CCP resilience and clearing membership[☆,☆☆]

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Abstract

We consider pre-funded waterfall resources, recovery tools and the assessment powers of major European and US central clearing counterparties to assess the possible exposure of clearing members. We also investigate loss allocation rules at the end of the waterfall and the impact of emerging resolution regimes on contingent liquidity. As the resilience of a central clearing counterparty depends on the soundness of the member base, we assess the payment capacity of a member base under normal and stressed scenarios. We show that under a cover 2 stressed scenario, member base quality dramatically erodes, jeopardising the ability of clearing members to provide contingent liquidity and to sustain the central clearing counterparty's resilience. We also discuss various conflicts of interest that can occur depending on the average quality and heterogeneity of member bases.

Keywords: CCPs, financial stability, risk mutualisation, contingent liquidity, recovery, resolution

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1. Introduction

The ongoing regulatory reforms and the shift towards central clearing of derivative products add to the importance of the role that central clearing counterparties (CCP) play in the financial markets. Given their growing systemic importance, regulators are enforcing a wide

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set of new rules that aim at maintaining and enhancing the resilience of CCPs.

The clearing landscape is also changing due to fiercer competition amongst CCPs and the introduction of several new CCPs over the last decade (Murphy, 2012; Zhu, 2011). CCP proliferation needs to be monitored, as it may negatively impact counterparty exposure, netting and collateral demand (Duffie and Zhu, 2011; Singh, 2011; Cont and Kokholm, 2014; Duffie et al., 2015). The competitiveness of a CCP is also dependent on its legal status as clearing members (CM) face lower capital charges when using recognised CCPs (BCBS, 2014a). This is a controversial issue as many US CCPs are not yet recognised by the European Securities and Markets Authority (ESMA), although they are compliant with the 'Principles for financial market infrastructures' (CPSS-IOSCO, 2012).[1]

The growing importance of central clearing also increases interconnections between CCPs and other market participants (Wendt, 2015; Yellen, 2013), which raises concerns about CCPs as a possible source of systemic risk. In cases where a CCP's resilience is threatened due to CM defaults that have depleted the pre-funded resources up to the CCP's skin-in-the-game, the CCP is dependent on liquidity injections from surviving CMs (or regulatory bail-ins). Here, the waterfall prescribes how losses are re-allocated across surviving CMs via risk-sharing mechanisms (Elliott, 2013; Pirrong, 2011). Firstly, the pre-funded default fund contributions of the survivors will be used to cover the losses. Secondly, the CCP has to deploy recovery tools, such as the replenishment of the default fund, by demanding liquidity from survivors, which can pose problems due to payment delays from members (Duffie, 2014). CCPs calibrate the default fund size based on internal stress tests, but they are under no obligation to disclose details of the methodologies used (CPMI-IOSCO, 2015; European Union, 2013a; CPSS-IOSCO, 2012). Thus, the level of stress that CCPs can withstand cannot be compared. Currently, regulators are considering the introduction of a standardised stress testing framework to enable the comparison of CCP risk profiles (Powell, 2014; Bailey, 2014).

Murphy and Nahai-Williamson (2014) assess the prudence of the cover 2 standard[2] for different distributions of risk exposure amongst CMs. Assuming that all CMs have the same probability of default, they investigate how the distribution of risk exposure among members impacts a CCP's resilience. They find that the cover 2 charge may not be prudent for uniform exposure distributions. Under these circumstances, CCP resilience depends on the CMs capacity to jointly carry losses beyond the default fund. Especially in a distressed market, a CM's lower payment capability and (possibly) higher default probability may impact his ability to raise (external) funding. Also, if CMs have higher default probabilities, the CCP will rely more on member mutuality to cover losses and possibly undergo more default shocks

[1] The Commodity Futures Trading Commission (CFTC) expressed their concerns as the internationally uncoordinated regulatory approach towards swaps execution has already led to fragmentation of global markets, causing isolated concentrations in the different markets (Giancarlo, 2014).

[2] The regulatory default fund standard (cover 2) requires the covering of the default of the two CMs to which a CCP would have the largest unmargined exposure under extreme market conditions in a stressed scenario (European Union, 2012). This definition does not take into consideration how much of the total risk these two members account for respectively.

(see Tarullo (2015)).

This article investigates the exposures of CMs via risk-sharing mechanisms embedded in the CCP waterfall. We consider pre-funded resources, recovery tools and assessment powers across EU and US CCPs in section 2 to assess possible CM exposure. We also discuss the impact of scheduled recovery and resolution regimes on contingent liabilities. As the efficiency of the waterfall, especially the default fund and its replenishment via assessment powers, depends on the soundness of a CCP's surviving member base, we investigate member base quality under normal and stressed scenarios in section 3. In addition, we provide a typology of member bases and examine possible conflicts of interest, which may jeopardise the stability of the financial system. Section 4 concludes.

2. Loss allocation rules and interconnectedness via exposures

In this section, we investigate the exposures of CMs via risk-sharing mechanisms embedded in the CCP waterfall structure. We consider pre-funded waterfall resources, recovery tools and the assessment powers of major European and US CCPs for IRS and CDS products to assess the possible exposure of CMs. Finally, we discuss risks related to recovery and resolution regimes, as these may bypass CCP rulebooks, resulting in unquantifiable exposures.

2.1. Default waterfall and risk exposure

CCP rulebooks regulate how losses incurred by the default of a member are allocated through the default waterfall (for a detailed overview see for example Pirrong (2011) or Cont (2015)). Table 1 summarises the default waterfall resources for the US CCP CME Clearing US.

Table 1: Default waterfall resources for CME Clearing US for all asset classes

Initial Margin (in mn)	Skin-in-the-game amount (in mn)	Default fund contributions (in mn)	Assessment powers (in mn)
131,000 $	300 $	7,415 $	10,657 $

Source: The financial data as at 30^{th} September 2015 for CME Clearing US. The data was retrieved from the CCP's website.

In case of a CM default, the CCP will use the defaulter's Initial Margin (IM) and default fund contribution to cover the incurred losses, followed by a designated tranche of CCP capital, referred to as the skin-in-the-game (SIG) amount. The IM amount provided to CME Clearing US for all asset classes illustrates the fact that IM is the main protection against member default (defaulter pays approach). An example of the effectiveness of IM is the Lehman Brothers Special Financing Inc. default in 2008 at LCH.Clearnet LTD. To close out the Lehman portfolio with a total notional value of \$9 trillion, encompassing a total of $66,390$ trades (LCH.Clearnet, 2008), LCH.Clearnet LTD used only 35% of the defaulter's IM (Cusenza and Abernethy, 2010).

In case of member defaults with losses exceeding the defaulter's IM and default fund contribution, the financial resilience of the CCP depends on two main factors: the CCP's skin-in-the-game and the surviving members' willingness and ability to jointly carry losses.

After using the CCP's SIG, losses will be re-allocated across survivors via risk-sharing mechanisms, which are embedded in the default waterfall structure, and possibly as part of either a recovery or a resolution regime. These loss allocation mechanisms are a possible source of risk for CMs: they face exposure via their pre-funded resources and, if the CCP calls for further liquidity, via possible contingent liabilities. They may also face unquantifiable exposures caused by recovery or resolution regimes (Arnsdorf, 2012; Pirrong, 2011).

There are two commonly applied risk-sharing mechanisms. The first is the default fund. Here, the level of risk exposure of a non-defaulted member depends on the financial resources preceding the default fund (defaulter's IM and default fund contribution, and SIG amount) and possible defaults of other CMs, in other words their credit quality at that point in time. In this situation, IM models that are not procyclical create increased reliance on CM mutuality. Nahai-Williamson et al. (2013) argue that IM requirements should reflect the credit quality of CMs. Under the 'Principles for financial market infrastructures' a CCP is obligated '*to effectively measure, monitor, and manage its credit risk from participants*' (see CPSS-IOSCO (2012), p.36). Thus, many CCPs monitor the counterparty risk of their clearing members using (internal) scoring methodologies[3]. These monitoring systems may also take into account external credit rating data[4] (see for example LCH.Clearnet (2014) or AFM (2014)). To mitigate an increase in a member's counterparty risk, CCP rulebooks provide CCPs with mechanisms to call for additional margin (see for example ICE Clear Europe (2014)).

The higher a CM's default probability, the higher the risks to other CMs as they may pay for his default losses via the default fund. In this way, the CMs are interconnected via the default fund and exposed to counterparty credit risk. As default probabilities are not considered

[3]The use of credit ratings as an explicit eligibility criterion for clearing membership has been dropped by major CCPs. For example, in April 2012, LCH.Clearnet LTD's rulebook contained a minimum rating requirement of at least an 'A' rating for prospective SwapClear participants. In contrast, the minimum rating for RepoClear participants was set at 'BBB' (the relevant section of the rulebook dated April 2012 is available at `http://www.google.fr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CCoQFjAB&url=http%3A%2F%2Fsecure-area.lchclearnet.com%2FImages%2FSection1_Cir%252026-03-2012_tcm6-61371.pdf&ei=C8uSVZS-LIGwUs_NiqgI&usg=AFQjCNHoxmuxe-62izHthrrhx-L7aQNMdQ&sig2=Q3f019_C9d7pVgXOeJDUwQ&bvm=bv.96783405,d.d24`). Furthermore, for CMs of both services that no longer adhered to the credit rating requirement, the CCP could apply a multiplier to the initial margin requirement. For example, for RepoClear the multiplier was set at 110% for a downgrade to 'BBB-' and at 200% for a downgrade to 'BB+'. A downgrade below 'BB+' resulted in the expulsion of the CM. Even before the new 'Principles for Financial Market Infrastructures' (CPSS-IOSCO, 2012) came into force, CCPs began implementing open, risk-based access requirements in 2012 (Fontaine et al., 2012). In the course of these changes, LCH.Clearnet LTD dropped the explicit minimum rating requirements for SwapClear and RepoClear.

