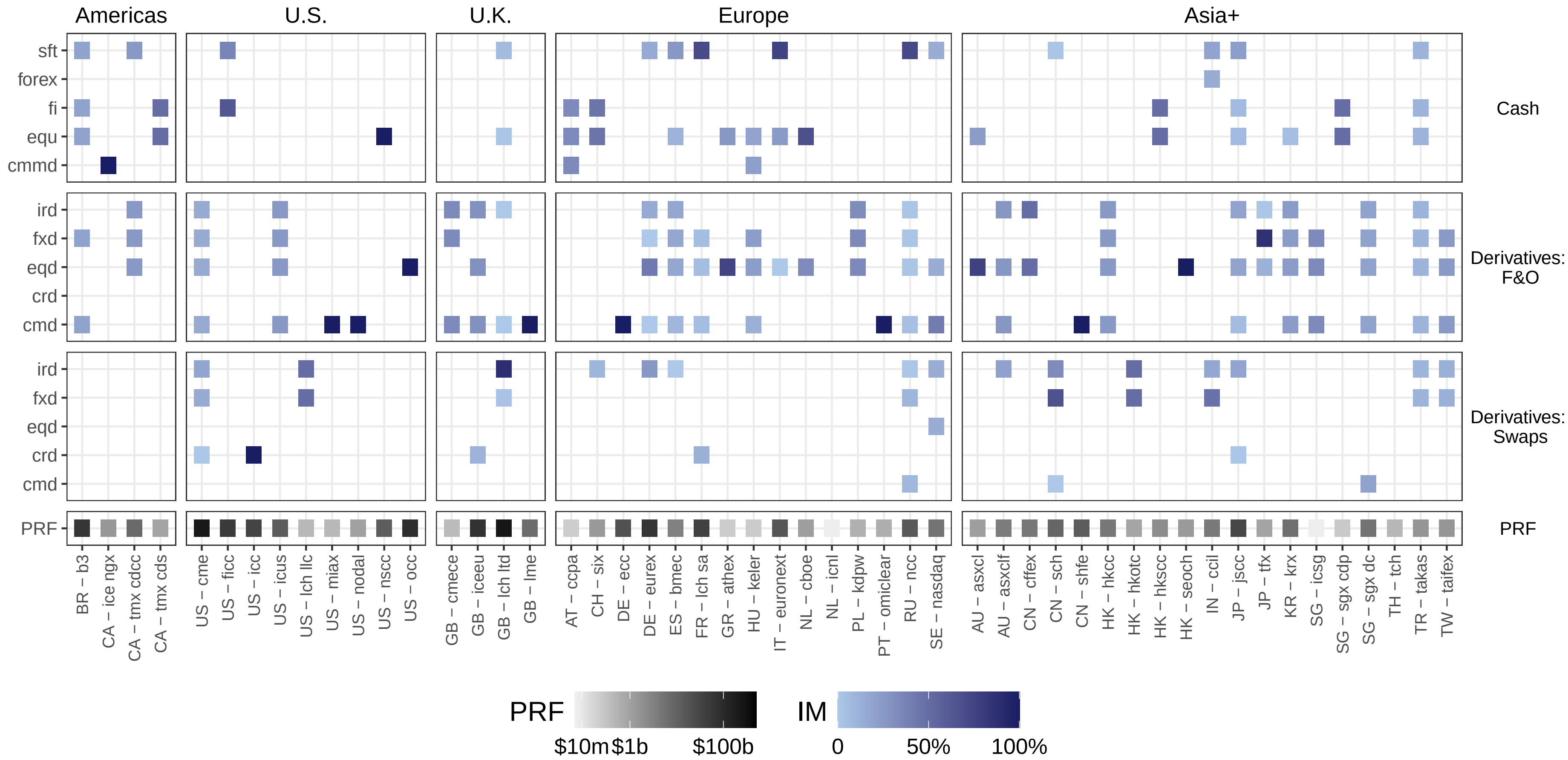
Within each "style" of contract, there are different asset classes listed. For the derivatives contracts, these include commodity derivatives (CMD), credit derivatives (CRD), equity derivatives (EQD), foreign exchange derivatives (FXD), and interest rate derivatives (IRD). For the cash transactions, these consist of commodities, equities, fixed income, and foreign exchange. Securities-financing transactions (SFT), which include both repurchase agreements (repo) and securities lending markets, are grouped with the cash transactions. These kinds of secured lending arrangements are economically similar to the simultaneous placement of a spot and futures trade (with physical delivery). They are grouped with the "Cash" transactions both because it is common for repo CCPs to clear spot transactions as well, and because the rate of turnover and requirements of physical settlement are shared in common.

The colored squares describe the fraction of the CCP's IM resources dedicated to clearing positions of a particular kind.[9] The CCP footprint is a risk-weighted measure of the relative cleared activity the CCP performs across these different markets. This figure contains partial information on the extent of cash and physical settlement at each CCP. By their nature, cash and repo transactions are necessarily physically settled. By contrast, derivatives transactions may instead be cash settled. There is still information missing on the extent to which transaction turnover requires or could require physical settlement to take place.

[9] Each clearing service, s, is assigned a set of asset classes that it clears, A_s. A CCP's footprint in a given asset class, a, is initial margin in all services clearing that asset class, $a \in A_s$, divided by the total IM at the CCP, $IM_c = \sum_{s \in c} IM_s$. Where a clearing service clears multiple asset classes, like the CME Base service, the total IM is shared equally among the cleared asset classes:

$$\%IM_c(a) = \frac{\frac{1}{|A_s|} \sum_{a \in A_s, s \in c} IM_s}{IM_c}$$

Figure 5: Cleared Product Type Footprint, %IM, (6.1) by CCP, Q3 2015-Q4 2024



Sources: *ClarusFT CCPView, Authors' analysis.*

5.2 Ex-post default management

In this section, we consider the liquid and capital needs of a CCP in the aftermath of the default of one of its members. The main insights are summarized below in **Table 2**. The need for capital resources comes from both movement in underlying prices over the duration of the MPOR, $\sqrt{\tau}\sigma W$, as well as market impact $\lambda(oi)$, and this is equivalent under both cash and physical settlement. In our framework, the CCP does not need liquid resources to cover price movements due to its own market impact, but it does need liquid resources to cover the turnover of physically settled contracts, $s^{\phi}P_{d-1}$. The two settlement mechanisms are contrasted for clarity in exposition, but note that cash settlement is a special case in which $s^{\phi} \to 0$.

Table 2: CCP Resource Needs

	Cash Settlement	**Physical Settlement**
Capital	$oi * [\sqrt{\tau}\sigma W + \lambda(oi)]$	$oi * [\sqrt{\tau}\sigma W + \lambda(oi)]$
Liquidity	$oi * \sqrt{\tau}\sigma W$	$oi * [s^{\phi}P_{d-1} + (1-s^{\phi})\sqrt{\tau}\sigma W]$

Source: *Authors' creation.*

5.2.1 Cash-settled futures

We consider a case in which a constant quantity of futures are exchanged between buyers and sellers. That is, for each buyer/seller pair, $N_s = N$ notional of futures contracts is exchanged each period. Here, we index the periods by s, the date on which the contracts expire. So, for contracts of tenor T signed at date t, we have $s = t + T$. In this case, at time t, the portfolio of each buyer/seller consists of

$$N_s = \begin{cases} N & s \in \{t+1, t+T\} \\ 0 & \text{o/w} \end{cases}$$

We can define the outstanding quantity of trade at any given time, the open interest, $OI^{\chi} \equiv T * N$.

The VM obligation for this portfolio at date $t+1$ is given by:

$$vm_{t+1} = \sum_{s=t+1}^{t+T} (F_{t+1,s} - F_{t,s}) * N_s = TN * \Delta P_{t+1}$$

We assume that default occurs at time d because one of the buyers or sellers fails to make VM payments. In this case, we suppose that the ability to place the defaulted positions is delayed until time $d - 1 + \tau$. This means that there is a period of τ between the last date at which the VM payment was made, $d - 1$, and when the defaulted contract is replaced.

The CCP is responsible for the VM obligation of the entire portfolio during this period. We consider this to be the quantity of liquid resources required by the CCP, lqd. The amount of this is given by:

$$\sum_{j=1}^{\tau} vm_{d-1+j} = \sum_{s=d}^{d-1+T} N_s * \sum_{j=1}^{\tau} \Delta F_{d-1+j,s} \approx \sum_{s=d}^{d-1+T} N_s * \sum_{j=1}^{\tau} \Delta P_{d-1+j}$$

$$= TN \cdot \sqrt{\tau}\sigma \cdot W = OI^{\chi} \cdot \sqrt{\tau}\sigma \cdot W \qquad W \sim \mathcal{N}(0,1)$$

The approximation is made to account for the contracts that expire during the MPOR and therefore may not continue to accrue VM obligations during that time. In practice, contract expiry is relatively infrequent, e.g., monthly or quarterly, compared to the MPOR, which is a matter of days. For this reason, very often, it may be the case that no contracts expire during the MPOR.

After the default, the CCP replaces the defaulted positions. So, for example, if the defaulter was the purchaser of the futures contracts, the CCP must sell futures contracts to an alternate market participant. Consider the futures contract originally signed at time $d-1$ and expiring at $d-1+T$ for $F_{d-1,d-1+T}$. At the end of the MPOR, the CCP must sell another contract expiring at $d-1+T$. The available price for such a contract is now $F_{d-1+\tau,d-1+T}$ and we further assume that forced sale of positions prompts a price impact of $\lambda(N)$.

After the contract has been replaced, the liquid resource needs and total losses of the CCP are capped. To see this, consider the VM obligations of the CCP to the seller of the futures contract at some date after contract replacement but prior to contract expiry, $d-1+\tau < t < d-1+T$. Total VM obligations to date t on the contract are given by:

$$F_{t,d-1+T} - F_{d-1,d-1+T} = \underbrace{\left[F_{t,d-1+T} - (F_{d-1+\tau,d-1+T} - \lambda(N))\right]}_{\text{new buyer}} + \underbrace{\left[F_{d-1+\tau,d-1+T} - F_{d-1,d-1+T}\right] - \lambda(N)}_{\text{CCP}}$$

Note that the first term is paid by the new buyer and the second by the CCP. Note also that the second term is fixed by the end of the MPOR, i.e. $d-1+\tau$.

Summing the CCP's losses over all the contracts in the portfolio of the defaulting counterparty, we obtain:

$$\sum_{s=d}^{d-1+T} N_s * \left[F_{d-1+\tau,s} - F_{d-1,s} - \lambda(N_s)\right] = \sum_{s=d}^{d-1+T} N_s * \left[\sum_{j=1}^{\tau} \Delta F_{d-1+j,s} - \lambda(N_s)\right]$$

$$\approx \sum_{s=d}^{d-1+T} N_s * \left[\sum_{j=1}^{\tau} \Delta P_{d-1+j} - \lambda(N_s)\right]$$

$$= TN * (\sqrt{\tau}\sigma W - \lambda(N)) = OI^{\chi} * (\sqrt{\tau}\sigma W - \lambda(N)) \qquad W \sim \mathcal{N}(0,1)$$

Again, an approximation is made to account for contracts that expire prior to the MPOR. Note also that the worst case scenarios for the CCP involve selling futures when the price has fallen during the MPOR, i.e. $W < 0$. For this reason, the losses due to price movement during the MPOR and the price impact are additive.

5.2.2 Physically-settled futures

Again, consider a case in which a constant quantity of futures are exchanged between buyers and sellers. That is, for each buyer/seller pair, $N_s = N$ notional of futures contracts is exchanged each period. Here, we index the periods by s, the date on which the contracts expire. So, for contracts of tenor T signed at date t, we have $s = t + T$. In this case, at time t, the portfolio of each buyer/seller consists of

$$N_s = \begin{cases} N & s \in \{t-\phi+1, t+T\} \\ 0 & \text{o/w} \end{cases}$$

We can define the outstanding quantity of trade at any given time, the open interest, $OI \equiv (T+\phi) * N$.

The VM obligation for this portfolio at date $t+1$ is given by:

$$vm_{t+1} = \sum_{s=t-\phi+1}^{t} \Delta P_{t+1} * N + \sum_{s=t+1}^{t+T} (F_{t+1,s} - F_{t,s}) * N_s = (T+\phi) N * \Delta P_{t+1}$$

Note that a price increase implies a payment of VM from the seller to the buyer. The cash settlement obligation for this portfolio on date $t+1$ is given by:

$$trf_{t+1} = \underbrace{F_{t-(T+\phi)+1,t+1} * N}_{\text{Contracted Price}} + \underbrace{\left[P_{t+1} - F_{t-(T+\phi)+1,t+1}\right] * N}_{\text{Return of vm}} = P_{t+1} * N$$

Suppose that default occurs at time d. A participant who is long the futures contracts fails to make both its VM payments and any settlement payments. Again, the CCP's ability to place defaulted positions is delayed until time $d-1+\tau$. There are τ periods between the time of last vm payment, $d-1$, and the replacement of the defaulted contracts.

The CCP is responsible for both VM and settlement payments for the entire portfolio during this period. This will constitute the quantity of liquid resources required by the CCP, lqd. This amount is given by:

$$\sum_{j=1}^{\tau} vm_{d-1+j} + \sum_{j=1}^{\tau} trf_{d-1+j} \approx \sum_{j=1}^{\tau} (T+\phi) N * -\Delta P_{d-1+j} + \sum_{j=1}^{\tau} N * P_{d-1+j}$$

Note that we have included a negative sign before the ΔP in the VM computation to indicate that the CCP incurs liquid resource obligations on behalf of the defaulted buyer when the price decreases.

Consider the volume of contracts settled at $s \in \{d, ..., d+\tau\}$. There is $N * \tau$ such notional volume. The liquid resource obligations for this volume are:

$$\sum_{j=1}^{s} vm_{d-1+j} + N * P_s = -N * (P_s - P_{d-1}) + N * P_s = N * P_{d-1}$$

We rewrite the total liquid obligations:

$$= \sum_{j=1}^{\tau} (T+\phi-\tau) N * -\Delta P_{d-1+j} + \tau * N * P_{d-1}$$

$$= \tau N * P_{d-1} + (T+\phi-\tau) N * \sqrt{\tau}\sigma * W$$

$$\equiv s^{\phi} OI^{\phi} * P_{d-1} + (1-s^{\phi}) OI^{\phi} * \sqrt{\tau}\sigma * W \qquad W \sim \mathcal{N}(0,1)$$

To assess the amount of loss-absorbing resources required by the CCP to cover losses, we suppose that by the end of the MPOR, $d-1+\tau$, the CCP has off-laid any inherited positions. It is now both long the underlying and long futures positions. It is long the underlying for all positions that have entered settlement between d and $d-1+\tau$. This consists of all positions terminating at $s \in \{d-\phi, ..., d-1+\tau\}$. It sells these positions at time $d-1+\tau$ at prevailing price $P_{d-1+\tau}$ with some price impact. For positions terminating at $s \in \{d-1+\tau+j\}_{j\geq 1}$, it goes short these positions at time $d-1+\tau$ at the prevailing futures price $F_{d-1+\tau,s} = P_{d-1+\tau}$, again with some price impact.