[4]A recent exploratory study addressing the use of credit ratings in the Netherlands (AFM, 2014) found that CCPs use ratings in their credit assessment of a potential clearing participant, but on a relatively small scale and only as one of the input factors for their internal scoring model.

when sizing the default fund via stress tests, the exposure of CMs may increase significantly under a stressed scenario. To assess the resilience provided via waterfall resources, we consider resource levels in sections 2.2 and 2.3 and investigate the possible impacts of resolution and recovery regimes on risk exposure in section 2.4. To quantify the possible magnitude of counterparty credit risk, we analyse the credit quality of member bases in section 3.

The second risk-sharing mechanism, the replenishment of the default fund, requires CMs to raise liquidity within a short period of time. If the level of unfunded default fund resources is high, the CCP would be very risky, as it would rely on liquidity in times when it is significantly more difficult for CMs to raise it. To give a rough idea, consider the default fund contributions and the assessment powers for CME Clearing US for all asset classes as displayed in Table 1: the assessment powers are higher than the amount of the pre-funded default fund contributions. Aside from the risk-sharing mechanisms described above, risk exposure is difficult to quantify. Moreover, regulators are currently considering further sources of liquidity and tools of loss allocation to enable the recovery of a CCP that has suffered losses beyond the pre-funded resources, such as cash calls and margin gain haircutting (CPSS-IOSCO, 2014). Since the international standard 'Recovery of financial market infrastructures' requires that a CCP '*take into account the extent to which participants, owners and third parties would have sufficient resources to meet their potential obligations when considering the reliability of a tool or set of tools*' (CPSS-IOSCO (2014), p.13), monitoring the ability of CMs to sustain a CCP by providing liquidity is also essential for recovery regimes.

Margin gain haircutting is a controversial tool, as its economic impact and compatibility with current regulations depends on the margin type. It is undertaken for IM or for Variation Margin (VM) and results in different types of exposures for the clearing participants. Although Variation Margin gain haircutting (VMGH) is compatible with the European Market Infrastructure Regulation (EMIR) and is already used by European CCPs (see section 2.3), it may create exposures for clearing participants. If the position on which VMGH is performed is a hedge position to a non-cleared, illiquid position on a CM's balance sheet, the CM may face actual losses. Furthermore, CCP users also argue that VMGH could have the unexpected consequence of causing procyclicality, if CMs - expecting cash gains from their realised VM- were to be forced to liquidate assets in order to raise liquidity (JPMorgan Chase & CO., 2014). In the opinion of the ISDA (2013, 2015), VMGH is an adequate loss allocation tool, as it preserves netting sets, does not create unquantifiable potential exposure for the CMs and CMs can manage the haircut risk by reducing their positions. Singh (2014) argues that the inclusion of VMGH in the default waterfall minimises the recourse to central bank liquidity and will incentivise CMs to push for sound risk management policies and better governance structures at the CCP level. On the other hand, if VMGH were to be used as a recovery measure, this may encourage market participants, especially end-users, to close out their positions at the early signs of a CCP in distress (Blackrock, 2014; Gibson, 2013).

CPSS-IOSCO (2013) promoted IM gain haircutting (IMGH) as it allows access to a larger asset pool than VMGH. In their revised version of 2014, they view the usage of initial margin more critically (CPSS-IOSCO, 2014). Besides being incompatible with EMIR, and in conflict with IM segregation regimes and bankruptcy remoteness, IMGH creates disincentives for participation in default management (ISDA, 2013). Given the amounts at stake, see Table 1, IMGH, in contrast to its purpose, may leave CCPs temporarily under-collateralised (Gibson, 2013) and could increase the potential for contagion risk (Coeuré, 2014). As mentioned above, there is the additional risk that the IM of non-defaulted CMs would be used either in a resolution or in a recovery regime. This corresponds to a bail-in via CM funds[5].

Our analysis of possible exposures and risks in the context of CCP loss allocation rules shows that clearing participants are exposed to counterparty credit risk via the default fund, may face liquidity risk and credit risk via the rights to assessment, and finally may not be able to quantify exposure experienced in a recovery or resolution regime.

2.2. Pre-funded waterfall resources

Let us now consider the default fund contributions.

Optimising the design of pre-funded resources has several aspects, including the choice of calculation methodology for IM[6] and default fund contributions, and the exact balance between IM and DF. Aside from regulatory requirements regarding minimum IM and DF requirements (CPSS-IOSCO, 2012, 2014; European Union, 2012, 2013a), CCP operators can design risk management systems tailored to their specific needs. Here, the choice of IM and default fund levels requires careful consideration of possible trade-offs, such as high IM requirements versus high default fund requirements.

Higher IM requirements imply that the defaulter's estate pays more, which reduces potential costs for the other CMs and helps prevent contagion effects. Thus a recourse to rights to assessment may not be required in times of stress. Higher default fund requirements decrease the amount of frozen collateral, but may lead to situations where survivors subsidise defaulting CMs (for a detailed discussion on these issues see Budding and Murphy (2014)).

The trade-off between IM (defaulter pays approach) and default fund (loss mutualisation) depends on the degree of interconnection and the default probabilities of the clearing participants. According to Haldane (2009) and Gourieroux et al. (2012), interconnection lowers the probability of default, whereas the probabilities of joint default are slightly increased. Moreover, Hauton and Héam (2015) find that in an interconnected network, the capacity of

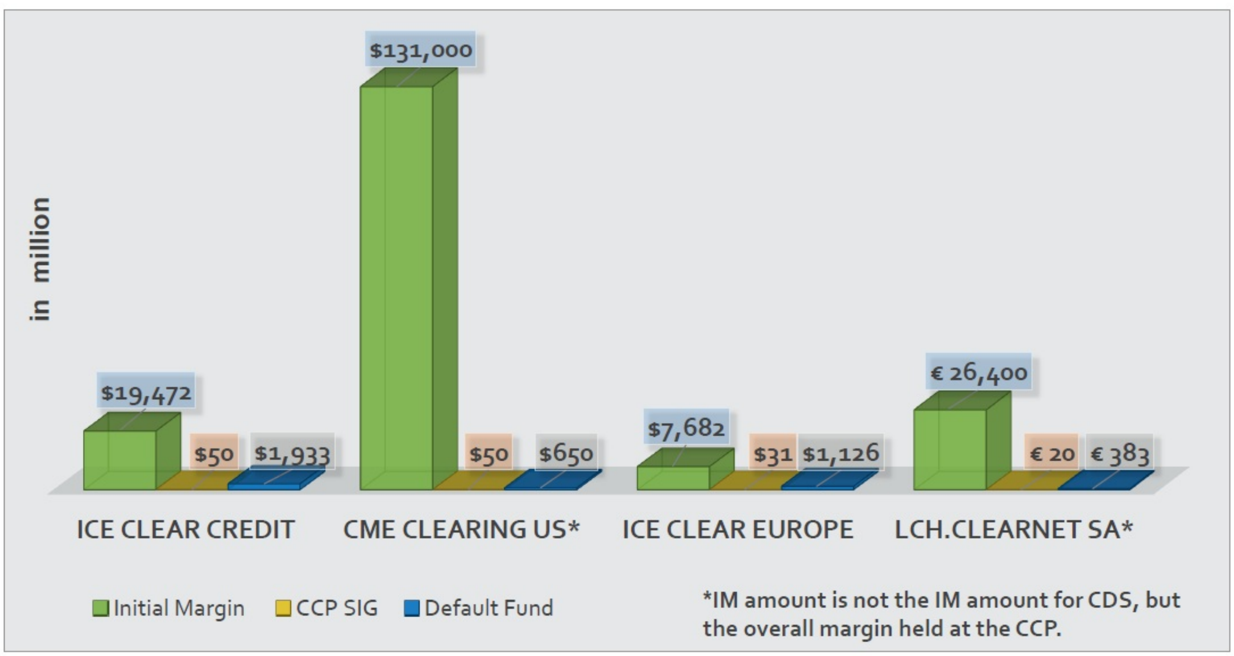
[5]According to BCBS (2014a), when IM is used for covering losses due to member default, it is to be included in the default fund. From a regulatory perspective, it is treated as a default fund exposure, as it becomes part of the mutualised resources. Thus the amount of mutualised resources is increased, which may lead to increased counterparty credit risk exposure and increase in the risks associated with interconnections of CMs.

[6]IM calculation issues have been extensively researched: procyclicality of margin requirements (Murphy et al., 2015, 2014; Heller and Vause, 2011), possible negative feedback between haircuts and collateral value via the margin spiral (Brunnermeier, 2009; Brunnermeier and Pedersen, 2009), negative effects of high margin requirements on welfare, default risk and trading volumes (Gibson and Murawski, 2013; Hardouvelis and Kim, 1995; Hartzmark, 1986), and possible negative effects of conservatively high margin requirements, such as reducing the benefit of heterogeneous loss allocation methods and diluting the incentives of clearing members (Gregory, 2015).

the banking system to carry risks increases as the default probabilities are smaller than in a network without connections. Furthermore, they find that in an interconnected network, systemic risk increases due to contagion and the probabilities of joint defaults are higher. Finally, Allen and Gale (2000) consider the effects of the degrees of interconnection. Their findings show that a complete network structure is optimal, when banks are exposed to small and diversified shocks. In this case, the interconnections constitute an insurance scheme. A complete network, in contrast, is prone to contagion, when banks are exposed to large shocks. Here, contagion spreads to all banks in the network, resulting in a sequence of bankruptcies.

The default fund can be designed in two basic ways: either a single default fund that covers all asset classes, or, several ring-fenced default funds, one per asset class. A single default fund is more cost efficient: default fund contributions are lower as diversification benefits across products can be taken into account. On the other hand, the use of a single default fund may lead to subsidising the more risky asset classes. CMs would face exposure to losses arising in a risky asset class, which would be mutualised across all clearing members, possibly leading to moral hazard issues (Gregory, 2014). In case of default, the risk of contagion would increase, as all CMs, regardless of the risk level of their own trades, would be interconnected through the default fund.