The losses incurred on the inherited securities are:

$$\sum_{s=d-\phi}^{d-1+\tau} P_{d-1+\tau} - \lambda(n*N) - P_{d-1} = (\tau+\phi)N*[\lambda(N)+\sqrt{\tau}\sigma W] \quad W \sim \mathcal{N}(0,1)$$

The losses incurred on the inherited long futures are:

$$\sum_{s=d+\tau}^{d-1+T} N*\left[F_{d-1+\tau,s} - F_{d-1,s} - \lambda(N)\right] = (T-\tau)N*[\lambda(N)+\sqrt{\tau}\sigma W] \quad W \sim \mathcal{N}(0,1)$$

Taking the sum of these two, we get the total losses:

$$(T+\phi)N[\sqrt{\tau}\sigma W + \lambda(N)] = OI^{\phi} * \left[\sqrt{\tau}\sigma W + \lambda(N)\right]$$

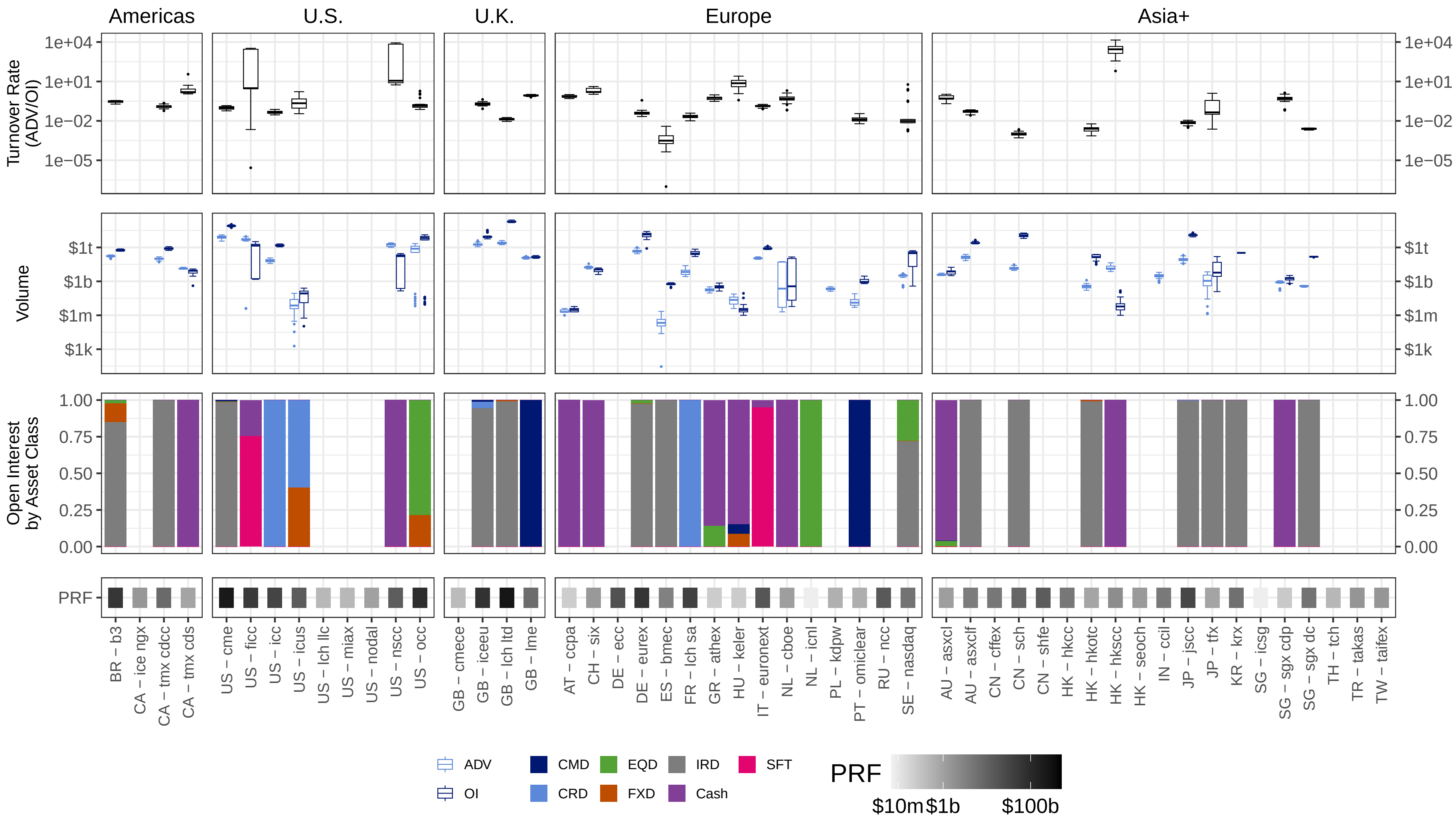
5.2.3 Data

Figure 6 shows information on the amount of trade activity at each CCP in the sample. Above the PRF size measures, the bottom-most panel describes the asset-class composition of cleared contracts, distinguishing between the five major derivative types, cash, and repo transactions.

The next-highest panel presents the average daily volume (ADV) and open interest (OI) at each CCP in notional amounts. Note that ADV corresponds to the new contracts placed daily in the framework, $\# * N$, in the framework whereas OI corresponds to the total outstanding contracts, $\sim \# * N * T = OI$.

The top-most panel describes the turnover rate, that is, the ADV divided by the OI. This corresponds to the fraction of new notional volume flowing into the stock of open positions at a CCP. Note that this tends to be higher where there are cash and sft transactions (like FICC), and it is also sometimes above unity at equity derivatives CCPs, like OCC, where 0DTE options may trade. This reflects a high degree of turnover. This provides partial insight into the extent of contract turnover for the purpose of liquid resource needs. There is a question, however, of how contracts leave the pool of OI, whether through final settlement or by the laying off of risk, and whether through cash or physical settlement.

Figure 6: CCP Volume (23.1.2; 23.2.1) Measures, Q1 2019-Q4 2024



Sources: *ClarusFT CCPView, Authors' analysis.*

5.3 Ex-ante resource management

In this section, we turn to how CCPs prepare for the possibility of subsequent default scenarios. We consider the risk management parameters they use to characterize default scenarios and, importantly, the way they mutualize default losses between members. Then, finally, we derive expressions for aggregate prefunded and liquid resources maintained by CCPs, putting together the various parameters we've introduced in our framework.

5.3.1 CCP risk-management parameters

In a market that is centrally cleared, the CCP is exposed to the losses associated with the default of any participant. The CCP also has the authority to determine the kinds and quantities of resource commitments required for market participants to trade. The CCP's risk management problem, then, is two-fold. On the one hand, it must estimate the quantity of aggregate default losses to which it may be subjected. On the other, it must provision sufficient resources of different kinds to meet those demands.

We consider a CCP, c, clearing transactions in a market composed of # market participants. Each participant is a CM with the CCP. The traded contracts are in zero-net supply and are traded between offsetting pairs of market participants. We assume the position sizes are identical and as defined in **Section 5.2**. Of the amount of outstanding quantity of trade in the market, during the MPOR, τ, a fraction s^{ϕ} will settle physically, a fraction s^{χ} will settle on a cash basis, and the remainder, $1-s^{\phi}-s^{\chi}$, will continue to be margined without entering final settlement.

The CCP chooses a default scenario defined by a number of simultaneous defaulting market participants, n, and a measure of the severity of adverse market conditions at the time of default, $\Phi^{-1}(\alpha)$. The number of simultaneous defaults often comes from a so-called "Cover-n" rule, often determined by the supervisor of the CCP. The adversity of market conditions comes from a modeling exercise, $\Phi(.)$, and a value-at-risk parameter, α, indexing the percentile in the loss distribution.[10]

The CCP provisions capital and liquid resources to meet the demands of a default scenario. Capital resources are loss absorbing; liquid resources are available for transfer on short notice. These attributes are independent in that different kinds of resources may have either of these attributes, neither, or both. Commitments that cannot be accessed quickly by the CCP, perhaps because of an investment strategy, are an example of a capital resource that is not liquid. Lines of credit, which can be accessed quickly but must be repaid and therefore cannot absorb losses, are an example of a liquid resource that is not a source of capital.

CCPs maintain different stores of capital resources. Prefunded resources, PRF, are those made available to the CCP by the members for use in the event of default scenarios without further intercession by the member. Prefunded resources consist of initial margins, IM, which members make available exclusively in the case of their own default, and default fund contributions, DF, which members make available for default in their own or in the event of others' default.[11] Committed resources, CMT, are resources that members do not prefund but instead promise to deliver if called to do so by the

[10]Note that, in practice, accuracy in the modeling exercise of tail risks is paramount. CCPs engage in sophisticated modeling techniques necessary to capture the pricing behavior of contracts they clear, the possibility of offsetting correlations between positions, and so on.

[11]CCP's own skin-in-the-game capital, $SITG$, is another example of a prefunded resource. We do not include these in our analysis because (1) they intended primarily to align the incentives of the CCP management rather than loss-absorption per say and (2) in practice, they represent relatively small contributions to total prefunded resources.

CCP in episodes of extreme losses. Because they must be called by the CCP, they are not available from members for covering losses prompted by their own default, but are mutualized and available for covering the default losses of others.[12] These sources of capital are summarized in **Table 3**.

We focus on only the CCP's prefunded resources, PRF. This is because the common "cover-n" rules used to calibrate CCPs' loss-absorbing resources are applied to prefunded resources specifically.[13] The CCP requires each member to contribute initial margin, im, and mutualized default fund resources, df. In our setting, these values will be identical across members and the values total the member's prefunded resource contribution, prf. Aggregates are denoted in capital letters and scale with the number of CMs, e.g. $PRF = \# * prf$. Effectively, the CCP chooses a degree of mutualization of prefunded resources, $\gamma \equiv \frac{DF}{PRF}$. This indicates the relative use of default fund resources compared to total prefunded resources.

CCPs also maintain various forms of liquid resources. Some liquid resources are made available through CM initial margin and default fund contributions. Importantly, the CCP has some discretion over the extent to which these contributions are held in liquid assets. For this reason, prefunded resources available for short-term liquidity needs may be only a fraction, $f \in [0,1]$, of the total. Because they are not prefunded, CM capital commitments to the CCP, cmt, are not generally available to meet liquidity needs. However, CCPs do obtain access to lines of credit, loc, to supplement their liquid resources. These lines of credit are not necessarily provided pro-rata by CMs, but are in several prominent cases.[14] Because lines of credit are not prefunded and only available once default has occured, in practice they are not available from the defaulting member, but are available from non-defaulting members. These sources of liquid resources are summarized in **Table 3**.[15]

Table 3: CM Capital and Liquid Resource Mutualization Schemes

<table>
<tr><th colspan="2">Resource Availability Scheme</th><th colspan="2">Resource Type and Magnitude</th></tr>
<tr><th>Own Default</th><th>Other CM Default</th><th>Capital (cap)</th><th>Liquidity (lqd)</th></tr>
<tr><td>yes</td><td>no</td><td rowspan="2">$prf \begin{cases} im \\ df \end{cases}$</td><td>$f^{im} * im \leq im$</td></tr>
<tr><td>yes</td><td>yes</td><td>$f^{df} * df \leq df$</td></tr>
<tr><td>no</td><td>yes</td><td>cmt</td><td>loc</td></tr>
</table>

Source: *Authors' creation.*

[12] While this is true in principle, there is a practical consideration as to whether, in the case of severe default of one member, other members would be in a position to make good on their commitments. Simultaneous losses on the balance sheets of non-defaulting members could prevent, or liquidity concerns might delay their ability to make these resources available. Evidence on the reliability of CM capital commitments is explored in Heilbron and Tompaidis (2025).

[13] The framework extends easily to CCP assessment powers and member committed resources, and is elaborated in **Appendix C**.

[14] FICC's *CCLF*, or Capped Contingency Liquidity Facility, is one such example where members make commitments to provide lines of credit the the event of member default.

[15] CCPs may or may not be permitted to utilize the liquid resources of non-defaulting CMs. This varies according to jurisdiction (see CME Group (2016) footnote 21). Where this is permitted, liquid IM contributions may be moved together with liquid DF contributions in the mutualization scheme of **Table 3**: $1-\delta^{LOC} = \frac{f^{im} * IM + f^{df} * DF}{LQD}$.

5.3.2 Prefunded and liquid resource requirements

Putting together the analysis from the previous sections, we derive expressions for the aggregate prefunded and liquid resources maintained by a CCP.

The required aggregate prefunded resource contributions is pinned down by considering the default of n members in adverse market conditions α. In such a case, default losses are incurred for n members and paid for out of n initial margins and the entirety of the default fund:

$$n * im + \# * df = n * oi[\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha) + \lambda(n * N)]$$

This expression can be rearranged to express the size of the PRF as a function of the risk management parameters of the CCP. In particular, we have:

$$PRF = OI * \frac{\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha) + \lambda(n/\# * OI)}{1 + (\#/n - 1) \cdot \gamma} = \# * \frac{oi[\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha) + \lambda(n/\# * OI)]}{1 + (\#/n - 1) \cdot \gamma} \equiv \# * \frac{T_1}{T_2}$$

To interpret this expression, note that T_1 gives the dollar losses in the event that a single CMs default. Its units are $\$ * default^{-1}$. T_2 indicates the quantity of resources available to meet a default, measured in units of an individual member's total prefunded resource contribution, $\$ * prf^{-1} * default^{-1}$. The ratio, then, yields the size of the individual member's prefunded resource contribution, prf. It is scaled by the total number of members, #, to obtain the CCP's aggregate prefunded resources, PRF.

T_2 indicates that the entirety of a defaulter's prefunded resources may be used, 1, and that several other members' default fund contributions may also be used, $(\#/n - 1) \cdot \gamma$. If, for example, the cover-n rule is sufficient to cover the default of 25% of CMs, then in the event of such a default, the default fund contribution of each CM may be scaled up by a factor of 4, less 1 because ones own default fund contribution was already used.

For the purpose of exposition, we have assumed that position sizes across market participants are equal sized. Empirically, there is considerable market concentration, in which a few CMs hold the majority of positions. This means our expressions suggest, somewhat misleadingly, that available DF resources can be scaled up many times relative to, for example, two members defaulting, when in fact there is relatively little additional DF available. In **Appendix B**, we give a simple extension of our setting to accommodate a case in which different market participants take different size positions. We do so by introducing an additional concentration parameter, κ_n, which measures the average size of the positions of defaulting members relative to the average size of all member positions.