Figure 1: Pre-funded CDS waterfall resources

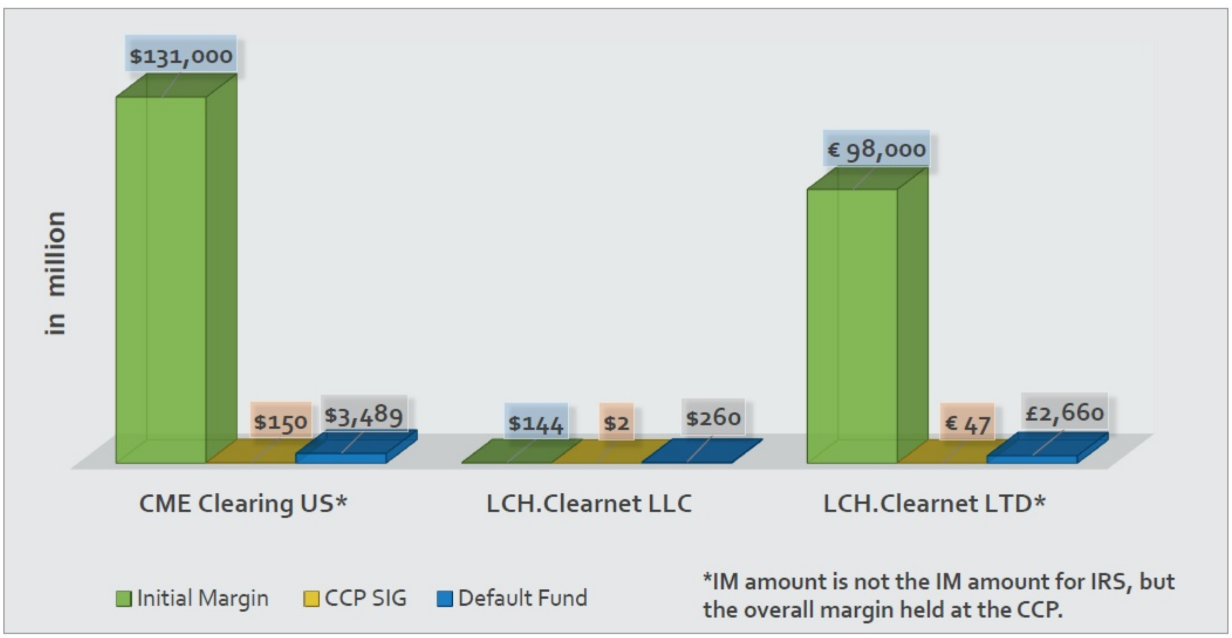


Source: The financial data as at 30^{th} September 2015 for ICE Clear Credit, as at 30^{th} September 2015 for CME Clearing US, as at 30^{th} September 2015 for ICE Clear Europe, and as at 30^{th} September 2015 for LCH.Clearnet SA. The data was retrieved from each CCP's website.

In Figure 1, the pre-funded CDS resources for ICE Clear Credit, CME Clearing US, ICE Clear Europe and LCH.Clearnet SA are displayed. For CME Clearing US and LCH.Clearnet SA the IM does not refer to the margin provided for CDS trades, but to the overall margin amount held by each CCP. Given the high IM amounts held by CCPs, the recourse to IMGH (following a depletion of mutualised resources) would entail the loss of significant amounts of pre-funded resources for the CMs. As the CMs would have to replace the IM amounts, liquidity risk would arise and the CCP may as a result be under-collateralised.

A CCP's capital contribution to the pre-funded resources serves as an incentive for the CCP to maintain prudent and rigorous risk management practices. Thus, the strength of the incentive depends on the size of the contribution and its placement in the waterfall structure (Carter and Garner, 2015). Considering that the 'Principles for financial market infrastructures' do not address SIG requirements at an international level, the observed differences in SIG amounts are of interest when comparing regulatory regimes and ongoing debates between CMs, CCP operators and regulators. Currently, the provision of SIG is mandatory in the EU, but not in the US: under EMIR, a CCP is required to contribute a SIG amount equal to 25% of its minimum capital requirement, which is to be used before using the surviving CMs default fund contributions.

Figure 2: Pre-funded IRS waterfall resources



Source: The financial data as at 30^{th} September 2015 for CME Clearing US and as at 30^{th} September 2015 for LCH.Clearnet LLC and LCH.Clearnet LTD. The data was retrieved from each CCP's website.

As part of the ongoing debate on SIG amounts, the industry side has proposed different approaches for calibrating[7] the SIG amounts, f.e. to size the amount in relation to the members default fund contributions (JPMorgan Chase & CO., 2014). Given the magnitude of

[7] Alburquerque et al. (2015) propose a SIG contribution of 8.1% for IRS default waterfalls and 11.4% for CDS default waterfalls.

the default fund contributions (see Figures 1 and 2), in the opinion of CCP operators, this would increase a CCP's risk exposure to its CMs, possibly leading to a situation, where the CCP would have to raise additional liquidity in stressed periods (LCH.Clearnet, 2014). For regulators the utility of CCPs lies in their ability to pool risks, thus, in their opinion, enormous increases in SIG amounts may result in changes of CCP balance sheets and business models, possibly leading to detrimental effects (Coeuré, 2015). Leaving aside the issue of how exactly SIG amounts should be calibrated, a properly sized SIG contribution will provide CCPs with a strong incentive to monitor changes in the risk profile of their member base.

In contrast to default funds that have a strictly ring-fenced structure, separated according to asset classes, Eurex established a combined default fund for listed and OTC products (see appendix A), with the exception of Eurex Credit Clearing. For Eurex Credit Clearing a separate default fund is in place. This integrated default fund is divided into different segments that are each associated with a certain group of products (liquidation groups). Losses arising from member default in a certain liquidation group can only be covered using the associated segment of the default fund. In this way, losses are, at first, mutualised amongst the active CMs in that specific liquidation group. If there is a surplus in another segmented default fund, this can be used to cover remaining losses (Eurex Clearing, 2014a). Eurex corroborates that their integrated default fund reduces the risk and size of the default fund by 30% as this structure benefits from portfolio effects between different products and asset classes (Eurex Clearing, 2014b).

All CCPs reviewed choose the cover 2 standard for the default fund size and place the SIG amount before the default fund in the waterfall. Anecdotal evidence shows that this is not always the case, as in the recent default of HanMag Securities, a futures broker at the South Korean exchange KRX (Vaghela, 2014). As HanMag's pre-funded resources were insufficient to cover its losses, KRX, in accordance with its rulebook, used the non-defaulters' default fund contributions to pay for the losses. According to KRX's rulebook, the exchange's SIG amount is placed behind the default fund in the waterfall structure. Apparently, clearing members were not aware of the KRX waterfall order and incurred $45 mn in losses via their default fund contributions. This example illustrates that clearing members are exposed to various risks when facing a CCP.

2.3. Unfunded waterfall resources

The exhaustion of the pre-funded resources forces CCPs to revert to recovery measures and to call for further liquidity from its members. The standard industry recovery measure is the replenishment of the default fund. In addition, VMGH is already part of many CCPs' rulebooks, especially in the UK.

Table 2: Assessment powers and VMGH application for cleared CDS

CCP	Assessment power		VMGH	
	Cap for single default	Cap for multiple default	Applied	Cap
ICE Clear Credit	100% of default fund contribution	3x100% of default fund contribution	No	No
CME Clearing US	Pro rata share of a size that covers 3rd and 4th largest losses	Pro rata share of a size that covers 3rd and 4th largest losses	No	No
ICE Clear Europe	100% of default fund contribution	3x100% of default fund contribution	No	No
LCH.Clearnet SA	100% of default fund contribution	3x100% of default fund contribution	Yes	The higher of 100 € mn or 100% of default fund contribution

Source: The assessment powers and VMGH information can be found in the rulebook of each CCP.

Table 3: Assessment powers and VMGH application for cleared IRS

CCP	Assessment power		VMGH	
	Cap for single default	Cap for multiple default	Applied	Cap
CME Clearing US	Pro rata share of a size that covers 3rd and 4th largest losses	Pro rata share of a size that covers 3rd and 4th largest losses	No	No
LCH.Clearnet LLC	100% of default fund contribution	3x100% of default fund contribution	Yes	The higher of 100 € mn or 100% of default fund
LCH.Clearnet LTD	100% of default fund contribution	3x100% of default fund contribution	Yes	The higher of 100 € mn or 100% of default fund

Source: The assessment powers and VMGH information can be found in the rulebook of each CCP.

Table 2 and Table 3 summarise the assessment powers and possible application of VMGH for CDS and IRS for the reviewed CCPs. CME Clearing US' assessment powers are capped at a size estimated to provide sufficient resources in the event of the default of the four clearing members to which the CCP has the most exposure as determined via internal stress tests. To give a rough idea of the size, CME Clearing US' default fund amounts and the estimated liquidity, which CME Clearing US could demand from its members via assessment powers, are displayed in Table 4. To evaluate the possible exposure of a CM, it must be taken into account that the displayed amounts are likely to be higher in times of stressed markets.

Table 4: Default fund size and assessment powers for CME Clearing US

Asset Class	CM Default fund contributions	Assessment powers of CME Clearing US
CDS	$\$650,000,000$	$\$86,000,000$
IRS	$3,489,000,000	$1,563,000,000

Source: The financial data as at 30^{th} September 2015 for CME Clearing US. The data was retrieved from the CCP's website.

For IRS assessment powers, CME Clearing US can call for additional liquidity almost equal to half of the default fund contributions. It is probable that during a financial crisis more than one CCP is in an extreme situation. For CMs, who clear on more than one CCP, which is the case for international dealer banks, a simultaneous demand for additional liquidity from multiple CCPs can lead to the amplification of the negative effects under stressed market conditions (Wendt, 2015).

There remains thus uncertainty, that all surviving CMs will be able to provide the necessary unfunded liquidity when market conditions are instable. Consequently, as the losses spread with each further default, the surviving clearing members might be exposed to contagion risk. This jeopardises regulators' wishes to mitigate interconnection risks and to promote transparency. For this reason, CCP users are promoting the idea of pre-funding all loss absorbency resources to eliminate this uncertainty (JPMorgan Chase & CO., 2014; PIMCO, 2014). CME Group (2015) promotes the idea that SIFI CMs with a huge client clearing business should provide additional funding to the default waterfall. In this way, solvent CMs are not exposed to risk arising from such a member's default and negative impacts for the defaulter's clients may also be avoided.

2.4. Impact of resolution versus recovery

Currently, international regulation covers neither recovery nor resolution regimes for CCPs. Only in the UK have regulators closed this gap by amending the Financial Services Act to address such issues. In the past three years, regulators have drafted consultative documents (FSB, 2011, 2014; European Commission, 2012; CPSS-IOSCO, 2013, 2014) to advance the creation of such regimes, but certain reservations remain. As noted by Duffie (2014), a CCP's failure cannot be safely and effectively concluded neither under the currently available forms of bankruptcy[8], nor under the Dodd-Frank Act's Title II administrative failure resolution. Though some authors have called for nationalising failed CCPs (Lubben, 2014), understandably regulators and central bankers are reluctant to agree to any kind of bail-out (Coeuré, 2015). Apart from the possibility of emergency lines of credit, all losses would then be supported by market participants. Here, it should be considered that CCPs, often operating as for-profit entities, may be exposed to profit-making incentives possibly contorting their function as a tool for mitigating systemic risk (Tucker, 2014).

[8]See Duffie and Skeel (2012) for a discussion of the costs and benefits of automatic stays for OTC-derivatives and repurchase agreements in the case of CCP bankruptcy.

As CCP capital involvement is quite limited, potential losses due to closing out market exposures of a defaulted market participant would then be mutualised (LCH.Clearnet, 2014), despite industry arguments that end-investors and surviving members should not pay the bill (Blackrock, 2014). As recently pointed out by the European Systemic Risk Board, current legislation does not clarify the timing and procedure to be applied when re-plenishing the default fund. Thus, clearing participants may have difficulties estimating the necessary financial resources, which must be considered from a procyclicality perspective (European Systemic Risk Board, 2015).

It is also likely that the resolution authorities would bypass the CCP waterfall. For instance initial margin haircutting is not formally banned in the latest document issued by the Financial Stability Board (FSB, 2014), even though variation margin haircutting[9] is the privileged route chosen by the most prominent CCPs. Such an option, left to the discretion of the relevant national supervisor, would significantly magnify the exposures of market participants since initial margin amounts are by far higher than default fund contributions. Similarly, resolution authorities could constrain the replenishment of the default fund beyond the CCP's rights to assessment. In practice, this would mean that extra contributions would be called from clearing members and clients, following the financial architects tendencies to favour recovery over resolution (FSB, 2014; CPSS-IOSCO, 2014).

Finally, the question of how resolution or recovery proposals fit into existing and future legal frameworks needs to be considered. There is always the possibility of extending existing frameworks, as observed in the UK, where the Financial Services Act was adapted to extend the Special Resolution Regime (SRR) to CCPs.

3. Analysis of member bases across EU and US CCPs

In this section, we consider the quality of clearing members as an indicator of the payment capacity of a CCP's member base. The analysis is conducted on major CCPs in the US and the EU. The financial resilience of a CCP can be considered from different points of view including clustering of defaults and contagion, various wrong way risks or crowded trade effects, design of initial margin and default fund models and interdependencies between CMs' trading positions (Pirrong, 2014; Cruz Lopez et al., 2014; Ghamami, 2015; Menkveld, 2015; Murphy and Nahai-Williamson, 2014; Lin and Surti, 2015; Cruz Lopez et al., 2011).

International guidelines also require CCPs to monitor their members ability to provide li-

[9]VMGH may not be suitable for asset classes, where a daily exchange of VM does not take place or transactions are physically settled. In the latter case, adjusting settlement prices may pose several practical issues (Elliott, 2013).

quidity[10] and also their credit quality[11][12][13]. As stated earlier, given that CCP bail-ins are privileged by regulators, the payment capacity of clearing members and the potential for moral hazard effects associated with dispersion in the credit quality of clearing members should not be ignored.

3.1. Motivation

If clearing members have higher default probabilities, a CCP might undergo more financial shocks in the form of member defaults. In such a situation, contagion risk may arise, as surviving CMs are interconnected via default fund exposures and possible contingent claims in case of cash calls (Wendt, 2015). These inter-member exposures may propagate financial contagion, especially when aggregate liquidity is insufficient to absorb shocks (Allen and Gale, 2000; Gourieroux and Héam, 2015). Therefore, to assess CCP safety, the financial strength of the member base should be taken into account.

In the case where losses due to member default(s) deplete the pre-funded resources up to the CCP's SIG, the survival of the CCP depends on the willingness and the capacity of its member base to absorb these losses. The use of default fund contributions means that CMs subsidise each other as there is a transfer of losses from lower quality to higher quality CMs (Gregory, 2014). The capacity of surviving CMs to carry losses beyond the pre-funded resources depends on their ability to absorb these losses by raising additional funds. Cont (2015) also notes that the depletion of the default fund is most likely to occur when two large CMs have already defaulted due to financial shocks or market losses. Consequently, the surviving CMs, most probably having experienced the same severe market conditions, may not be able to raise large amounts of liquidity for replenishing the default fund.

Raising funds via the interbank markets may prove difficult, if the functioning of these markets is diminished as demonstrated during the recent crisis (see for example De Socio (2013) and Gorton and Metrick (2012)). A CM's ability to raise funds by selling his assets may decline as a result of fire sales caused by capital erosion due, in turn, to falling asset prices coupled with the simultaneous tightening of lending standards and margin (Brunnermeier, 2009; Brunnermeier and Pedersen, 2009). The funding ability of a CM may also depend on the potential lenders' perception of his credit quality reflected by indicators such as credit ratings and default probabilities. Karam et al. (2014) find that rating downgrades of banks from an investment to a speculative rating grade are associated with a persistent decline of ac-

[10] The 'Principles for financial market infrastructures' state that an '*FMI should have a robust framework to manage its liquidity risks from the full range of participants and other entities.*' (CPSS-IOSCO (2012), p.59).

[11] The 'Principles for financial market infrastructures' state that a CCP '*should effectively measure, monitor, and manage its credit exposures to participants*' (CPSS-IOSCO (2012), p.57).

[12] Constancio (2015) mentions '*the interconnectedness via common exposures to clearing members as well as possible knock-on effects on the banking sector that could arise in case the guarantee fund of a CCP is wiped out and clearing members are required to cover the CCP losses*'.

[13] CCPs consider that they would '*be adversely impacted by the financial distress or failure of one or more of our clearing firms*' (CME GROUP INC. (2014), p.19); they consider the credit quality of market participants as a risk factor related to their business (Intercontinental Exchange, Inc., 2015).

cess to uninsured and wholesale funding sources. Clearing participants attempting to insure themselves against credit rationing, may resort to hoarding liquidity (Gale and Yorulmazer, 2013), which may in turn have negative effects on the interbank markets, such as increases in interbank lending rates for both secured and unsecured lending (Allen and Carletti, 2008; Acharya and Merrouche, 2013).

We investigate the financial soundness and thus the ability of the member base to keep up their financial commitments to the CCP. As the creditworthiness of a financial entity is related to its credit rating, we will further use available credit rating information to assess the credit quality of a CCP's member base.

3.2. Member and credit rating data

The dataset is comprised of 8 European and 5 US CCPs (see Table 5). For each CCP, the list of CMs is available on each CCP's website. Only CMs that can directly interact with the CCP are included in the sample, all other CM types are excluded.

Table 5: CCP overview

Group	CCP	Domicile	Company structure	Ownership structure
CME Group	CME Clearing US CME Clearing EU	US EU	For-profit entity	Exchange:100%
Deutsche Börse Group	Eurex	EU	For-profit entity	Exchange:100%
Intercontinental Exchange Inc.	ICE Clear Credit ICE Clear Europe ICE Clear US The Clearing Corporation	US EU US US	For-profit entity	Exchange:100%
LCH.Clearnet Group	LCH.Clearnet LLC LCH.Clearnet LTD LCH.Clearnet SA	US EU EU	For-profit entity	Exchange:60%, Other:40%
London Stock Exchange Group	CC&G	EU	For-profit entity	Exchange:100%
	EuroCCP	EU	For-profit entity	User:25%, Exchange:100%, Other:25%
	ECC	EU	For-profit entity	Exchange:100%

For each CM considered, credit rating data from Bloomberg is extracted for Moodys Investor Service, Fitch Ratings and Standard & Poor's. To best capture the ability of the CMs to honor their financial commitment to the CCP, the following rating categories are chosen: 'Long-Term Rating' and 'Senior Unsecured Debt' from Moodys, 'Long-Term Issuer Default Rating' and 'Senior Unsecured Debt' from Fitch Ratings, and 'Long-Term Foreign Issuer Credit' from Standard and Poor's. If a member is not rated in either category and a rating in one of the above categories is available for the parent company, the ratings of the parent company are used.

Descriptive statistics on the availability of CM credit rating data are displayed in Table 6. The CCPs with the highest percentage of not-rated CMs are ICE Clear US with 35.14% and CME Clearing US with 35.29%. The reason for such a high percentage of not-rated CMs is due to the fact that in many cases these are privately held companies that handle orders on behalf of their clients. Amongst the European CPPs, CC&G has the highest percentage of not-rated CMs (31.25%). This is partly due to the fact that in the aftermath of the financial crisis, rating agencies withdrew from rating several Italian banks (see for example Moody's Investors Service (2013a)) or the banks were placed under the administration of their national supervisor, the Bank of Italy (see for example Moody's Investors Service (2013b)).

Table 6: Availability of credit ratings

CCP	CMs Total	Not-rated CMs	Rated CMS	Percentage of not-rated CMs
CME Clearing US	68	24	44	35.29 %
CME Clearing EU	21	2	19	9.52 %
Eurex	174	34	140	19.54 %
ICE Clear Credit	28	0	28	0.00 %
ICE Clear Europe	80	19	61	23.75 %
ICE Clear US	37	13	24	35.14 %
The Clearing Corporation	12	1	11	8.33 %
LCH.Clearnet LLC	16	0	16	0.00 %
LCH.Clearnet LTD	156	11	145	7.05 %
LCH.Clearnet SA	103	18	85	17.48 %
CC&G	80	25	55	31.25 %
EuroCCP	48	11	37	22.92 %
ECC	21	2	19	9.52 %

Remark: All European CCPs listed in Table 6, except for ICE Clear Europe, have been authorised by the ESMA to offer clearing services in the EU. Furthermore, CME Clearing US and ICE Clear Credit have been designated as systemically important Financial Market Infrastructures (FMU) under Title VIII of the Dodd-Frank Act.