The aggregate quantity of required liquid resources can be expressed in the same way. In this case, default by n cash payers occurs in adverse market conditions α. Liquid resource needs must be met by liquid resources in the im of defaulters, the df of all members, and the loc of non-defaulting members:

$$n \cdot f^{im} im + \# \cdot f^{df} df + (\# - n) \cdot loc = n \cdot oi[s^{\phi} P_{d-1} + (1 - s^{\phi})\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)]$$

We define as parameters the fraction of total liquid resources available from the default fund, $\delta^{df} \equiv \frac{f^{df} * DF}{LQD}$, and available from lines of credit, $\delta^{loc} \equiv \frac{LOC}{LQD}$. (The fraction available through IM resources is then the residual, $1 - \delta^{df} - \delta^{loc}$.) The expression can now be rearranged to express aggregate liquid resource needs, *LQD*, as a function of market characteristics and CCP risk-management decisions:

$$LQD = OI \cdot \frac{s^{\phi} P_{d-1} + (1-s^{\phi})\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)}{(1-\delta^{loc}) + (\#/n - 1)(\delta^{df} + \delta^{loc})} = \# \cdot \frac{oi[s^{\phi} P_{d-1} + (1-s^{\phi})\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)]}{(1-\delta^{loc}) + (\#/n - 1)(\delta^{df} + \delta^{loc})}$$

These expressions clarify interpretations of the level of CCP liquid and prefunded resources. Firstly, these values can be thought of as risk-weighted measures of the amount of cleared activity. This can be seen most clearly by defining $w^{LQD} \equiv \frac{LQD}{OI}$ and similarly for PRF. The weights reflect potential loss amounts given default. In practice, the empirical values of the weights are driven by the requirements of the regulatory apparatus, the information and inference of the CCP, and, to a limited extent, competition in the market place for the provision of clearing services.[16]

Second, these expressions are written in terms of measurable market attributes and reflect many commonly discussed features of CCP clearing. There is intermittent public reporting on many of these features of cleared markets. In particular, the expressions reflect the following measures:

- $OI \equiv \# * oi$, the total outstanding notional quantity of cleared positions.
- σ, the volatility of the underlying of cleared positions.
- τ, the CCP's MPOR.
- α, the risk-aversion of the CCP.
- $p_n \equiv \frac{n}{\#}$, the fraction of CMs accounted for in the cover-n rule.
- $\kappa_n \equiv \frac{\overline{oi}_n}{\overline{oi}_{\#}}$, the average size of cover-n defaulters' positions relative to the average size of all positions.
- $\lambda(.)$, the liquidity of the market for replacing the cleared positions.
- $OI * \lambda(p_n \kappa_n \cdot OI)$, the concentration charges associated with increasing position size.
- $\gamma \equiv \frac{DF}{PRF}$, the degree of mutualization of the CCP's prefunded resources. N.B. $\frac{\partial}{\partial \gamma} IM < 0$.
- δ^{loc} (δ^{df}) the degree of reliance on lines-of-credit (default fund held in liquid assets) for liquid resources.
- s^{ϕ}, the fraction of notional positions that are physically settled and that enter final settlement within the duration of the MPOR.

We provide a more detailed description of mappings from these (and other) parameters to empirical measures in **Table 5**.

Finally, by deriving these expressions from a common setting, we can better interpret the difference in magnitude between liquid and prefunded resources at CCPs. We write and rearrange the ratio of the two as follows:

$$\frac{LQD}{PRF} = \frac{1 + s^{\phi} \cdot [\frac{P_{d-1}}{\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)} - 1]}{1 + \frac{\lambda(n/\# * OI)}{\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)}} * \frac{1 + (\#/n - 1) \cdot \gamma}{(1-\delta^{loc}) + (\#/n - 1)(\delta^{df} + \delta^{loc})}$$

[16] These are undoubtedly sophisticated market actors, and this interpretation is helpful to a first order. The market features many "frictions" - natural monopolies and moral hazards - that may distort the resources actually collected.

Taking the first-order log approximation, we obtain:

$$\log \frac{LQD}{PRF} \approx s^{\phi} \cdot [\frac{P_{d-1}}{\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)} - 1] - \frac{\lambda(n/\# * OI)}{\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)} + (\#/n - 1) \cdot (\gamma - \delta^{df} - \delta^{loc}) + \delta^{loc}$$

The expression is involved. As a useful starting point, consider the following set of conditions, under which aggregate prefunded and liquid resource demands would be equal, i.e. $\frac{LQD}{PRF} = 1$ and $\log \frac{LQD}{PRF} = 0$:

- Cleared trades are entirely cash settled ($s^{\phi} = 0$)
- Offloading large quantities of cleared positions on the open market has no price impact ($\lambda(.) = 0$)
- Lines of credit are not employed ($\delta^{loc} = 0$) and df and im resources are invested in a liquid manner to an equal extent ($\delta^{df} = \frac{f*DF}{f*(DF+IM)} = \frac{DF}{DF+IM} = \gamma$).

This essentially says that there are no extra liquidity needs coming from physical settlement. There are no extra capital needs coming from liquidation costs. And that liquid and capital resources are mutualized to the same extent. For this reason, aggregate needs for each are of equal magnitude. With this benchmark in mind, there are several important determinants of the ratio:

- Settlement arrangements: Are contracts being settled physically or on a cash basis? How rapidly are these contracts turning over relative to the MPOR? (In the exposition, contract turnover was driven by contract tenor; in practice, it depends also on whether participants roll over risk before entering final settlement.)
- Underlying pricing characteristics: Is the underlying security volatile? Is it illiquid? How concentrated are the positions being sold on the market in the case of default?
- Mutualization arrangements: Are capital and liquid resources only available in the case of a particular *cm* default, or available for any *cm* default. More resources may need to be set aside in aggregate if access to them is restricted.
- CCP risk management: The framework has assumed that the default scenario governing liquid and prefunded resource management is identical. In practice, CCPs may use different default scenarios, i.e. different Cover-*n* rules or value-at-risk confidence intervals, α. For example, Cover-2 rules are common in the United States for determining the level of PRF. CCPs report the results of liquid resource stress testing based on a Cover-1 methodology, in which only the single largest CM fails to make payments.

5.3.3 Data

Figure 7 presents various CCP risk-management parameters. The lowest panel indicates the Cover-*n* rule, that is, the number of CMs defaulting in the scenario for which the CCP prepares. This need not be the same in preparing for liquid and capital losses, but very often Cover-2 is used for both. This can be used to compute $p_n \equiv \frac{n}{\#}$, the extensive margin of defaults. Above this, we present the concentration of activity among the top-5 members in the next panel. We report this both for concentration of IM and OI, though these are correlated. This can be used to construct $\kappa_n \equiv \frac{\#}{5} \cdot \%OI_{\text{top-5}}$. Above this, we note the variation in the MPOR, τ, across CCPs, and the VaR confidence level, α.

Figure 8 shows the degree of resource mutualization among the CMs of the different CCPs. This corresponds to the parameter γ in the framework described above. For each CCP in each quarter, DF contributions is computed as a fraction of the total PRF contributions of the CMs. That is:

$$\frac{DF}{DF + IM + SITG}$$

Note that the DTCC CCPs, FICC and NSCC, are distinct in their complete mutualization of prefunded resources. There is, however, considerable variation both within and across CCPs, in the extent of resource mutualization. This variability appears to be somewhat lower in the largest CCPs.

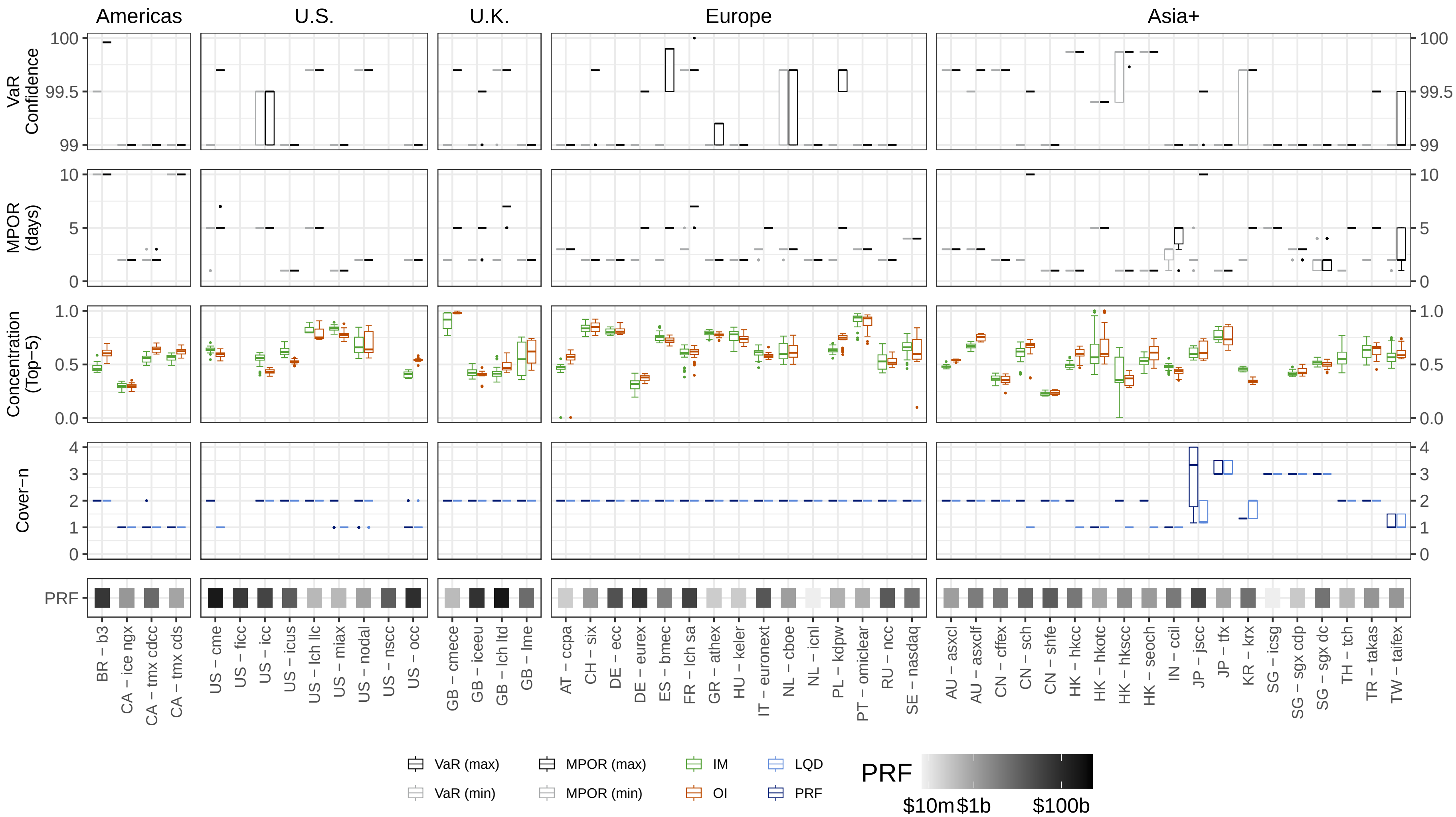
Figures 9 and **10** depicts the composition of prefunded and liquid resources by asset class. In both, there are a variety of venues where a CCP may store cash, including central or commercial banks. Liquid resources may include lines of credit in addition to cash. Note that the fraction of liquid resources made up of lines of credit corresponds to δ^{loc}.[17] While our framework does not explain differences in the composition of PRF, some patterns are salient. Major CCPs in the U.S. and in Europe leave deposits with their respective central banks. This is much less common in Asia and even in the U.K. European and U.K. CCPs commonly hold non-domestic sovereign bonds, which are possibly U.S. Treasury securities. And, finally, CCPs facilitating the trade of equity derivatives commonly have equity securities composing a large fraction of their PRF.[18]

Finally, **Figure 11** depicts the size of liquid resources, LQD, relative to prefunded resources, PRF. This is the primary object of interest in our analytical framework. The ratio is computed for each CCP in each quarter available, and the plot shows, for each CCP, a box-and-whisker plot across quarters. We note, again, that we rely on CCPs' own reporting of what constitutes liquid resources in the PQDs. What is ultimately of interest is the ability to use resources as payment on the timescale in which VM and settlement obligations come due, possibly as quickly as several hours. It is possible that reporting standards introduce bias or measurement error in this regard.

[17]The data do not allow us to distinguish liquid resources due to the DF from those due to IM contributions and for this reason we cannot compute δ^{df}.

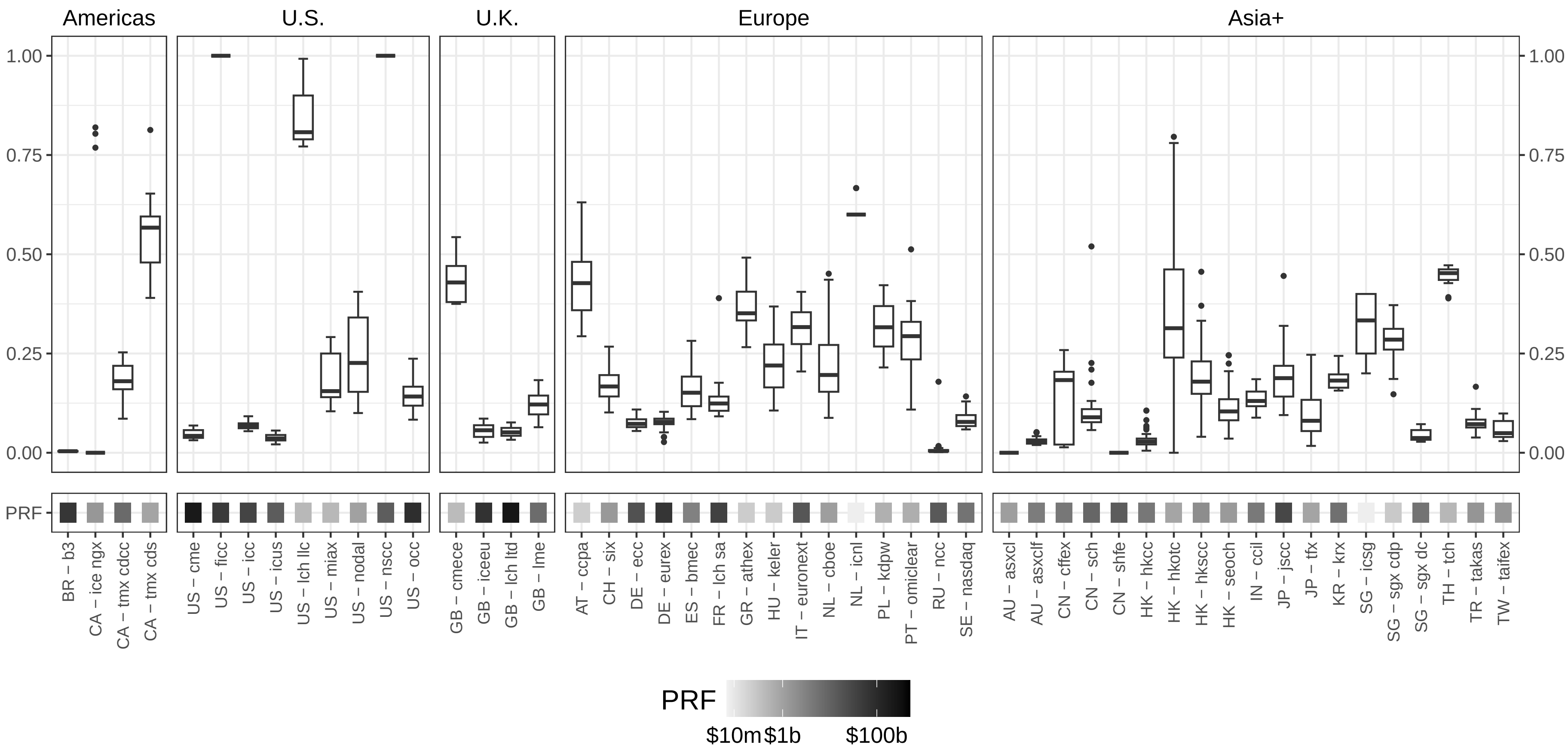
[18]These findings are consistent with the work of Aldasoro, Avalos, and Huang (2023).