For further quantitative studies, we assign default probabilities to not-rated CMs as follows: the Basel III regulatory framework (see BCBS (2015b), §146) assigns a 'BB' credit rating to not-rated counterparties (see Table 7). We checked for indicators of financial strength to validate this standard mapping. Unfortunately, in many cases standard indicators of financial strength are not available.

Table 7: Regulatory assignment of default risk weights to credit rating category

Credit rating category	AAA	AA	A	BBB	BB	B	CCC	Unrated
Default risk weight	0.5%	2 %	3 %	6 %	15 %	30 %	50 %	15 %

Source: BCBS (2015b), §146.

3.3. Risk distribution of CCP member bases

To conduct the analysis of the credit risk distribution of a CCP's member base, methods for estimating probabilities of default (PD) with credit ratings[14] can be used, see Tasche (2013), Gordy and Lütkebohmert (2013), Schuermann and Hanson (2004) and Lando and Skødeberg (2002). Ranges for estimated borrower default probabilities associated with Standard & Poor's whole letter rating grades, as provided by Tasche (2013) and Gordy and Lütkebohmert (2013), are displayed in Table 8.

Table 8: Credit rating grades and associated one year probabilities of default

S&P rating grade	Probability of default (in %) as in Tasche (2013)	Probability of default (in %) as in Gordy and Lütkebohmert (2013)
AAA	≤ 0.003	≤ 0.02
AA	$0.006 - 0.025$	$0.02 - 0.06$
A	$0.047 - 0.173$	$0.06 - 0.18$
BBB	$0.299 - 0.797$	$0.18 - 1.06$
BB	$1.138 - 2.280$	$1.06 - 4.94$
B	$3.943 - 19.557$	$4.94 - 19.14$
CCC	48.355	> 19.14

Such a mapping can also be obtained by following the guidelines provided by the Basel III document 'Revisions to the securitisation framework' (BCBS, 2014b). Given the regulatory default risk weights, we can calculate the associated default probabilities[15] according to the regulatory formula[16][17] (see BCBS (2006), p.64):

[14] Raw historical default frequencies provided by rating agencies (see Moodys Investors Service (2014) and Standard & Poor's (2012)) have some drawbacks, such as being equal to zero for corporations considered to be of high quality.

[15] In the existing literature on CCP resilience, it is often assumed that the probability of default is equal for each clearing participant (see for example Barone Adesi et al. (2015)). Our analysis of member bases, on the contrary, shows that this assumption may not hold for all CCPs, see appendix C.

[16] The formula provides the loss quantile as derived from the one factor model of Gordy (2003) and Vasicek (2002). See BCBS (2005) for a detailed explanation of the economic foundations as well as the underlying mathematical model and its input parameters.

[17] The maturity adjustment has been set equal to one (see §155 of the July 2015 version of the 'Fundamental review of the trading book' (BCBS, 2015b) and the expected loss has been included in the computation as prescribed in §49 of the 'Revisions to the securitisation framework' (BCBS, 2014b). As the regulatory prescribed risk weight for defaulted exposure is equal to 100 %, we also need to set LGD equal to 100 % (BCBS, 2014b).

$$DRW = N\left(\frac{1}{\sqrt{1-R}} \times G(PD) + \sqrt{\frac{R}{1-R}} \times G(0.999)\right), \tag{1}$$

$N(.)$ denotes the cumulative distribution function for a standard normal random variable, $G(.)$ denotes the corresponding inverse cumulative distribution function, PD is the default probability over a one year horizon, and R the coefficient of correlation, defined as:

$$R = 0.12 \times \frac{1-\exp^{-50\times PD}}{1-\exp^{-50}} + 0.24 \times \left(1 - \frac{1-\exp^{-50\times PD}}{1-\exp^{-50}}\right). \tag{2}$$

In Table 9, resulting associated probabilities of default are displayed according to credit rating[18]. Results are well in line with Tasche (2013) and Gordy and Lütkebohmert (2013). We will hereafter use the regulatory derived default probabilities for the empirical analyses.

Table 9: S&P rating grades and associated one year default probabilities

S&P rating grade	AAA	AA	A	BBB	BB	B	CCC	Unrated
Associated PD	0.01 %	0.05 %	0.09 %	0.23 %	1.16 %	5.44 %	14.21 %	1.16 %

Given the previous analysis of the possible impact of cash-calls and contingent liquidity, we need to assess the financial strength of clearing members under a stressed scenario. The regulatory cover 2 standard refers to the two CMs to which the CCP has the largest unmargined exposures in a stressed scenario. As this information is not available to us, we choose two average CMs. Based on the scenario under normal market conditions, we identify two average CMs for each CCP. Under the assumption that they have defaulted, we then calculate the conditional one year default probabilities[19]. We will hereafter denote by $F_i(.)$ the marginal cumulative distribution function associated with the default of CM i. In the remainder of this sub-section, we provide an overview of the calculation of the one year conditional default probabilities. This is achieved using the Basel framework, i.e. a one factor default model as previously described. For more details on these models, we refer to Vasicek

[18]In contrast to our approach, the current regulatory mapping of default probabilities to credit quality steps by the European Union is more conservative (European Union, 2013b). The resulting correspondence between Standard and Poor's rating grades and default probabilities (see Joint Committee of the European Supervisory Authorities (2015), p.55, and Joint Committee of the European Supervisory Authorities (2014)) is as follows: the rating grades 'AAA' and 'A' are associated with a default probability of 0.01%, 'A' with 0.25%, 'BBB' with 1% and 'BB' with 7.5%. We do not apply this approach for the following reasons: firstly, default probabilities associated with 'B' and 'CCC' rating grades are not provided. Secondly, the default probabilities are much higher than those provided by Tasche (2013) and Gordy and Lütkebohmert (2013). Furthermore, the Basel Committee on Banking Supervision provides the following mapping of Standard and Poor's rating grades to default probabilities BCBS (2015a): the rating grade 'AAA' is associated with a default probability of 0.006%, for the category 'AA' the assigned probability of default ranges from 0.010% to 0.025%, for 'A' from 0.041% to 0.105%, for 'BBB' from 0.169% to 0.437%, for 'BB' from 0.703% to 1.818%, for 'B' from 2.923% to 7.561%, and finally for 'CCC' the associated default probability is 27.000% .

[19]Hansen (2013) identifies two sources of systemic risk. Exposures to common shocks and networks of interconnected exposures. Our approach focuses on the resilience of CCPs to macro shocks. Interconnections would result in increased financial fragility, but would be difficult to assess in our context due to lack of data.

(2002), Pykhtin and Dev (2002) and Gordy (2003).

Let τ_i denote the default date of CM i for a CCP with n CMs for a given time period of one year. We denote the latent variable X_i for $i \in \{1, ..., n\}$, as $X_i = -\sqrt{R_i} \times Y + \sqrt{1 - R_i} \times Z_i$, where $Y, Z_1, ..., Z_n$ are independent standard normally distributed random variables and R_i is the correlation coefficient of CM i as defined in (2). Thus, we obtain $\tau_i = F_i^{-1}(N(X_i))$ and the conditional default probability of CM i given Y as

$$P(\tau_i < t|Y) = N\left(\frac{G(F_i(t)) + \sqrt{R_i} \times Y}{\sqrt{1 - R_i}}\right). \tag{3}$$

Under the definition of the cover 2 standard, we must calculate the one year conditional default probabilities given that two (average) clearing members have defaulted. Denoting by τ_{j_l}, for $j \in \{1, ..., n\}$ with $j_l \neq i$ and $l \in \{1, 2\}$, the default time of an average CM, we can write the conditional default probability of CM i $P(\tau_i < 1|\tau_{j_1} < 1, \tau_{j_2} < 1)$ under this scenario as follows. Given that τ_i, τ_{j_1} and τ_{j_2} are independent, conditionally on Y, the conditional default probability of joint defaults is the product of the single conditional default probabilities, we obtain

$$\begin{aligned} P(\tau_i < 1|\tau_{j_1} < 1, \tau_{j_2} < 1) &= \frac{E[P(\tau_i < 1, \tau_{j_1} < 1, \tau_{j_2} < 1|Y)]}{E[P(\tau_{j_1} < 1, \tau_{j_2} < 1|Y)]} \\ &= \frac{\int P(\tau_i < 1|y) \times P(\tau_{j_1} < 1|y) \times P(\tau_{j_2} < 1|y)\,\phi(y)\,dy}{\int P(\tau_{j_1} < 1|y) \times P(\tau_{j_2} < 1|y)\,\phi(y)\,dy}, \end{aligned}$$

where $\phi(.)$ represents the Gaussian distribution function. The denominator and numerator can be computed using various numerical approaches (Monte Carlo simulation, Gauss-Hermite quadrature, Trapezoidal integration). Results for the conditional probabilities are displayed in Table 10.

Table 10: Conditional default probabilities under cover 2 scenario

	PD of defaulted CMs						
CM PD	*0.01 %*	*0.05 %*	*0.09 %*	*0.23 %*	*1.16 %*	*5.44 %*	*14.21 %*
0.01 %	1.10 %	0.95 %	**0.45 %**	0.42 %	**0.21 %**	0.08 %	0.05 %
0.05 %	2.86 %	1.86 %	**1.83 %**	1.51 %	**0.75 %**	0.33 %	0.21 %
0.09 %	4.70 %	3.45 %	**2.97 %**	2.23 %	**1.19 %**	0.54 %	0.36 %
0.23 %	6.22 %	5.92 %	**5.84 %**	4.23 %	**2.42 %**	1.18 %	0.81 %
1.16 %	16.91 %	13.99 %	**12.28 %**	11.00 %	**7.12 %**	4.13 %	3.09 %
5.44 %	26.34 %	27.29 %	**25.94 %**	22.87 %	**17.79 %**	12.48 %	10.39 %
14.21 %	47.56 %	46.44 %	**43.78 %**	41.35 %	**34.30 %**	26.60 %	23.19 %

As expected, the lower the default probability of the two defaulted clearing members, the higher the negative impact on default probabilities. Since such a scenario is likely to be a systemic event, the stressed default probabilities are much higher than the unconditioned (through the cycle) default probabilities. For instance, if the two defaulted clearing members were associated with a default probability of 1.16 % (corresponding to a 'BB' rating grade), the resulting conditional default probability of a not-defaulted member with the same initial default probability would jump to 7.12 %, corresponding to a 'B' rating.