Figure 7: Concentration (18.2-3), and Risk-Management (4.4.1; 6.4.5,11; 7.1.1) Measures, Q3 2015-Q4 2024



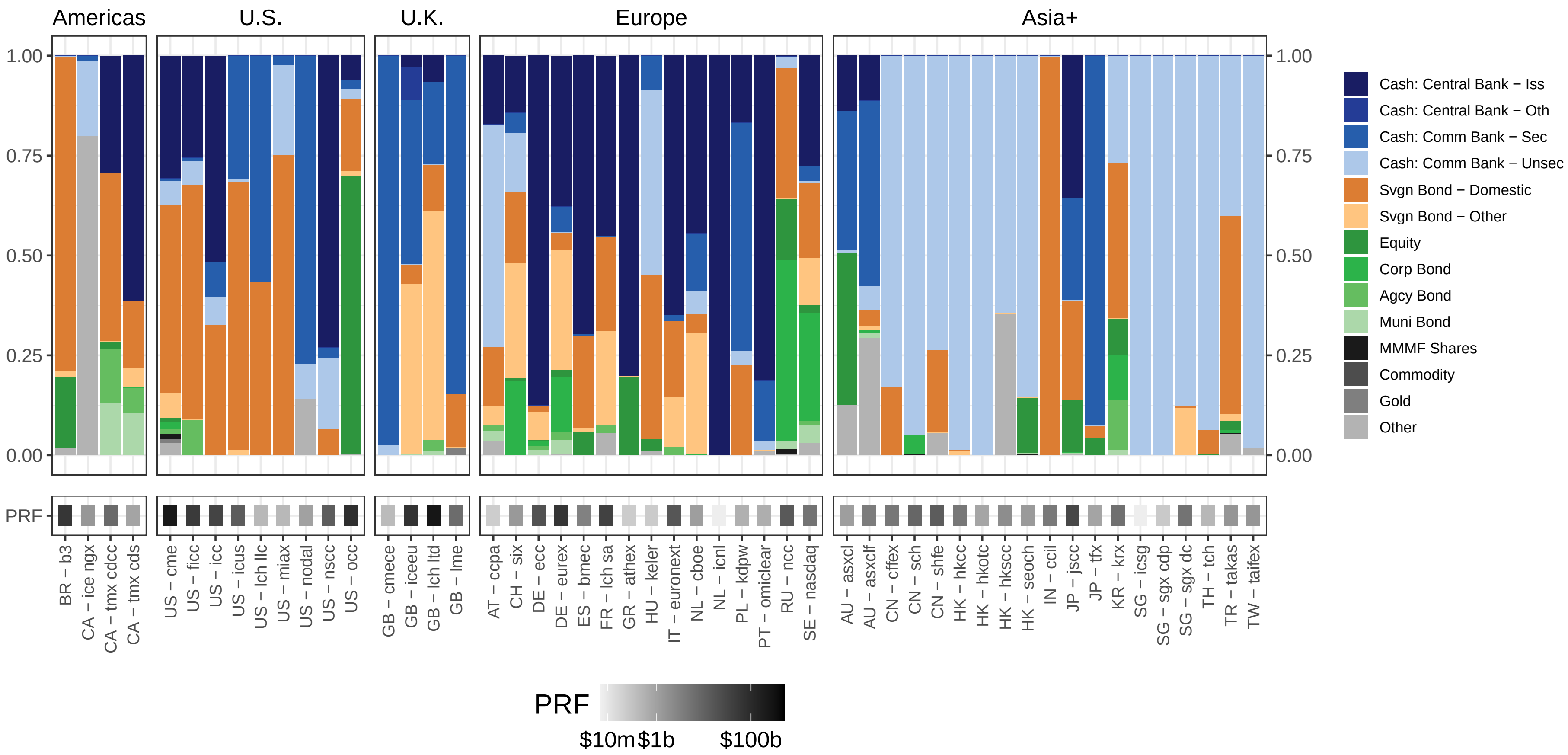
Sources: *ClarusFT CCPView, Authors' analysis.*

Figure 8: Mutualized Resource Intensity, $\frac{DF}{PRF}$, (4.1.1-4; 6.1.1) by CCP, Q3 2015-Q4 2024



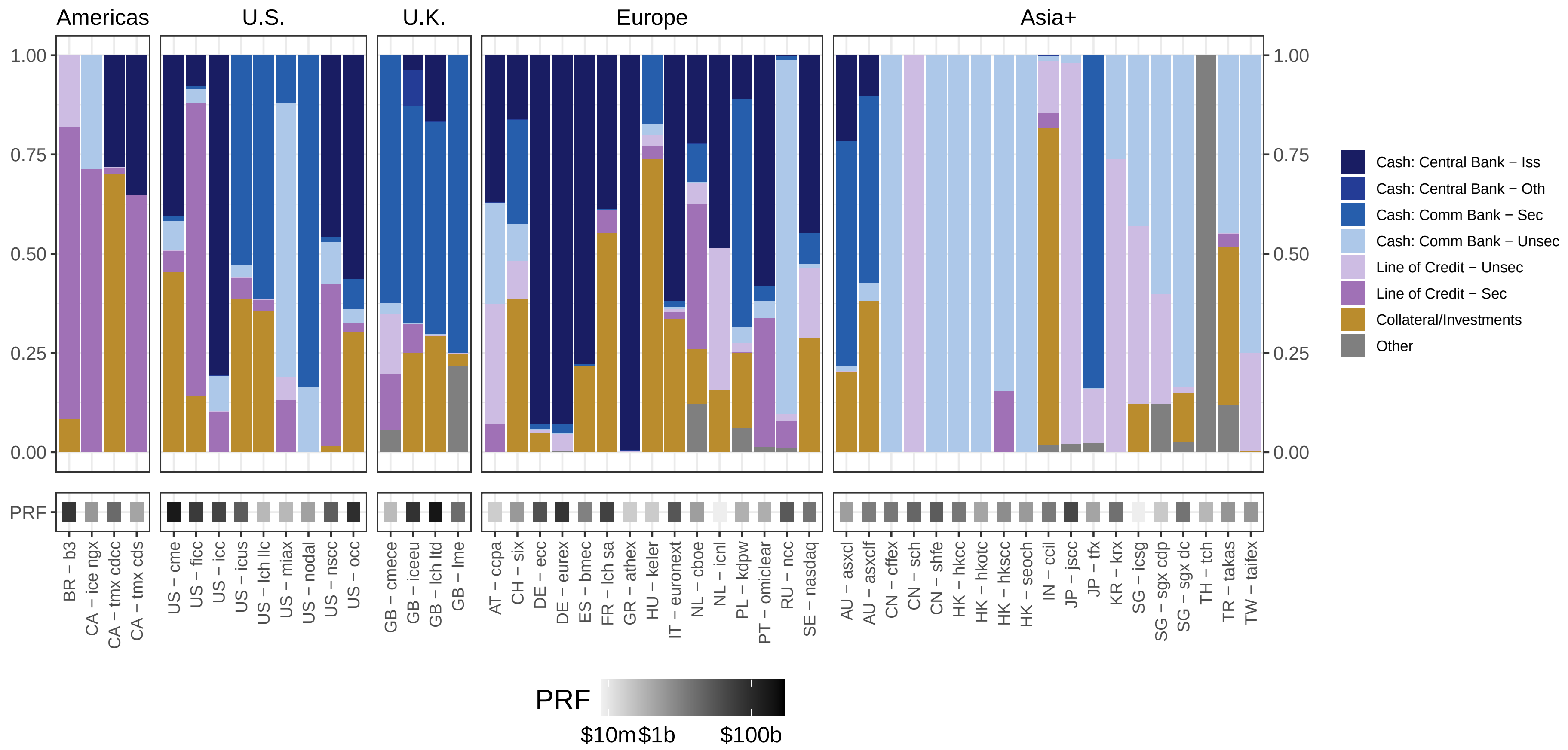
Sources: *ClarusFT CCPView, Authors' analysis.*

Figure 9: PRF Asset Class Composition (4.3; 6.2) by CCP, Q3 2015-Q4 2024



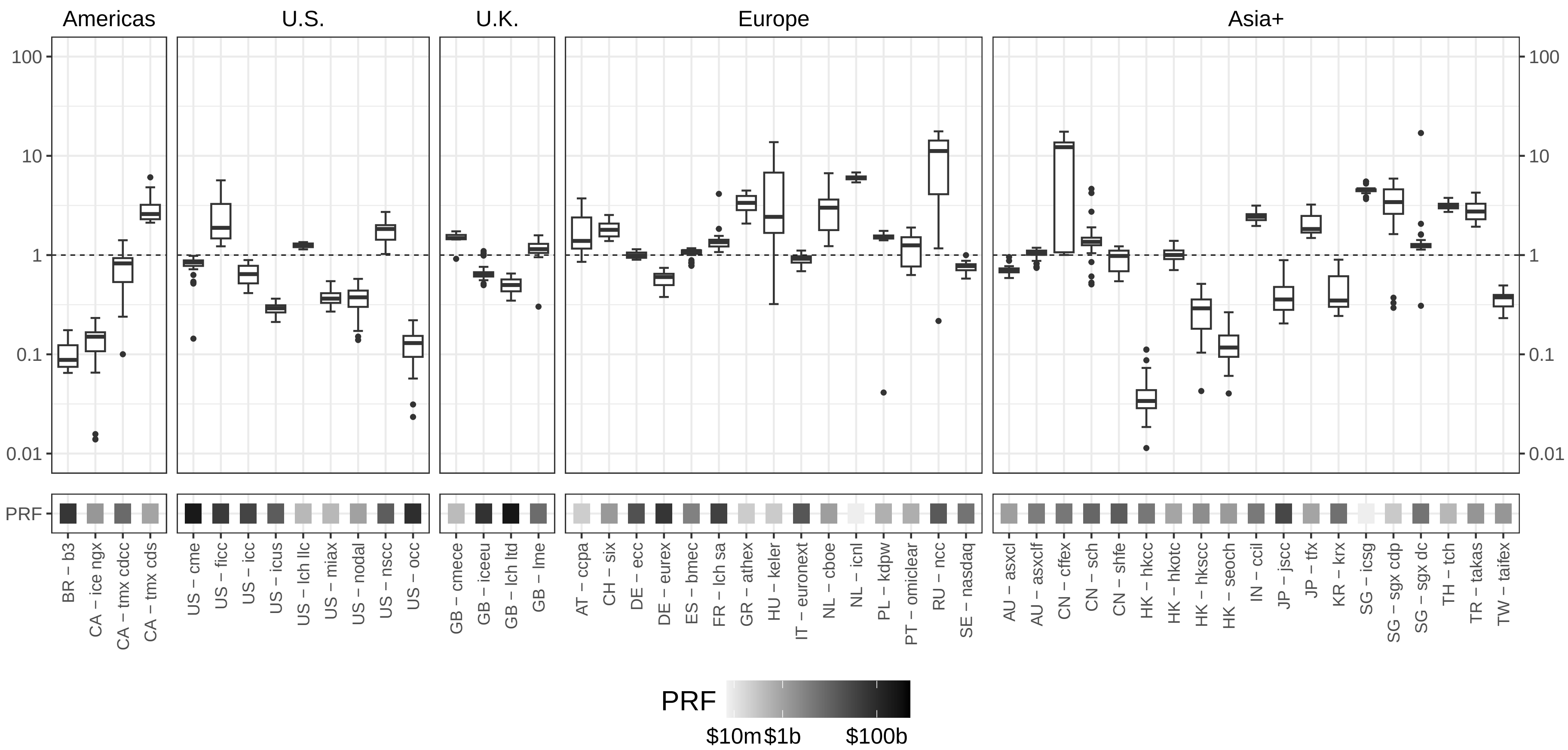
Sources: *ClarusFT CCPView, Authors' analysis.*

Figure 10: LQD Asset Class Composition (7.1-2) by CCP, Q3 2015-Q4 2024



Sources: *ClarusFT CCPView, Authors' analysis.*

Figure 11: Liquid Resource Intensity, $\frac{LQD}{PRF}$, (4.1.1-4; 6.1.1; 7.1-2) by CCP, Q3 2015-Q4 2024



Sources: *ClarusFT CCPView, Authors' analysis.*

6 CCP liquidity management in context

The previous section supplements the more standard analysis of CCP capital resource needs with an analysis of liquid resource needs. In the following section, we consider the significance of the CCP's use of liquid resources. We begin by explicating how CCPs mutualize liquid resources in addition to default losses. Subsequently, we consider potential sources of liquid resource needs that are not well captured by the simple modeling framework used to guide the analysis.

6.1 Risk sharing, resource mutualization, and CCP ownership

6.1.1 Sharing of default loss and funding risks

CCPs offer resource mutualization schemes for market participants facing counterparty credit risk. Counterparty default imposes different costs depending on whether the market transaction involves cash or physical settlement. Both types of transaction carry the possibility of default loss. Physically settled transactions also carry the need for additional funding after the intended time of sale. CCPs offer resource mutualization commensurate with the settlement procedures, which means that physically-settled CCPs actually insure CMs in two distinct ways.

To illustrate this point, we consider how liquid resource demands and capital losses are distributed in the aftermath of a counterparty default. In order to show the mutualization of resource demands, we compare the case of a CCP to the case of a bilateral contract. For comparability, we assume that the margining in bilateral contracts is equivalent to prefunded resources at a CCP with two members and degree of mutualization γ. In practice, this would be equivalent to a collateral scheme in which the IM put up by both members is sufficient only to cover value-at-risk losses indexed by $\alpha' < \alpha$. In order to show the different kinds of resource mutualization offered by different CCPs, we explicitly parameterize the extent of final settlement conducted on a physical basis. For simplicity of exposition, we assume that CCPs use lines of credit to procure liquid resources associated with final settlement payments but not VM payments.

We begin by considering liquid resource needs of surviving members after the default of a cash-paying counterparty. In particular, we consider the period after the failure to pay cash but before the liquidation of the securities intended for sale. During this interval, the CCP raises cash to meet settlement obligations of the defaulters by posting the securities delivered by the defaulters' original counterparties to the lines of credit established at all surviving CMs (including but not limited to the defaulters' original counterparties). Each of these market participants, therefore, experiences a reduction in cash in the amount:

$$\frac{s^{\phi} \cdot oi}{{}^{\#}\!/n - 1} P_{d-1}$$

And an increase in the number of securities on its balance sheet in the amount:

$$\frac{s^{\phi} \cdot oi}{{}^{\#}\!/n - 1}$$

This is a funding shock. In a bilateral arrangement, the original counterparty must finance the position longer than expected because the sale could not be settled. In a cleared arrangement, the original counterparty must contribute to financing the CCP's position, and therefore still requires funding. But because these funding costs are allocated across lines of credit of other CMs, the original counterparty's own contribution is somewhat lessened. In either case, the drawdown of cash is offset by the pledge of collateral, meaning that the CM is not experiencing a capital loss.

For intuition into how mutualization functions as an insurance scheme, consider a market with a large number of market participants, m. Each cash payer has a small and independent probability of default, $p \sim 0$. In a bilateral agreement, we have $\# = 2$ and so with, with probability p, the seller experiences a funding shock of:

$$X^{bilat} = \begin{cases} s^{\phi} oi \cdot P_{d-1} & \text{with prob. } p \\ 0 & \text{with prob. } 1-p \end{cases}$$

By contrast, in the case of a CCP, we have $\# = m$, and the number of defaulting cash payers in any period will tend to $n = p * \frac{\#}{2}$. Surviving sellers then experience a funding shock of:

$$X^{cleared} = \frac{p}{2-p} \cdot s^{\phi} oi \cdot P_{d-1} \underset{p\approx 0}{\approx} \frac{p}{2} \cdot s^{\phi} oi \cdot P_{d-1}$$

The size of the funding shock for surviving sellers has changed in two ways. Firstly, on average it has been reduced by a factor of 2:

$$E[X^{cleared}] = \frac{1}{2} * E[X^{bilat}]$$

This is due to the fact that surviving cash-payers are also responsible for extending credit to the CCP in the scenario when some cash-payers default. There is no such additional source of liquidity in the case of the bilateral contract. Secondly, the funding obligations of the surviving sellers has become more predictable:

$$0 = Var(X^{cleared}) < Var(X^{bilat})$$

This is due to the risk-sharing benefits of gathering the default risks (which were assumed to be idiosyncratic). Note that both of these effects depend on the cleared trades being physically-settled, $s^{\phi} > 0$.

Considering default losses, assume the same market with a mass of market participants, m. Each has independent probability, p, of defaulting. Collateral arrangements provision for adverse market conditions, α, and expected default by members. This is the case in both the bilateral arrangements and in the centrally cleared arrangement. Then, the contribution of prefunded resources of each market participant is:

$$prf = oi * \frac{\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha) + \lambda}{1 + \gamma * \frac{1-p}{p}} \equiv \frac{D^{\alpha}}{1 + \gamma * \frac{1-p}{p}} \approx \frac{D^{\alpha}}{1 + \frac{\gamma}{p}}$$

In the bilateral arrangement, the losses incurred by the surviving member are then given by:

$$Y^{bilat} = \begin{cases} D^{\alpha} - prf \approx \frac{df}{p} & \text{with prob. } p \\ 0 & \text{with prob. } 1-p \end{cases}$$

In the centrally cleared arrangement, $p * m$ members default by the law of large members, and survivors incur the following default losses:

$$Y^{cleared} = \frac{pm*(D^{\alpha} - prf)}{(1-p)m} = \gamma * prf = df$$

Again, comparing the expected losses, we find:

$$E[Y^{cleared}] = E[Y^{bilateral}]$$

And

$$0 = Var(Y^{cleared}) \leq Var(Y^{bilateral})$$

Again, this mechanism completely insures against idiosyncratic risk. Note, though, that in this case Y is not a function of s^{ϕ} and does not vary across physically settled vs cash settled CCPs.

6.1.2 Trade-off theories of resource mutualization

We can consider endogenizing the degree of resource mutualization, γ, according to a trade-off theory as in Wang, Capponi, and H. Zhang (2021). This is different to the analysis in **Section 5** because we are no longer taking γ as given but instead consider how it might be chosen by the CCP. The gist of the trade-off theory is that, on the one hand, mutualizing resources enables the CCP to meet resource demands at lesser expense to the members, a benefit. This is due to the reduced opportunity cost associated with locking up collateral. On the other hand, there are moral hazards associated with mutualizing resources. If losses will be covered by others (i.e. less of a CM's own resources can be seized in the form of IM after a default), then CMs have less incentive to properly mitigate their own credit risk.

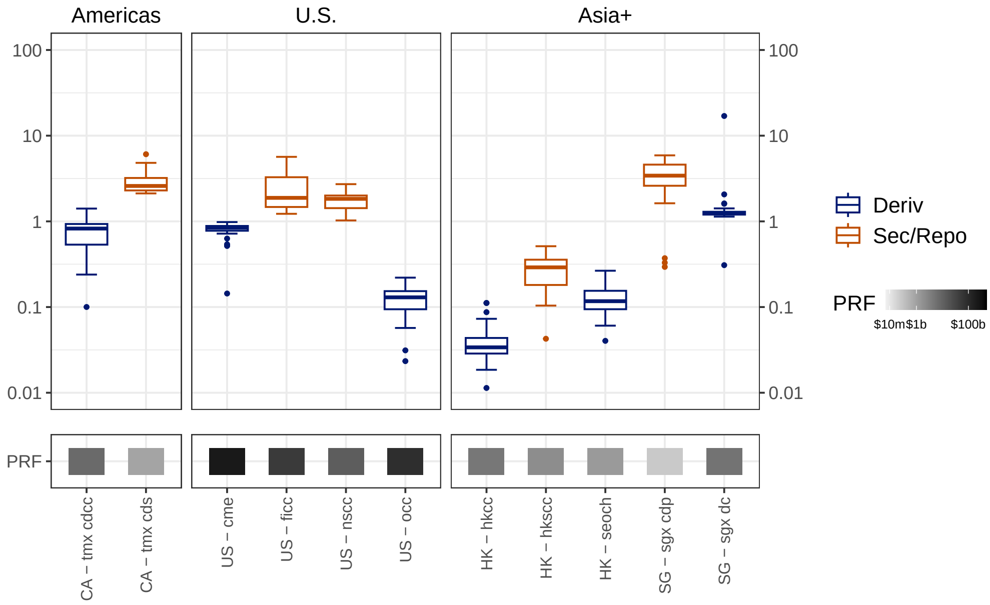
As described in the previous sections, mutualized and prefunded resources have two uses - they can cover liquidity shortfalls and they can cover default losses. Their usefulness in covering liquid shortfalls depends on the degree of turnover of physically settled contracts at a CCP. We might therefore expect a high degree of mutualization at such CCPs.

In fact, this is what we find. While we do not have the data to measure s^{ϕ} directly, in many instances it is possible to compare CCPs predominantly involved in cash and repo transactions, i.e. with physical settlement and high turnover, to CCPs predominantly involved in exchange-traded derivatives transactions, i.e. with much lower turnover and likely more cash settlement. In the U.S., for example, this means comparing FICC and the NSCC to OCC and the CME. In **Figure 12a**, we confirm that cash and repo CCPs have a higher degree of liquid resource intensity, LQD/PRF, than the derivatives CCPs. This is consistent with the prior analysis. **Figure 12b** shows that these cash and repo CCPs also exhibit a higher degree of resource mutualization, $\gamma = DF/PRF$, than their derivatives clearing counterparts.

Finally, we note that there is a degree of complementarity between resource mutualization and common ownership. Where resource mutualization increases, so do the agency costs associated with credit risk management. Collective ownership may help resolve some of these agency costs through, for example, information sharing agreements that allow member-owners to monitor each others' trading behavior. Ownership structure is a discrete variable and so evidence provides less statistical power in a setting with already few observations. However, this hypothesis is consistent with the fact that FICC and NSCC are member-owned rather than privately owned.

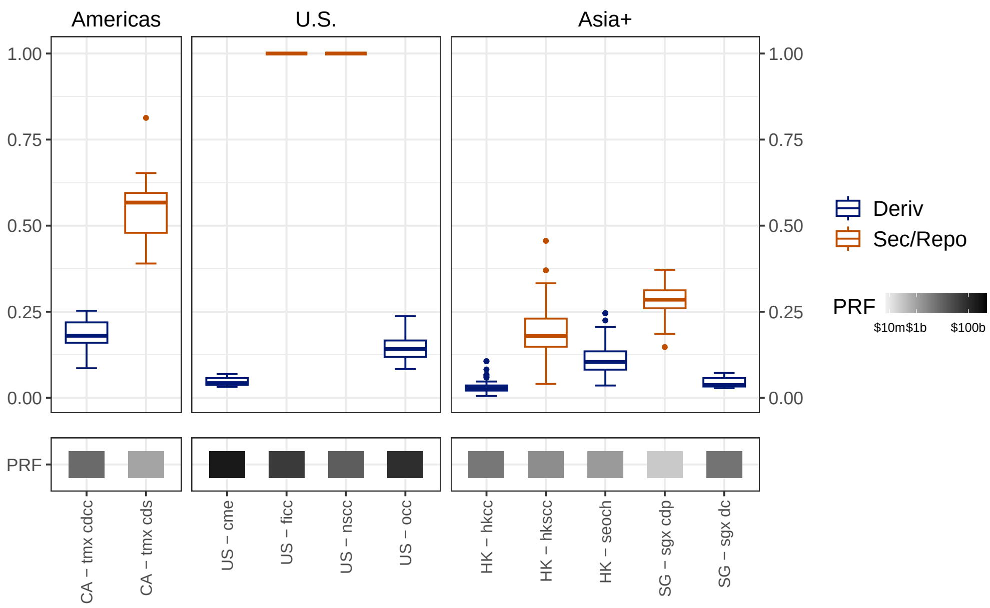
Figure 12: Resource Management at Cash vs. Derivatives CCPs

(a) LQD Intensity, $\frac{LQD}{PRF}$



Sources: *ClarusFT CCPView, Authors' analysis.*

(b) PRF Mutualization, $\frac{DF}{PRF}$



Sources: *ClarusFT CCPView, Authors' analysis.*

6.2 Price dislocations and CCP discipline of market liquidity management

6.2.1 Determinants of CCP liquidity needs

The framework highlights two important sources of liquidity needs that CCPs face when managing the default of a CM. The first are VM obligations that come due before a defaulter's positions have been laid off, $\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha)$. The second are payment obligations due for final settlement of the defaulting member's positions, P_{d-1}.

In our stylized setting, the VM obligations are "second-order" in magnitude, in that they correspond to changes in the price of the underlying security, ΔP. The physical settlement obligations are "first-order" in magnitude, in that they correspond to the level of the price of the underlying security, P_{d-1}. The VM obligations apply to all the positions in the portfolio whereas the final settlement obligations arise only from positions being physically settled during the default window. Finally, VM liquidity needs contribute to capital needs because they represent losses on positions that CCPs have inherited from defaulting members. Final settlement obligations, in contrast, do not constitute capital losses because they are offset by value in the form of the security delivered to the CCP.

The simplicity of the framework helps to clarify these distinct sources of CCP liquidity needs. In some important instances, however, demands on CCP liquid resources in practice may differ from the intuitions built into the framework. Further elaborating the framework is beyond the scope of this paper, but we offer instead some reflections on its limitations.

The reason that VM liquidity needs amount to CCP capital needs is that the price process has been modeled as a random-walk. This means that innovations to the price are entirely permanent; there is no temporary component of these shocks. This, in turn, means that resource demands arising immediately, and therefore requiring liquid resources, persist in expectation to the end of default proceedings when capital losses must also be absorbed. In actuality, price processes may occasionally exhibit reversion. In such an alternative scenario, it is conceivable that a CCP will need to make VM payments for inherited defaulted positions that will be subsequently repaid and therefore not ultimately constitute capital losses.

Additionally, although price changes are generally of smaller magnitudes than price levels, extreme asset market volatility is a hallmark of stress episodes. For example, before the London Metal Exchange tore up contracts in March 2022, the price of nickel contracts had nearly quadrupled in the course of three trading days (Heilbron 2024; see **Figure 13a**). During periods of such pronounced distress, the prospect of default by a CM (as was the case in the LME episode), threatens to saddle the CCP with large associated VM obligations. Short squeezes and fire sales are among the mechanisms that may generate this outsize price fluctuation.

Circumstances in which CCPs face extreme price dislocation and possible price reversion present unique challenges for CCPs. It may be that their liquidity needs in such circumstances are considerably larger than their capital needs. But CCPs may be unable to obtain sufficient credit to cover these needs because they do not have collateral to post. Unlike in the case when liquidity needs arise from obligations in final settlement, CCPs do not have securities on hand. They may not be able to access collateralized lines of credit from their CMs and they may not be eligible for lines of credit from the central bank.[19]

[19] This problem is analogous to the one examined by Bernanke (1990), who considers challenges associated with recapitalizing CCPs after losses. He suggests that the Fed could require banks to help recapitalize CCPs as part of deals to receive *ex-post* emergency funding.

6.2.2 Revisiting the LME and disciplining liquidity management

Market stress at the LME was prompted by a short squeeze. Several market participants including, most prominently, a metal manufacturer named THG, took large short positions in nickel when the price moved against them. Without sufficient liquidity to make the associated margin calls, THG faced the threat of being put in default. To avoid this, it could close out its positions by going long, though it would do so at a loss. And furthermore, doing so would further increase upward price pressure, exacerbating their liquidity needs for any outstanding positions (Heilbron 2024).

A challenge in managing a short squeeze is the behavior of other market participants. Relatively sophisticated and risk-tolerant participants increase demand for the position. Although the price is higher than, say, a discounted cash flow notion of value would suggest, these actors figure the short will need to buy out of its position at inflated prices and so they will turn a profit from the trade. On the other hand, risk-averse participants become concerned that, if they sell but prices continue to rise, they will find themselves with large margin obligations they cannot meet, and will therefore need to close out such positions at a loss. They therefore pull back from putting downward price pressure on the position. Overall, then, liquidity dries up in the market and the prevailing price increases by a first-order magnitude.