Although, the increase in default probabilities under the cover 2 scenario is striking, computations have been done under mild dependency assumptions. Firstly, we remain within the Gaussian copula framework associated with smooth tail dependencies. We refer to Burtschell et al. (2009) for a comparison of dependency structures. Then, we use low Basel II correlations[20]: typically pairwise correlations around 20%, being much lower than the 30% used by Murphy and Nahai-Williamson (2014), which as stated by the authors tends to underestimate joint losses.

A stressed environment is usually associated with a sharp increase in default dependencies, as clearly experienced in 2008. Consequently, the figures in Table 10 can be regarded as robust lower bounds that will underestimate the weakening of member bases in a cover 2 scenario.

According to our approach, member defaults in the case of a CCP with high quality average clearing members is a more severe scenario (see for comparison columns 4 and 6 of Table 10).

3.4. Assessment of CCP resilience

In this section, we assess the distribution of default probabilities under normal market conditions and a stressed cover 2 scenario. To illustrate our analysis we use the traffic lights approach displayed in Figure 3. We choose to set the PD ranges as displayed in Figure 3 as they reflect the upper and lower bounds of the default probabilities associated with the respective regulatory default risk weights as displayed in Table 9.

[20]Basel II correlations range from 12% to 24% (see equation (2)). Furthermore, the Basel Committee's findings indicate that the asset value correlations for financial corporations are at least 25% higher than for non-financial corporations (BCBS, 2009). To reflect this higher degree of correlation, current legislation (European Union, 2013b) sets out that for all exposures to large financial sector entities and to unregulated financial entities, the coefficient of correlation is multiplied by 1,25. Thus, the Basel III correlations range from 15% to 30%.

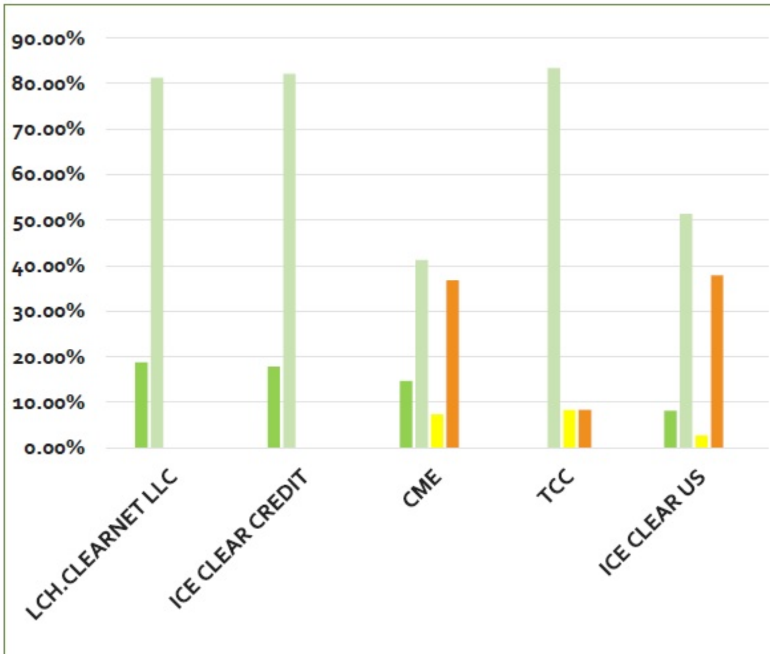
Figure 3: S&P rating grades and associated PD range

S&P Rating Category	PD ranges (in %)
AAA	[0 - 0.05)
AA	[0.05 - 0.09)
A	[0.09 - 0.23)
BBB	[0.23 - 1.16)
BB	[1.16 - 5.44)
B	[5.44-14.21)
CCC	≥14.21

3.4.1. Risk distributions under normal and stressed market conditions

CM risk distribution under normal market conditions The default probability distribution of CMs is displayed in Figures 4 and 5 for US and EU CCPs. The default probability distributions for each CCP are detailed in appendix C.

Figure 4: Default probability distribution of US CCPs under normal market conditions

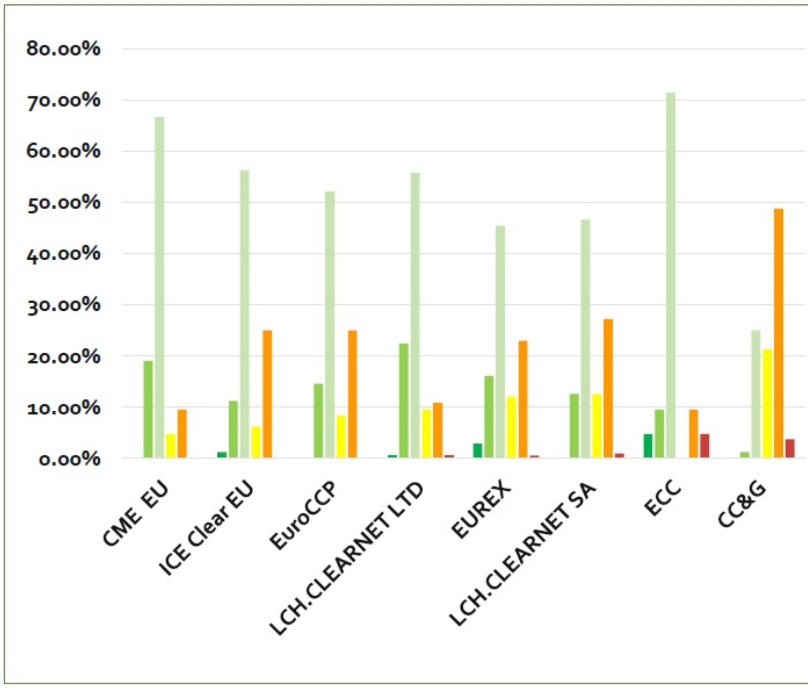


S&P Rating Category	DRW (in %)	PD (in %)
AAA	0.05	0.01
AA	2	0.05
A	3	0.09
BBB	6	0.23
BB	15	1.16

A qualitative inspection of Figure 4 shows that LCH.Clearnet LLC and ICE Clear Credit have the stronger member bases. CME Clearing US, The Clearing Corporation and ICE Clear US lag behind. Their member bases exhibit a lower quality and a higher degree of heterogeneity. This suggests that it might be difficult to align various interests, ex-ante in day-to-day risk management processes and ex-post when closing-out a defaulted member's open trades.

Turning to the default probability distributions of the EU CCPs as displayed in Figure 5, the member bases seem overall weaker compared to those of the US CCPs. CME Clearing EU followed by ICE Clear Europe and EuroCCP have the strongest member bases. A second group consists of LCH.Clearnet LTD and Eurex: the CMs credit quality is lower on average and shows a much greater degree of heterogeneity. Furthermore, we can observe that five out of the eight European CCPs have members with a default probability of 5.44 %, which corresponds to a 'B' rating grade. Especially, ECC and CC&G each have about 5% of members in this category.

Figure 5: Default probability distribution of EU CCPs under normal market conditions



S&P Rating Category	DRW (in %)	PD (in %)
AAA	0.05	0.01
AA	2	0.05
A	3	0.09
BBB	6	0.23
BB	15	1.16
B	30	5.44

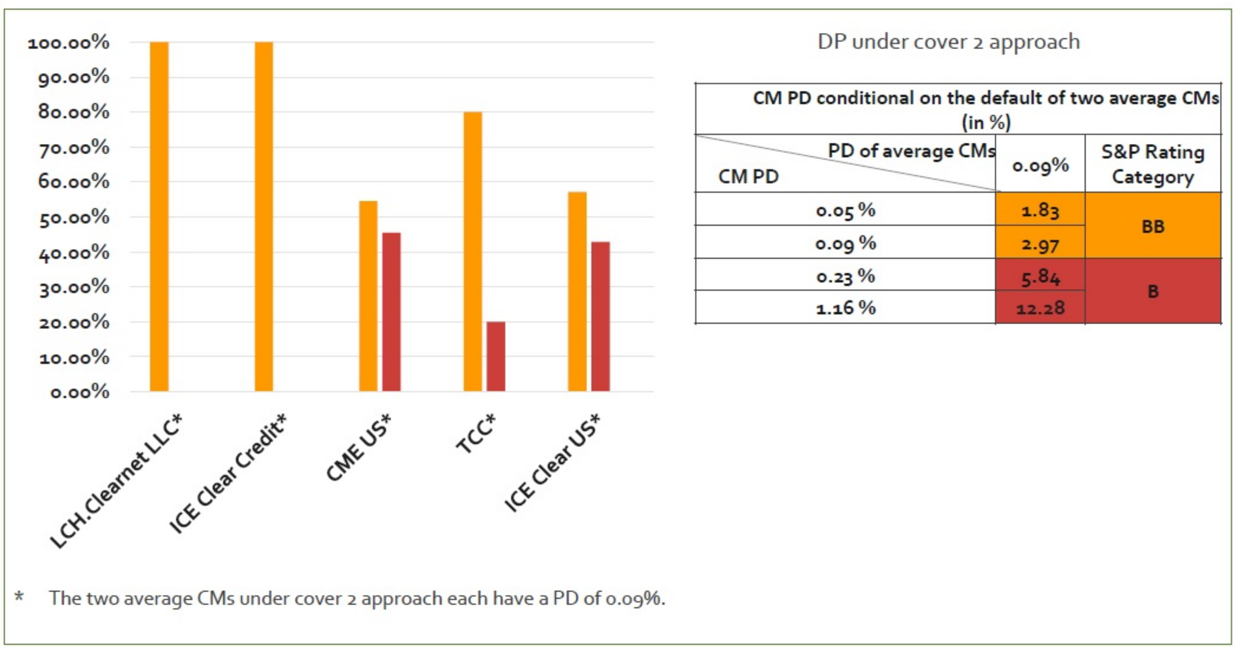
These findings can partly be explained by different business models, for example the importance of client clearing in the US and the average lower credit quality of clearing members from the European periphery (Norman, 2012). The introduction of mandatory clearing and the wide scope of cleared repos in Europe are also likely to negatively impact the composition and size of CCP member bases (Lane et al., 2013). As a result of regulatory changes, CCPs are required to have objective, risk-based and publicly disclosed criteria for member admission (CPSS-IOSCO, 2012). Thus, the high proportion of not-rated CMs is a challenge for several CCPs.