When a CCP puts a member into default, it inherits a portfolio of positions on an interim basis. Therefore, it needs enough liquid resources to take over for that member who, in this case, was caught in a short squeeze. Whether the short squeeze continues depends in part on the availability of liquid resources to the CCP. Suppose the CCP has unlimited liquid resources at its disposal. Then, unlike the defaulted clearing member, it will be able to make its margin payments and will not have to close out its positions. This means that the buying pressure from sophisticated market actors will dissipate and the selling pressure from all market actors will resume. And this means that the CCP will not accrue large losses.

When the CCP has more limited liquid resources, it faces a challenge in putting a member into default and taking over that member's positions. If it does so, and market actors are not convinced it has liquid resources to meet its margin obligations, it risks being caught in the same short squeeze as the now defunct member. It will sell positions and sustain large losses. Alternatively, it might (as in the case of the LME) see that the squeezed members' contracts are cancelled, thereby alleviating the liquidity demands. However, in doing so, it will have failed to discipline the offending party for the poor liquidity management that generated the short squeeze in the first place. This threatens to create some moral hazard because the CCP may not be able to credibly commit to putting members in default when circumstances like this arise.

Figure 13a plots the price of 3M Nickel at the LME. The short squeeze produced a spike in prices around March 7-8 of a first-order magnitude, i.e. a change in prices comparable to the level of prices itself. Ordinarily, VM calls correspond to change in prices and so these price changes also imply large VM obligations, to be fulfilled by the CCP itself in the event that CMs defaulted. Importantly, because of the cancellation of contracts, the most dramatic spike in prices, on March 8, did not ultimately stand.

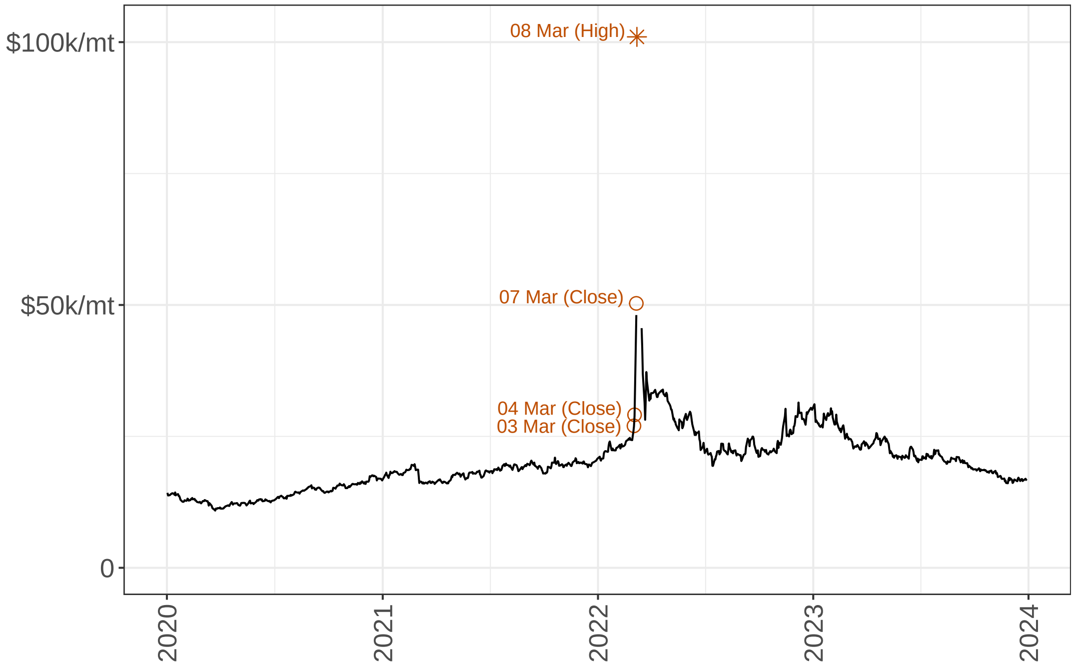
Had the LME not canceled contracts on March 8, LME Clear's liquid resources would have been strained by VM obligations inherited from defaulting CMs. Uncertainty regarding the sufficiency of its liquidity may have failed to end the short squeeze. Based on PQD data at the end of Q4 2021, we estimate LME Clear's available liquid resources to be ∼\$12.5b (see **Figure 13b**).[20] According to LME's scenario analysis on the morning of March 8, standard margining would have required a call of ∼\$20b and would have put 5-12 members into default (Heilbron 2024).[21] Even if surviving CMs were responsible for and made 37.5% of this large VM call, LME Clear's liquid resources would have been wiped out. This suggests that LME Clear risked inheriting the short squeeze from its defaulting members and needing to offload positions on short notice and at large losses.

[20]By the end of Q1 2022, available liquid resources roughly doubled to ∼\$25b. The increase appears to be due to top-up calls in the aftermath of the market stress. Because of increased volatility, LME Clear demanded increased IM contributions. Roughly <\$8b of these were due by end-of-day on March 8 (Heilbron 2024). Such increases would not have been available for LME Clear to cover, for example, mid-day VM obligations on March 8. We therefore judge the level in the prior quarter to better approximate available LQD.

[21]These numbers are larger than PQD estimates of liquidity needs in Q1 2022. First, actual VM payments were mitigated because of the contract cancellation. Second, the PQDs only consider potential or realized payment obligations of the single largest CM, but multiple clearing members threatened default in March 2022 and some smaller CMs had exposure to some of the largest nickel short positions.

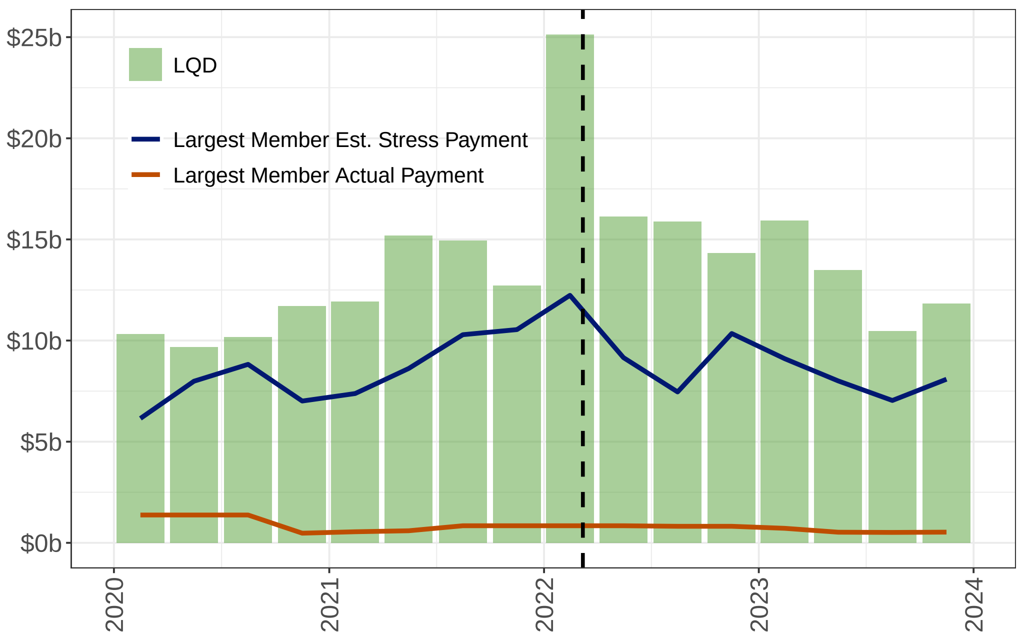
Figure 13: Market Stress and Liquidity Management at the LME

(a) 3M Nickel Price at the LME, 2020-2023



Sources: *Bloomberg Analytics, Authors' analysis.*

(b) Cover-1 Needs (7.3.1,4) and LQD Resources (7.1-2), Q1 2020-Q4 2023



Sources: *ClarusFT CCPView, Authors' analysis.*

7 Conclusion

CCPs manage counterparty credit risk. To do so, among other mechanisms, they require market participants to set aside collateral that can be seized in case of default. Despite this common function, individual CCPs are highly idiosyncratic. They vary in the contracts and underlying securities they clear, their procedures for final settlement, their mutualization of capital and liquid resources, and the nature of the scenarios guiding their risk management.

To illustrate the commonality in CCP market function across these various dimensions of heterogeneity, this paper presents a highly stylized model of CCP liquid and capital resource management. In the framework, it is possible to derive closed-form expressions of required aggregate liquid and prefunded resources as a function of key CCP observable characteristics. Moreover, the paper presents novel summary statistics on the cross-sectional heterogeneity among contemporary CCPs.

A key contribution of this paper is to analyze CCP liquid and capital needs in a common framework. Doing so helps to interpret differences in capital and liquid resources in the cross section of CCPs. It highlights that CCPs, particularly those clearing physically settled contracts, may play a role in mutualizing liquid resources during times of crisis in addition to mutualizing default losses among their members. Finally, it raises questions about the ability of CCPs to meet liquid resource demands at times when market failures drive large but predictably reverting VM obligations.

There are several directions for improvement of the highly stylized modeling framework. It could be useful to extend the framework to better interpret resource management of CCPs clearing options, forwards, and swaps. It could be useful to better account for different size positions among CMs or the house-client structure of most cleared activities. It could be useful to further study instances of predictable price reversion as opposed to a random walk to better understand how CCPs might manage their liquidity needs.

While this paper gives a thorough presentation of publicly available data on CCPs, the extent of these data are limited. Better standardized, more frequent, and more granular data are essential for better understanding the behavior of CCPs, the adequacy of their risk-management, and the types of systemic risks they may pose. A non-exhaustive list of fields that could be improved in this regard are: CCP services, contract types, trading volumes, settlement procedures, linked market impact measures and benchmark volatilities, concentration charges, and house and client trade activity and margining. While clearing has helped improve direct supervisory insight into market activity, the promise of better market transparency through mandated central clearing has gone, to a large extent, as yet unrealized.

8 Tables

Table 4: CCP Sample Summary Statistics

	N	$\bar{x}$	s_x	min	p25	p50	p75	max
Sample Characteristics								
$1\{2024Q4\}$	51	0.90	0.30	0	1	1	1	1
# Quarters	51	29	9.3	2	24	31	37	37
CCP Size								
PRF ($b)	51	21.5	41	0	0.9	5.2	18.3	197.4
%Δ PRF	51	$881k\%$	$6m\%$	-36%	18%	30%	70%	$45m\%$
Service Count	51	2	2	1	1	2	3	10
CM Count (min)	50	62.8	98.5	3	16	29	65	602
CM Count (max)	50	93.9	110.5	3	29	61	120	602
Resource Composition								
$\frac{\text{SITG}}{\text{PRF}}$	51	0.076	0.15	0	0.0027	0.017	0.041	0.62
$\frac{\text{DF}}{\text{PRF}}$	51	0.20	0.18	0	0.072	0.14	0.30	0.86
$\frac{\text{IM}}{\text{PRF}}$	51	0.72	0.27	0	0.58	0.83	0.91	0.99
$\frac{\text{LQD}}{\text{PRF}}$	51	1.8	2.1	0.041	0.54	1.0	2.2	11
Top-5 %IM (min)	49	51.5%	17.6%	20%	38%	50%	62%	92%

Continued on next page

	N	$\bar{x}$	s_x	min	p25	p50	p75	max
Top-5 %IM (max)	49	64.4%	19.5%	23%	49%	63%	83%	92%
Trade Flows								
ADV ($ notional)	35	\$542k	\$1m	\$1	\$316	\$14k	\$114k	\$7m
OI ($ notional)	33	\$9m	\$32m	\$3	\$8k	\$150k	\$1m	\$176m
$\frac{\text{ADV}}{\text{OI}}$ Turnover Rate	33	20k%	72k%	0%	4%	22%	73%	361k%
Top-5 %OI (min)	48	52.5%	17.9%	24%	37%	53%	62%	98%
Top-5 %OI (max)	48	65.3%	19.6%	24%	52%	67%	81%	98%
CCP Risk Management								
PRF Cover-n (min)	51	1.9	0.5	1	2	2	2	3
PRF Cover-n (max)	51	2	0.7	1	2	2	2	5
LQD Cover-n (min)	51	1.8	0.6	1	1	2	2	3
LQD Cover-n (max)	51	1.8	0.6	1	1	2	2	4
MPOR (min)	51	2.7	1.8	1	2	2	3	10
MPOR (max)	51	3.8	2.4	1	2	3	5	10
VaR CI (min)	47	99.12	0.54	96.11	99	99	99.41	99.87
VaR CI (max)	47	99.35	0.34	99	99	99.4	99.7	99.96
Cleared Product Footprint (IM)								
CMD %IM	49	0.14	0.33	0	0	0	3.4e-4	1.0

Continued on next page

	N	$\bar{x}$	s_x	min	p25	p50	p75	max
CRD %IM	49	0.026	0.14	0	0	0	0	1.0
EQD %IM	49	0.083	0.25	0	0	0	0	1.0
FXD %IM	49	0.041	0.17	0	0	0	0	0.87
IRD %IM	49	0.054	0.15	0	0	0	0	0.89
Multi (Deriv) %IM	49	0.27	0.39	0	0	0	0.53	1.0
Cash %IM	49	0.18	0.35	0	0	0	0.23	1.0
SFT %IM	49	0.077	0.20	0	0	0	0	0.76
Multi (Deriv & Cash) %IM	49	0.093	0.27	0	0	0	0	1.0
Cleared Product Footprint (OI)								
CMD %OI	36	0.058	0.23	0	0	0	0	1.0
CRD %OI	36	0.077	0.25	0	0	0	0	1.0
EQD %OI	36	0.059	0.21	0	0	0	3.3e-5	1.0
FXD %OI	36	0.021	0.065	0	0	0	0	0.27
IRD %OI	36	0.39	0.48	0	0	0	0.99	1.0
Multi (Deriv) %OI	36	0	0	0	0	0	0	0
Oth (Deriv) %OI	36	4.7e-5	2.8e-4	0	0	0	0	0.0017
Cash %OI	36	0.28	0.44	0	0	0	0.85	1.0
SFT %OI	36	0.047	0.20	0	0	0	0	0.95

Sources: *ClarusFT CCPView, Author's Analysis*

Table 5: Parameters in Analytical Framework

Category	Parameter	Description	Data Sources	Figure
CCP Structure	#	The total number of CMs at the CCP.	CPMI-IOSCO PQDs: 18.1.3.1-3.	Figure 4 Panel 1.
	-	The total number of clients at the CCP.	CPMI-IOSCO PQDs: 19.1.1.	Figure 4 Panel 2.
	-	Number of clearing services within the CCP.	CPMI-IOSCO PQDs and Qualitative Disclosures.	Figure 4 Panel 4.
Trade Volumes	$adv = N$	Notional (average) daily volume of a single CM.	-	-
	$ADV = \# * adv$	Notional (average) daily volume.	CPMI-IOSCO PQDs: 23.1.2, ClarusFT CCPView CCP Volumes, CCP Websites	Figure 6 Panel 2.
	$oi = N * T$	Total notional outstanding of a single CM.	-	-
	$OI = \# * oi$	Total notional outstanding at a CCP.	CPMI-IOSCO PQDs: 23.2.1, ClarusFT CCPView CCP Volumes, CCP Websites.	Figure 6 Panel 2.

Continued on next page

Category	Parameter	Description	Data Sources	Figure
	s^{ϕ}	Share of outstanding notional under physical settlement in a given period. Note that spot and repo contracts are necessarily physically settled, though the rate of turnover of these contracts may vary. Some derivatives contracts may be physically settled if, for example, the trading parties' goals are to obtain the underlying in addition to hedging or gaining exposure to some risk. The extent and degree of turnover of these contracts is an empirical question.	Inferences about transaction type. CCP Websites.	-
	s^{χ}	Share of outstanding notional under cash settlement in a given period. Derivatives contracts may be cash settled if, for example, parties' goals are to obtain exposure to certain risks rather than actually obtain the underlying.	Inferences about transaction type. CCP Websites.	-

Continued on next page

Category	Parameter	Description	Data Sources	Figure
	$s \equiv s^{\phi} + s^{\chi}$ $= \tau * \frac{ADV}{OI} = \frac{\tau}{T}$	Total share of outstanding notional settling in a given period.	Approximated by $\frac{ADV}{OI}$ from ClarusFT CCPView CCP Volumes. Note this is related to $(Tenor)^{-1}$ also available in CCP Volumes data.	Figure 6 Panels 1.
Market Characteristics	a	Asset class of transactions cleared by CCP.	CPMI-IOSCO PQDs and Qualitative Disclosures. CCP Websites. ECB Analysis.	Figure 5 Panels 1-3.
	σ	the volatility of the cleared positions.	Bloomberg.	-
	$\lambda(.)$	Liquidity of the market for replacing the cleared positions.	-	-
Risk Management Features	n	Number of CMs accounted for in the cover-n rule. Note this can differ for loss and liquidity stress scenarios.	CPMI-IOSCO PQDs: 4.4.1 for PRF, 7.1.1 for LQD	Figure 7 Panel 4.
	$p_n \equiv \frac{n}{\#}$	The equal weighted proportion of cover-n CMs.	See n and #; CPMI-IOSCO PQDs: 18.2-3 for concentration.	-

Continued on next page

Category	Parameter	Description	Data Sources	Figure
	$\kappa_n \equiv \frac{\overline{oi}_n}{\overline{oi}_{\#}}$	Concentration as measured by the ratio of average OI of the cover-n CMs to all CMs. This functions like a change of measure converting the equal-weighted proportion of cover-n CMs to an activity-weighted proportion. In practice, we estimate $$\kappa_n \approx \kappa_{\text{top-5}} = \frac{\overline{oi}_{\text{top-5}}}{\overline{oi}_{\#}} = \frac{\#}{5} * \%OI_{\text{top-5}}$$ This is generally biased downward because cover-n CMs are defined as the largest 1-2 in most all cases.	CPMI-IOSCO PQDs: 18.2-3.	Figure 7 Panel 3.
	$\gamma = \frac{DF}{PRF}$	the degree of mutualization of the CCP's resources.	CPMI-IOSCO PQDs: see DF and PRF.	Figure 8 Panel 1.
	$W \sim \Phi$	Modeling of tail risk.	CPMI-IOSCO PQDs: 6.4.1-12 (provides some modeling choices).	-
	α	CCP risk-tolerance. The percentile of price fluctuation for which a CCP aims to cover default losses.	CPMI-IOSCO PQDs: 6.4.5.	Figure 7 Panel 1.
	τ	The margin period of risk (MPOR).	CPMI-IOSCO PQDs: 6.4.11.	Figure 7 Panel 2.

Continued on next page

Category	Parameter	Description	Data Sources	Figure
Resource Demands	*CAP*	Total capital resources.	CPMI-IOSCO PQDs: 4.1.1-3 (SITG), 4.1.4 (DF), 4.1.7 (CMT), 6.1.1 (IM).	-
	PRF	Total prefunded resources.	CPMI-IOSCO PQDs: 4.1.1-3 (SITG), 4.1.4 (DF), 6.1.1 (IM).	Figure 4 Panel 5.
	IM	Total initial margin contributions. Non-mutualized prefunded resources contributed by CMs.	CPMI-IOSCO PQDs: 6.1.1.	-
	DF	Total default fund resources. All mutualized prefunded resources.	CPMI-IOSCO PQDs: 4.1.4.	Figure 8 Panel 1.
	CMT	Total committed resources. Includes commitments by CMs to contribute resources in event of participant default. (N.B. Does not include CCP commitments or CM commitments to replenish the default funds.)	CPMI-IOSCO PQDs: 4.1.7.	-
	LQD	Total liquid resources. N.B. What "counts" as liquid depends on what can be accessed on the time-scale of default, usually several hours under turbulent market conditions.	CPMI-IOSCO PQDs: 7.1-2.	Figure 11 Panel 1.
	LOC	Total lines of credit.	CPMI-IOSCO PQDs: 7.1.6-7.	Figure 10 Panel 1.

A Repo Clearing

A.1 Margining and settlement of repo contracts

As a particularly salient application of both cash and futures transactions with physical settlement, we consider the margining of a repo transaction. Note that a repo transaction is the coincident placement of the sale of a security today and a purchase today of a futures transaction coming due tomorrow. We consider a pairs of cash-borrowers, who sell and subsequently repurchase securities, and cash-lenders, who purchase and subsequently resell them. We consider the standpoint of the cash-borrower in what follows.

Consider the quantity of repo position of the cash-borrower as the notional value of positions sold, N_t. This means both that the cash-borrower has contracted to sell N_t of securities in the spot market at date t and also has gone long N_t futures contracts. We consider a case of overnight repo, in which the tenor of the futures contract is one period, $T = 1$.

Note that the net sales by the cash-borrower in a given period is given by:

$$\Delta N_t \equiv N_t - N_{t-1}$$

N_t are new repo which the cash-borrower commits to at date t. N_{t-1} are expiring repo for which the futures contract is coming due at date t.

We suppose net sales in each period are settled physically and that final settlement is delayed by ϕ periods. We assume VM is exchanged during the tenor of the futures contract as well as during the entire period of final settlement and that the security is purchased at $P_{t+\phi}$. The margin and settlement obligations of the cash-borrower at date $t+1$ are then:

$$\text{Sources of cash obligations} \begin{cases} \sum_{j=1}^{\phi} \Delta N_{t-j+1} * \Delta P_{t+1} & \textit{vm} \text{ paid for net sales in settlement} \\ \quad = (N_t - N_{t-\phi}) * \Delta P_{t+1} & \\ N_t * \Delta P_{t+1} & \textit{vm} \text{ received for long futures at } t \\ \Delta N_{t-\phi+1} * P_{t+1} & \textit{trf} \text{ received to settle net sales at } t-\phi+1 \end{cases}$$

Note that total VM received is:

$$\left[N_t - (N_t - N_{t-\phi})\right] * \Delta P_{t+1} = N_{t-\phi} \Delta P_{t+1}$$

It is as though the cash-borrower is paying VM on long futures placed at $t-\phi$ and margined at $t-\phi+1$ rather than the futures placed one period ago at t. The futures placed at t are offset by the purchases made at t which have been executed but are still being margined because they have not yet been settled. The number of purchases made at t exactly offsets the number of sales made at $t-1$, and so the VM obligations offset as well, and so on. The purchases made at $t-\phi+1$, however, are due to futures contracts placed at $t-\phi$. These would be offset by sales made at $t-\phi$, but these sales have already finished settlement at date t. The participant must pay the margin associated with those purchases.

Note also that, if the cash-borrower maintains a constant repo position, $N_t = N$, there are no transferred resources for final settlement as $\Delta N_{t-\phi+1} = 0$. The only obligations are VM obligations associated with futures or purchase orders that have not yet reached final settlement.

A.2 Prefunded and liquid resources requirements for repo contracts

We consider a settlement period of ϕ, a MPOR of τ, and a borrower who borrows in various tenors, $T \in \mathbb{T}$. We note the notional quantity of repo borrowing done in each tenor by N_T. We assume there is no interest rate on the repo contract and also that there is no haircut. The borrower rolls over each of these contracts upon termination. At any one point in time, the OI in any one tenor is given by $OI_T = N_T(T+\phi)$. The total OI is then $OI = \sum_{T\in\mathbb{T}} N_T * (T+\phi)$.

We CCP resource needs after the default of a CM who is a cash borrower, m. We begin by examining a single tenor of contract, T. **Figure 14** gives a schema for considering the kinds of positions the CCP must lay off in this scenario. The last date of contract is d, at $d+1$ the CM fails to make VM payments and is put in technical default, and by $d+\tau$ the CCP anticipates having laid off all inherited positions.

m has some securities sales (the first leg of a repo contract) that have not yet been finally settled at $d+1$. In general these are any positions that have not yet been settled by $d+\phi$, which is the date when the most recent purchases, those made at d, will be settled. Supposing m fails to produce the defaulted securities, the CCP will need to obtain these by purchasing them. For the sake of exposition, we might assume they borrow them temporarily and make the outright purchase at $d+\tau$. The amount of such purchases will be $\frac{\phi}{T+\phi}OI_T$.

The cash borrower will also be long futures contracts that have not yet been settled. These include positions with a final settlement date up to $d+T+\phi$, the date of settlement for the closing leg of the most recently placed repo contracts. Contracts settling after $d+\tau$ can be replaced by going short futures contracts, placed by the end of the MPOR. Contracts settling before $d+\tau$ will have to be purchased outright, requiring interim liquidity. These securities can be sold by the end of the MPOR. From the analysis in the main text, the ultimate losses associated with laying off a purchased security or selling a futures contract are identical under our assumptions. The total volume of required sales are OI_T.

We assume that securities received for defaulted purchases cannot be used to fulfill defaulted sales. And that offloading securities on the open market with simultaneous purchases and sales does not offset market impact. Note, though, that cash received as VM from a sale can be used towards a purchase and *vice versa*. The interim liquidity needs accruing by the end of the MPOR are therefore:

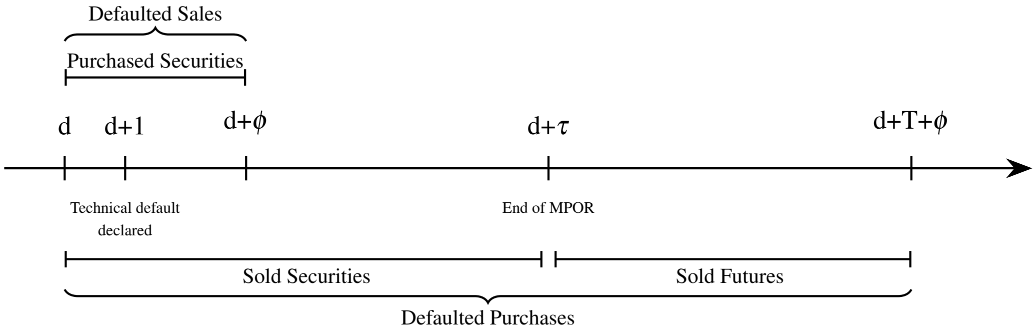
$$oi_T * [\frac{\tau}{T+\phi}P_d + \frac{T-\tau}{T+\phi}\sqrt{\tau}\sigma \cdot W]$$

The ultimate capital losses once the risks have been laid off at the end of the MPOR are:

$$oi_T * [\frac{T}{T+\phi}\sqrt{\tau}\sigma \cdot W + \frac{T+2\phi}{T+\phi}\lambda(\cdot)]$$

The total liquidity and capital needs can be obtained by summing up across the various contract tenors. And the level of required liquid and prefunded capital resources can be determined in the usual way, by a choice of scenario involving Cover-n defaults and sufficiently adverse market conditions, α.

Figure 14: Contract replacement by repo CCP for default by cash borrower



Source: *Authors' creation.*

A.3 Institutional features of FICC

FICC is the CCP responsible for clearing transactions of U.S. Treasuries and mortgage-backed securities. Because the market for U.S. Treasuries is large and systemic, FICC is an important institution to understand in its own right. Moreover, FICC has many design features that make it distinctive even among CCPs. The purpose of this section is to provide a brief overview of the design features at FICC, clarify how they relate to our more general schema for CCPs, and suggest that some design features are well-suited to FICC's role in clearing repo transactions.

FICC is composed of two corporate divisions and various clearing services. The government securities division (FICC-GSD) clears cash and repo Treasury transactions and repo of mortgage-backed securities. FICC-GSD supports multiple clearing services, including delivery-versus-payment (DVP) for cleared bilateral repo transactions, as well as general collateral finance (GCF) for trilateral repo transactions for which the Federal Reserve Bank of New York (BONY) manages the collateral (Hempel et al. 2022). The mortgage-backed securities division (FICC-MBSD) clears cash MBS transactions.

Some of FICC's design features are analogous to those at other CCPs, but differ in naming conventions. FICC facilitates cash transfers including VM payments through a mechanism known as "funds-only settlement" (FOS), it maintains mutualized prefunded resources akin to a default fund in its "clearing fund", and it requires members to pledge lines of credit through its "capped contingency liquidity facility" (CCLF).

Still, several features of FICC's institutional design are distinctive, if not entirely unique, among CCPs. We summarize some of these below:

1. FICC relies on a high degree of liquid resources and lines-of-credit in particular.
2. FICC mutualizes the contents of the "clearing fund" entirely.
3. FICC is owned by its clearing members rather than by independent shareholders.
4. FICC has a cross-margining agreement with the CME.
5. FICC makes a variety of models available for clients to access clearing services. These include the Sponsored Clearing Model (SCM) and the Agency Clearing Model (ACM).

In many cases, these design features relate to the requirements and opportunities associated with clearing repo transactions. Repo transactions are distinctive because they are economically equivalent to two transactions: a cash sale and subsequent futures purchase of a piece of collateral. Because parties to a repo transaction wish to make use of each others' cash and securities temporarily, these trades must be settled physically. And, finally, even when repo are not centrally cleared, it is common for there to be contracted haircuts, reductions in cash relative to the security value, to protect the cash lender from default by the borrower.

As spelled out in the main text, features 1-3 are consistent with the physical settlement entailed by repo contracts. The CCP may need large amounts of liquid resources in default, may provide better risk sharing among members by mutualizing resources, and may remain member owned because of complementarities with mutualization. Feature 4 relates to the fact that repo contain futures transactions that are natural hedges for the Treasury futures traded on the CME. Though important, feature 5 is beyond the scope of our framework as we have abstracted away from client-clearing.