CM risk distribution under stressed market conditions As CCPs publish neither exposure nor default fund contributions at the CM level, and IM calculation methodologies and stress test scenarios are not yet publicly disclosed, we cannot quantitatively assess risk exposures. However, the unconditional and stressed default probabilities of their members can be evaluated.

In Table 10, the default probabilities for CMs according to their initial default probability and the initial default probabilities of the two average defaulted members are displayed. Except for CC&G, all CCPs in the sample have average CMs with a default probability of 0.09%, corresponding to an 'A' rating grade. Thus the probabilities reported in column 4 would be the respective default probabilities for a CM under the cover 2 scenario. For CC&G, the two average CMs have an initial default probability of 1.16% corresponding to a 'BB' rating grade, i.e. below investment grade. Thus, the probabilities reported in column 6 refer to the default probabilities for a CM under the cover 2 scenario for CC&G. The default probability distribution of CMs is displayed in figures 6 and 7 for US and EU CCPs. As for the default dependencies, we used an approach that may tend to underestimate the erosion of member bases: our default probabilities associated with 'B' and 'CCC' rating grades are lower than those provided by Tasche (2013) and by Gordy and Lütkebohmert (2013).

Under the stressed scenario for US CCPs, the resulting default probabilities would correspond to credit ratings that are all below investment grade. Murphy and Nahai-Williamson (2014) investigate the prudence of the cover 2 charge for CCPs. In their approach, all CMs are assigned the same default probability of 5%, which is within the ranges of conditional default probabilities of our stressed scenario. Interestingly, the authors consider 5% to be a very high value for the default probability of a member. Our results show, on the contrary, that the stressed default probabilities are likely to be much higher.

Figure 6: Default probability distribution for US CCPs under stressed market conditions



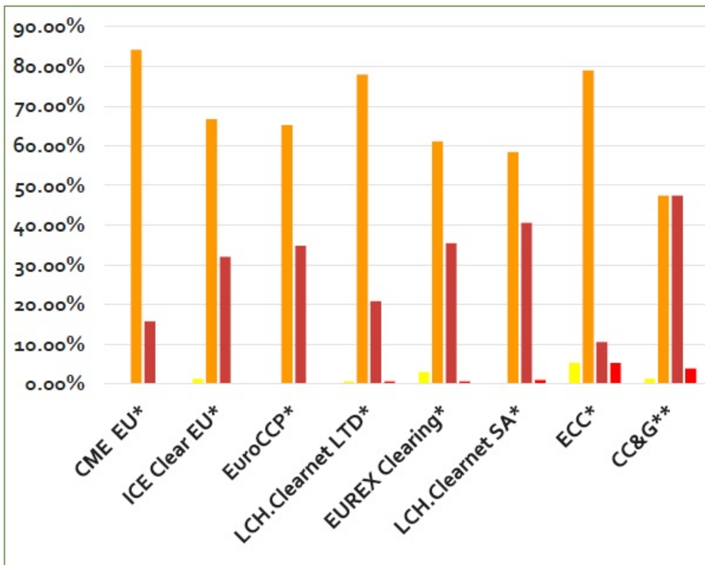
CM PD conditional on the default of two average CMs (in %)		
PD of average CMs / CM PD	0.09%	S&P Rating Category
0.05 %	1.83	BB
0.09 %	2.97	
0.23 %	5.84	B
1.16 %	12.28	

In the cover 2 stress scenario, ICE Clear US and CME Clearing US would each have a high percentage of members that have a default probability greater than 5.44%, which corresponds to a credit rating of 'B': ICE Clear US would have 46% and CME Clearing US approximately

43%. If the CCP demands liquidity via cash-calls, these CMs may face major problems raising liquidity in a short period of time due to the sensitivity of funding sources to credit rating downgrades (Karam et al., 2014). For ICE Clear US and CME Clearing US the risks would be concentrated in two large subsets of CMs corresponding to CMs without rating assignment. As already mentioned, not-rated CMs account for more than one third of these two major CCPs. Consequently, our results strongly depend upon the assignment of a pre-stressed default probability corresponding to a 'BB' rating for such members (as in BCBS (2013)). This quantification might obviously be disputable. Nevertheless, it does not undermine the broad concerns regarding the weakening of member bases in stressed scenarios.

Similar to US CCPs, the credit quality of European CCPs member bases would be severely impacted under a stressed scenario. Credit ratings of typical clearing members would be in the 'BB' or 'B' rating category, thus below investment grade. As mentioned previously, this would jeopardise the ability of CCPs to make cash calls on surviving clearing participants to replenish depleted default funds. This means that CCPs without public support would remain in a weak position for a certain period of time, possibly threatening financial stability.

Figure 7: Default probability distribution for EU CCPs under stressed market conditions



* The two average CMs under cover 2 approach each have a PD of 0.09%.
** The two average CMs under cover 2 approach each have a PD of 1.16%.

DP under cover 2 approach

CM PD conditional on the default of two average CMs (in %)		
PD of average CMs / CM PD	0.09%	S&P Rating Category
0.01 %	0.45	BBB
0.05 %	1.83	BB
0.09 %	2.97	
0.23 %	5.84	B
1.16 %	12.28	
5.44 %	25.94	CCC

CM PD conditional on the default of two average CMs (in %)		
PD of average CMs / CM PD	1.16%	S&P Rating Category
0.05 %	0.75	BBB
0.09 %	1.19	BB
0.23 %	2.42	
1.16 %	7.12	B
5.44 %	17.79	CCC

As the member bases of European CCPs are not heterogeneous, we may face run problems. As mentioned by Nahai-Williamson et al. (2013), heterogeneity of member bases is associated with incentive problems that may be mitigated with credit sensitive IM requirements and default fund contributions.

The small proportion of high quality, resilient clearing members would be exposed to the risk of having to subsidise the CCP. Moreover, considering the number of clearing members with 'CCC' ratings for CC&G and ECC, it is likely that the presented cover 2 scenarios are not conservative enough.

Considering that the regulatory cover 2 charge and stress test scenarios for determining default fund size do not take into account the possibly significant proportion of members with critical payment capacities, risk-sharing mechanisms may prove inefficient when market conditions deteriorate and the quality of a member base further erodes. The higher the default probability of a CM, the higher the possibility that the CCP may have to revert to the default fund. Thus, the member base quality should be taken into account when designing stress scenarios for sizing the default fund.

3.5. Member base typology

In the second step of the analysis, we represent the results using a two dimensional mesh. For this we introduce a matrix consisting of four cells, where each cell corresponds to a member base with varying proportions of good and lower quality members, see Figure 8. Based on the CM risk distribution of each CCP, we assign each CCP to the corresponding cell. This facilitates the understanding of possible issues specific to a certain type of member base composition without assessing in detail the member list of the respective CCP.

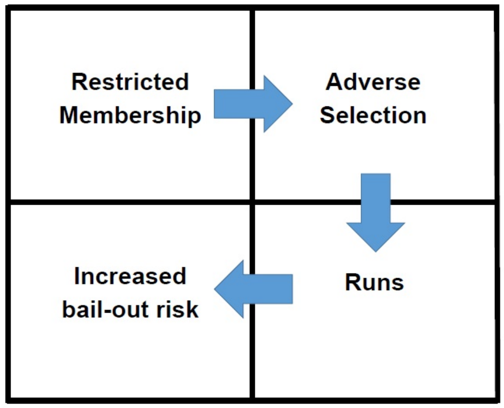
Figure 8: Member base typology

Member base consists only of good quality	**Member base majority is of good quality, small proportion of low quality CMs**
Member base majority is of low quality, only a small proportion of good quality CMs	**Member base majority is of good quality, but significant proportion of low quality CMs**

• **LCH.CLEARNET LLC** • **ICE CLEAR CREDIT**	• **ECC** • **CME CLEARING EU** • **LCH.CLEARNET LTD** • **TCC** • **EUREX**
• **CC&G**	• **ICE CLEAR US** • **CME CLEARING US** • **EUROCCP** • **LCH.CLEARNET SA** • **ICE CLEAR EU**

As we have seen in section 3.4, member base quality may erode over time, especially in times of crisis. The four different types of member base composition, as identified in Figure 8, allow the illustration of such a process. The composition of a member base deteriorates throughout four different stages, where each stage is associated with varying levels of good and low quality members. Starting from the upper left cell and going clockwise, the member base quality decreases with each further stage, resulting in a member base of low quality with only few good quality clearing members. In Table 9, we present possible issues associated with each of the four stages.

Figure 9: Financial stability dilemma



Each type of member base may pose different kinds of issues:

- A CCP with only good quality CMs may restrict membership. Given CCP proliferation and possibly 'races to the bottom', CCPs of this category may not be sustainable in the long term, unless CCP regulation and supervision is stringent.
- For a member base with a majority of good quality CMs and only a small proportion of low quality CMs, adverse selection problems may arise. The overall stronger payment capacity may result in lower pre-funded contributions. Such a constellation is most probably going to attract low quality CMs.
- A member base consisting primarily of good quality CMs, but with a significant proportion of low quality members, is prone to runs. If confronted with a costly bail-in in case of failure, the good quality CMs may choose to run from the CCP.
- For a member base with a majority of low quality and only a small proportion of good quality CMs, market instability may cause further erosion of the CMs' credit quality and lead to increases in default probabilities. If such a CCP is not systemically important, it will be most probably resolved. In contrast, a CCP of systemic importance may face a costly bail-out.