B Market Concentration

The main text makes the simplifying assumption that all market participants hold positions of the same size (though of potentially opposite directionality). In practice, there is considerable concentration in the activity of market participants. A few players are responsible for the majority of trades. This is depicted in **Figure 7** Panel 3 depicts this concentration.

In this section, we relax the assumption of identically sized positions and show how our expressions can be generalized to a simple setting with heterogeneous levels of market activity across participants. While these expressions develop intuition and further facilitate a mapping between our analytical exposition and publicly available data, they continue to rely on somewhat restrictive assumptions. Among these are (i) all members' prefunded resource contributions are penalized for increasing concentration of the cover-n institutions and (ii) initial margin contributions scale perfectly with market activity. We document in **Figure 7** Panel 3 that (ii) is roughly but not perfectly true.

We define the cover-n OI concentration, κ_n^{oi} as the average aggregate position size of the institutions hypothetically defaulting under the cover-n scenario relative to the average aggregate position size of all members:

$$\kappa_n^{oi} \equiv \frac{\overline{oi}_n}{\overline{oi}_\#}$$

We define the cover-n initial margin concentration, κ_n^{im}, in an analogous way:

$$\kappa_n^{im} \equiv \frac{\overline{im}_n}{\overline{im}_\#}$$

We suppose these are equal and so define a single cover-n concentration measure:

$$\kappa_n \equiv \kappa_n^{oi} = \kappa_n^{im}$$

Note that this measure is 1 when all positions are of equal size and therefore our formulas will reduce to the formulas in the main text. When there is variation, because the cover-n rules generally assume default of the largest institutions, we will have that $\kappa_n > 1$.

To see the influence of this concentration measures, we begin by rewriting our expressions equating available prefunded resources with losses. In this instance, we must keep track of the prefunded resource contributions and OI of distinct clearing members because they may vary.

$$\sum_{i\in D^n} im_i + \sum_{i\in CM} df_i = \sum_{i\in D^n} oi_i \Big[\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha) + \lambda\Big(\sum_{i\in D^n} oi_i\Big)\Big]$$

We can rewrite this using the concentration measure κ_n:

$$p_n\kappa_n \cdot IM + DF = p_n\kappa_n \cdot OI[\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha) + \lambda(p_n\kappa_n \cdot OI)]$$

The we rearrange the expression. We can rewrite IM and DF in terms of γ and PRF, divide both sides by $p_n\kappa_n$, and isolate PRF on one side of the equation to obtain:

$$PRF = OI * \frac{\sqrt{\tau}\sigma \cdot \Phi^{-1}(\alpha) + \lambda(p_n\kappa_n \cdot OI)}{1 + (\frac{1}{p_n\kappa_n} - 1) \cdot \gamma}$$

Note that this reduces to the expression in the main text when $\kappa_n = 1$. Note that the same intuition from the main text holds. There is a scaling up of the amount of DF resources available in the event of default because these resources are mutualized. Because prefunded resources are held in proportion to activity, though, the extent of additional resources available is dampened by the extent of concentration.

C CCP Assessment Powers

As described in **Section 5.3**, a CCP has three primary sources of loss-absorbing capital: initial margins, default fund contributions, and committed resources.[22] These varieties of capital are distinguished by their position in the waterfall, but also by their availability to cover different types of default losses. In particular, each may or may not be available to cover losses associated with the contributing member's default or another CM's default.

We can derive an expression for total capital resources, CAP, from trade and risk-management fundamentals in our highly stylized setting. We consider a new default scenario, defined by Cover-$\widehat{n}$ and value-at-risk confidence level $\widehat{\alpha}$. In this scenario, total capital resources must absorb the default losses associated with $\widehat{n}$ simultaneous defaults after adverse market conditions indexed by $\widehat{\alpha}$. We also define $\widehat{\gamma}^{df} \equiv \frac{DF}{CAP}$ and $\widehat{\gamma}^{cmt} \equiv \frac{CMT}{CAP}$. These represent measures of slightly different forms of loss mutualization. We assume that $CAP = IM + DF + CMT$ and so $1 - \widehat{\gamma}^{df} - \widehat{\gamma}^{cmt} = \frac{IM}{CAP}$.

As in the main text, we set available capital equal to capital needs:

$$\widehat{n} * im + \# * df + (\# - \widehat{n}) * cmt = \widehat{n} * oi[\sqrt{\tau}\sigma \cdot \Phi^{-1}(\widehat{\alpha}) + \lambda(\widehat{n}/\# * OI)]$$

We rearrange the expression, substituting in the measures of capital mutualization, to obtain:

$$CAP = \# * \frac{oi[\sqrt{\tau}\sigma \cdot \Phi^{-1}(\widehat{\alpha}) + \lambda(\widehat{n}/\# * OI)]}{(1 - \widehat{\gamma}^{cmt}) + (\#/\widehat{n} - 1)(\widehat{\gamma}^{df} + \widehat{\gamma}^{cmt})} \equiv \# * \frac{\widehat{T}_1}{\widehat{T}_2}$$

[22] We set aside skin-in-the-game resources, which are small and intended primarily for incentive alignment rather than loss absorption

Again, the term $\widehat{T}_1$ indicates the losses incurred by the CCP for each default, $default^{-1}$. The term $\widehat{T}_2$ indicates the amount of resources available for each default, measured in units of an individual member's capital contributions, $cap^{-1}default^{-1}$. The ratio determines the size of each member's capital contribution, and this is scaled by the number of members, # to determine the aggregate CCP capital resources.

In the denominator, note that only a defaulting member's *im* and df contributions are available when they default. This means that $(1-\widehat{\gamma}^{cmt})$ of their own capital contributions are available. As before, there are $\frac{\#}{\widehat{n}} - 1$ non defaulting members available to contribute mutualized resources for each defaulting member in the cover-$\widehat{n}$ scenario. These non-defaulting members make df and *cmt* resources available, that is $(\widehat{\gamma}^{df} + \widehat{\gamma}^{cmt})$ of their total capital resource contributions.

Because committed resources require the intercession of a CM to make them available to the CCP, we suppose that they are not available for use on demand by the CCP, and therefore do not count toward liquid resource totals, *LQD*. Substituting in the new expression for capital resources, the remainder of our analysis is therefore unchanged.

References

Acemoglu, Daron, Asuman Ozdaglar, and Alireza Tahbaz-Salehi. Systemic Risk and Stability in Financial Networks. American Economic Review 105.2 (Feb. 2015), pp. 564–608. ISSN: 0002-8282. https://search.ebscohost.com/login.aspx?direct=true&db=eoh&AN=1471422&site=ehost-live&scope=site (visited on 01/25/2023).

Aldasoro, Iñaki, Fernando Avalos, and Wenqian Huang. Liquid assets at CCPs and systemic liquidity risks. BIS Quarterly Review (Dec. 2023).

Baer, Herbert L. et al. Opportunity Cost and Prudentiality: An Analysis of Collateral Decisions in Bilateral and Multilateral Settings. eng. *Research in Finance. Vol. 21*. Ed. by Andrew H. Chen. Bingley, U.K: Emerald, 2005. ISBN: 9781849503136.

Benos, Evangelos, Gerardo Ferrara, and Angelo Ranaldo. Collateral Cycles. Bank of England Staff Working Paper (Apr. 2023).

Bernanke, Ben S. Clearing and Settlement during the Crash. The Review of Financial Studies 3.1 (1990), pp. 133–151. ISSN: 08939454, 14657368. http://www.jstor.org/stable/2961962 (visited on 07/13/2025).

Biais, Bruno, Florian Heider, and Marie Hoerova. Clearing, Counterparty Risk and Aggregate Risk. ECB Working Paper Series (Oct. 2012).

Bignon, Vincent and Guillaume Vuillemey. The Failure of a Clearinghouse: Empirical Evidence*. Review of Finance 24.1 (Dec. 2018), pp. 99–128. ISSN: 1572-3097. DOI: 10.1093/rof/rfy039. eprint: https://academic.oup.com/rof/article-pdf/24/1/99/31899415/rfy039.pdf.

Capponi, Agostino et al. The collateral rule: Evidence from the credit default swap market. Journal of Monetary Economics 126 (2022), pp. 58–86. ISSN: 0304-3932. DOI: 10.1016/j.jmoneco.2021.12.003. https://www.sciencedirect.com/science/article/pii/S0304393221001458.

Chang, Felix B. The Systemic Risk Paradox. en. Columbia Business Law Review (2015), Vol. 2014 No. 3. DOI: 10.7916/CBLR.V2014I3.1783.

CME Group. *CME Group Response to IOSCO's Consultation Document on Resilience and recovery of central counterparties (CCPs): Further guidance on the PFMI*. Tech. rep. 2016.

Cont, Rama and Samim Ghamami. Skin in the Game: Risk Analysis of Central Counterparties. SSRN Electronic Journal (Sept. 27, 2023). ISSN: 1556-5068. DOI: 10.2139/ssrn.4584822.

Cont, Rama and Thomas Kokholm. Central Clearing of OTC Derivatives: Bilateral vs Multilateral Netting. en. SSRN 2140055 (Sept. 2012). DOI: 10.2139/ssrn.2140055. https://papers.ssrn.com/abstract=2140055 (visited on 03/27/2023).

Cox, John Carrington and Mark Rubinstein. *Options markets*. 22. print. Upper Saddle River, NJ: Prentice-Hall, 2002. 498 pp. ISBN: 0136382053.

Cox, Robert T. and Robert S. Steigerwald. "Incomplete demutualization" and financial market infrastructure: central counterparty ownership and governance after the crisis of 2008–9. The Journal of Financial Market Infrastructures 4.3 (Mar. 2016), pp. 25–38. ISSN: 2049-5404. DOI: 10.21314/jfmi.2016.057.

CPMI-IOSCO. *Public quantitative disclosure standards for central counterparties*. Tech. rep. Feb. 2015. https://www.bis.org/cpmi/publ/d125.pdf.

CPSS-IOSCO. *Principles for financial market infrastructures*. Tech. rep. Apr. 2012. https://www.bis.org/cpmi/publ/d101a.pdf.

Duffie, Darrell, Martin Scheicher, and Guillaume Vuillemey. Central clearing and collateral demand. en. Journal of Financial Economics 116.2 (May 2015), pp. 237–256. ISSN: 0304-405X. DOI: 10.1016/j.jfineco.2014.12.006. https://www.sciencedirect.com/science/article/pii/S0304405X14002761 (visited on 03/29/2023).

Duffie, Darrell and Haoxiang Zhu. Does a Central Clearing Counterparty Reduce Counterparty Risk? The Review of Asset Pricing Studies 1.1 (July 2011), pp. 74–95. ISSN: 2045-9920. DOI: 10.1093/rapstu/rar001. eprint: https://academic.oup.com/raps/article-pdf/1/1/74/24404255/rar001.pdf.

Ferrara, Gerardo, Xin Li, and David Marszalec. Central counterparty auction design. Bank of England Staff Working Paper (Aug. 2017).

Glasserman, Paul, Ciamac Moallemi, and Kai Yuan. Hidden Illiquidity with Multiple Central Counterparties. OFR Working Paper Series (May 7, 2015).

Guse, Matthew, Matthew Hoops, and Maria Perozek. Central Clearing Counterparties in the Financial Accounts of the United States. FEDS Notes (July 2024). DOI: 10.17016/2380-7172.3540.

Heilbron, John. Central clearing and trade cancellation: the case of London Metal Exchange nickel contracts on March 8, 2022. The Journal of Financial Market Infrastructures (2024). ISSN: 2049-5412. DOI: 10.21314/jfmi.2024.010.

Heilbron, John and Efstathios Tompaidis. The Impact of CCP Liquidity and Capital Demands on Clearing Members Under Stress. Working Paper (2025).

Hempel, Samuel et al. Why Is So Much Repo Not Centrally Cleared? Lessons from a Pilot Survey of Non-centrally Cleared Repo Data. OFR Brief Series (2022).

Huang, Wenqian and Elod Takats. Model risk at central counterparties: Is skin-in-the-game a game changer? BIS Working Papers 866 (May 2020).

Huang, Wenqian and Haoxiang Zhu. CCP Auction Design. BIS Working Papers (May 2021).

King, Thomas et al. Central Clearing and Systemic Liquidity Risk. en. Finance and Economic Discussion Series (May 2022). https://www.federalreserve.gov/econres/feds/central-clearing-and-systemic-liquidity-risk.htm (visited on 02/01/2023).

Kress, Jeremy. CREDIT DEFAULT SWAPS, CLEARINGHOUSES, AND SYSTEMIC RISK: WHY CENTRALIZED COUNTERPARTIES MUST HAVE ACCESS TO CENTRAL BANK LIQUIDITY. Harvard Journal on Legislation 48.1 (2009).

Kubitza, Christian, Loriana Pelizzon, and Mila Getmansky Sherman. Loss Sharing in Central Clearinghouses: Winners and Losers. The Review of Asset Pricing Studies 14.2 (Jan. 2024), pp. 237–273. ISSN: 2045-9920. DOI: 10.1093/rapstu/raae002. eprint: https://academic.oup.com/raps/article-pdf/14/2/237/57572204/raae002.pdf.

Magerle, Jurg and Thomas Nellen. Interoperability between central counterparties. Swiss National Bank Working Papers (Nov. 14, 2011).

Menkveld, Albert J. Crowded Positions: An Overlooked Systemic Risk for Central Clearing Parties*. The Review of Asset Pricing Studies 7.2 (May 2017), pp. 209–242. ISSN: 2045-9920. DOI: 10.1093/rapstu/rax016. eprint: https://academic.oup.com/raps/article-pdf/7/2/209/24518381/rax016.pdf.

Menkveld, Albert J. and Guillaume Vuillemey. The Economics of Central Clearing. Annual Review of Financial Economics 13.1 (2021), pp. 153–178. DOI: 10.1146/annurev-financial-100520-100321. (Visited on 12/23/2022).

Paddrik, Mark and Simpson Zhang. Central Counterparty Default Waterfalls and Systemic Loss. en. OFR Working Paper Series (June 2020). https://www.financialresearch.gov/working-papers/2020/06/18/central-counterparty-default-waterfalls-and-systemic-loss/ (visited on 01/19/2023).

Peirce, Hester. Derivatives Clearinghouses: Clearing the Way to Failure. Cleveland State Law Review 64.3 (2016), p. 589.

Saguato, Paolo. The Ownership of Clearinghouses: When Skin in the Game Is Not Enough, the Remutualization of Clearinghouses. Yale Journal on Regulation 34 (2017).

Squire, Richard. Clearinghouses as Liquidity Partitioning. Cornell Law Review 857 (2014).

Wang, Jessie, Agostino Capponi, and Hongzhong Zhang. A Theory of Collateral Requirements for Central Counterparties. Management Science (June 6, 2021).

Wolkoff, Neal L. and Jason B. Werner. History of Regulation of Clearing in the Securities and Futures Markets, and its Impact on Competition. Review of Banking and Financial Law 30 (2010), pp. 313–381.