4. Conclusion

As the clearing landscape is changing rapidly and regulations are continuously being introduced, and due to the prominent role of central clearing, researchers must address a number of adverse effects and sources of financial fragility that could materialise within the new architecture. The ability of a CCP to withstand member defaults can be improved in various ways, such as better control of membership eligibility, sizing-up IM requirements, especially for clients that do not contribute to the default-fund, increased default fund requirements and limited allowance of unfunded contributions for lower quality clearing members. Each of the above ideas should be considered with moderation, as each has some clear drawbacks in terms of transaction fees for client clearing, limited access to central clearing, freeze of liquid assets and potentially pro-cyclical requirements. Quality at the heart of the financial system comes at a price and resources should thus be devoted in a rational way. CCP enhances multilateral forms of interconnection and deserves special attention since uncontrolled exposures via default funds of core clearing members may create the same kind of opaqueness that led to the disparagement of OTC derivatives during the financial crisis. Topics such as regulatory uncertainty regarding the remoteness of IM during a resolution process (so called IM-haircutting) are of particular concern as they might dramatically increase the risky amounts at stake. In the same vein, regulation should be cautious about incentives provided to market participants that could result in races to the bottom or runs in the context of increased CCP competition, subsidising of low quality CMs that might overload a CCP at the expense of others, thus jeopardising the efficiency of the new risk-sharing mechanisms. For this purpose, a closer look at default fund exposures and failure mechanisms is of major importance. Furthermore, the default fund should be sensitive with regards to risk and the differences between the different default fund structures.

Analysis of CCP membership base, both in terms of average financial soundness and heterogeneity among default fund contributors appears to be an important aspect of CCP monitoring and supervision. Given also the European regulators approach to transfer costs arising under resolution regimes to members, participants, investors and clients (European Commission, 2015), the ability of CMs to provide contingent liquidity may prove to be crucial for the resilience of a CCP and thus for financial stability. Our approach is based on CM ratings and the assignment of default probabilities. The member base composition shows a great degree of heterogeneity among CCPs. A number of CCPs have a significant proportion of members with critical payment capacities. An even greater proportion have quite heterogeneous member bases. We show that under a stressed scenario member base quality erodes and many CCPs may face severe liquidity problems, if CMs cannot provide contingent funding to sustain the CCP's resilience. The performance of low quality CMs with a banking license can also be affected by specificities, such as resolution regimes, public support, emergency liquidity or central bank administration. From the point of view of a CCP, the quantification of such impacts may prove difficult.

This brings into question membership eligibility, the design of IM requirements and default fund contributions for CMs and their clients, keeping in mind the overall objective of open and fair access to central clearing. Analysis of membership base is only a part of the monitoring of counterparty default risk related to central clearing; other issues such as netting efficiency, i.e. the ratio of required IM to the notional of cleared contracts are obviously to be taken into account and might lead to different outcomes. Since we do not believe that regulatory authorities will leave default fund risks in the shadows, the issue of properly assessing capital charges for counterparty risk is also critical. A decrease in a CM's credit quality leads to an increase of the common exposure via the default fund. Thus CCPs may consider integrating default fund add-ons for members with decreasing credit quality into existing risk management frameworks. Such add-ons should be calibrated to avoid procyclical effects.

As member base composition has just recently become a topic of interest for researchers, regulators and other CCP interested parties, they will need tools that allow the monitoring of member base quality and also the dispersion of risk amongst members. The approaches presented here may be a first step in this direction.

AppendixA. Waterfall resources

Table A.11: Pre-funded default waterfall resources for EU CCPs

CCP	Asset Class	Initial Margin (in mn)	SIG (in mn)	Default Fund (in mn)
ECC	Commodities	1105€	5.5€	130€
Eurex	Derivatives Securities Financing Cash	65020€	50€	3640€
ICE Clear Europe	Futures and Options CDS	34508 \$ 7682 \$	100 \$ 31 \$	1850 \$ 1126 \$
CC&G	Equity Derivatives & Shares Bonds Energy Derivatives Agricultural Commodity Derivatives	12117€	5€	1750€ 3000€ 14€ 1.2€
LCH.Clearnet LTD	ForexClear SwapClear Commodities Listed Rates Equities RepoClear	98000€	5.1€ 47€ 1.4€ 0.6€ 2.7€ 14.2€	434 \$ 2660 £ 122 \$ 35 £ 155 £ 1087€
LCH.Clearnet SA	CDSClear Cash&Derivatives Fixed Income €GCPlus	26400€	20€ 14.3€ 11€ 0.7€	383€ 1591€ 1218€ 74€

Source: The financial data as at 31^{st} May 2015 for ECC, as at 31^{st} July 2015 for Eurex, as at 30^{th} September 2015 for ICE Clear Europe, as at 29^{th} October 2015 for CC&G, and as at 30^{th} September 2015 for LCH.Clearnet LTD and LCH.Clearnet SA. The data was retrieved from each CCP's website.

Remark: Waterfall resources are not available for CME Clearing Europe.

Table A.12: Pre-funded default waterfall resources for US CCPs

CCP	Asset Class	Initial Margin (in mn)	SIG (in mn)	Default Fund (in mn)
ICE Clear US	Futures	12811 \$	50 \$	402 \$
ICE Clear Credit	CDS	19472 \$	50 \$	1933 \$
LCH.Clearnet LLC	IRS	144 \$	2 \$	260 \$
CME Clearing US	Base Financial	131000 \$	100 \$	3276 \$
	IRS		150 \$	3489 \$
	CDS		50 \$	650 \$

Source: The financial data as at 30^{th} September 2015 for ICE Clear US, as at 30^{th} September 2015 for ICE Clear Credit, as at 30^{th} September 2015 for LCH.Clearnet LLC, and as at 30^{th} September 2015 for CME Clearing US. The data was retrieved from each CCP's website.

Remark: As at 30^{th} September 2015 there is no open interest at The Clearing Corporation. Consequently, the CCP's current initial margin on deposit is 0\$. The default fund amount as at 30^{th} September 2015 is equal to 1.2\$ mn. The information was retrieved from the CCP's website.

AppendixB. Credit rating and default risk weight assignment

Table B.13: Credit rating and default risk weight assignment

Interpretation	Moodys	Fitch Rating	Standard & Poor's	DRW
Extremely strong payment capacity	Aaa	AAA	AAA	0,5%
Very strong payment payment capacity	Aa	AA	AA	2 %
Strong payment capacity	A	A	A	3 %
Adequate payment capacity	Baa	BBB	BBB	6 %
Likely to fulfil payment obligations, high credit risk	Ba	BB	BB	15 %
Highly Speculative, very high credit risk	B	B	B	30%
Extremely speculative, extremely high credit risk	Caa	CCC	CCC	50%
Not rated				15 %

AppendixC. PD distributions

Table C.14: PD distribution among CMs per EU CCP

	PD						
CCP	0.01 %	0.05 %	0.09 %	0.23 %	1.16 %	5.44 %	14.21 %
CME Clearing EU	0.00%	19.05%	66.67%	4.76%	9.52%	0.00%	0.00%
ICE Clear Europe	1.25%	11.25%	56.25%	6.25%	25.00%	0.00%	0.00%
LCH.Clearnet LTD	0.64%	22.44%	55.77%	9.62%	10.90%	0.64%	0.00%
ECC	4.76%	9.52%	71.43%	0.00%	9.52%	4.76%	0.00%
Eurex	2.87%	16.09%	45.40%	12.07%	22.99%	0.57%	0.00%
EuroCCP	0.00%	14.58%	52.08%	8.33%	25.00%	0.00%	0.00%
LCH.Clearnet SA	0.00%	12.62%	46.60%	12.62%	27.18%	0.97%	0.00%
CC&G	0.00%	1.25%	25.00%	21.25%	48.75%	3.75%	0.00%

Table C.15: PD distribution among CMs per US CCP

	PD						
CCP	0.01 %	0.05 %	0.09 %	0.23 %	1.16 %	5.44 %	14.21 %
LCH.Clearnet LLC	0.00%	18.75%	81.25%	0.00%	0.00%	0.00%	0.00%
ICE Clear Credit	0.00%	17.86%	82.14%	0.00%	0.00%	0.00%	0.00%
CME Clearing US	0.00%	14.71%	41.18%	7.35%	36.76%	0.00%	0.00%
The Clearing Corporation	0.00%	0.00%	83.33%	8.33%	8.33%	0.00%	0.00%
ICE Clear US	0.00%	8.11%	51.35%	2.70%	37.84%	0.00%	0.00%

Table C.16: Conditional PD distribution among CMs per EU CCP

	Conditional PD range			
CCP	$[0.23-1.16)$	$[1.16-5.44)$	$[5.44-14.21)$	≥ 14.21
CME Clearing EU	0.00 %	84.21 %	15.79 %	0.00 %
ICE Clear Europe	1.28 %	66.67 %	32.05 %	0.00 %
LCH.Clearnet LTD	0.65 %	77.92 %	20.78 %	0.65 %
ECC	5.26 %	78.95 %	10.53 %	5.26 %
Eurex	2.91 %	61.05 %	35.47 %	0.58 %
EuroCCP	0.00 %	65.22 %	34.78 %	0.00 %
LCH.Clearnet SA	0.00 %	58.42 %	40.59 %	0.99 %
CC&G	1.28 %	47.44 %	47.44 %	3.85 %

Table C.17: Conditional PD distribution among CMs per US CCP

	Conditional PD range		
CCP	[1.16 – 5.44)	[5.44 – 14.21)	≥ 14.21
LCH.Clearnet LLC	100.00 %	0.00 %	0.00 %
ICE Clear Credit	100.00 %	0.00 %	0.00 %
CME Clearing US	54.55 %	45.45 %	0.00 %
The Clearing Corporation	80.00 %	20.00 %	0.00 %
ICE Clear US	57.14 %	42.86 %	0.00 %

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