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CENTRAL COUNTERPARTIES

Risk management of central counterparties focusing on the analysis of stress tests

Ph.D. dissertation

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2021, Budapest

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ACKNOWLEDGMENTS

This research would not have been possible without the support of many people. First and foremost, I have to thank my research supervisor, Mrs. Kata Váradi. Without your assistance, perseverance, and dedicated involvement in every step, both professionally and personally, this thesis would have never been accomplished throughout the process. I want to thank you very much for your support, understanding, and endless patience over these past four years.

I would also like to show gratitude to the pre-committee, including Mrs. Edina Berlinger, Mrs. Ágnes Nagy and Mr. Dániel Béres. They raised many precious observations during the draft dissertation discussion, and I hope that I have managed to address several of them here. Thank you for your time and professional critiques that helped the improvement of my research. I am grateful to my Department of Finance colleagues for their suggestions to advance my researches throughout the years. I am grateful for my research team members Mrs. Kira Muratov-Szabó and Ms. Andrea Prepuk, and my fellow co-author and professional advisor, Ms. Csilla Szanyi.

When in 2015 I applied for a job at the Hungarian Central Securities Depository, I never imagined I would be standing here and presenting a thesis, reaching such a high level of professionality in the field. The biggest "push" in this way came from Mr. Károly Mátrai, the CEO of KELER CCP at that time. He offered the possibility to study while he supported my carrier as well. No words can describe how thankful I am for believing in me and encouraging me on my path. I am also thankful to my current bosses, Jelencsik Attila and Demkó-Szekeres Zsolt, from KELER Ltd. for helping me finish my studies. Mr. Béli Marcell also provided great aid to my research. The brainstorming and the discussions were always fruitful, and I enjoyed every bit of it. Thank you for this.

Getting through my dissertation required more than academic support, and I have many friends and family members to thank for listening to and, at times, having to tolerate me over the past four years. To my parents, Melinda and Ferenc Szodorai, and my dearest sister, dr. Rita Szodorai – it would be an

understatement to say that, as a family, we have had a bumpy road behind us in the past four years. But whenever I was ready to quit, you motivated me to push it further, and I am forever grateful. Most importantly, none of this could have happened without my husband, Viktor Friesz, the love of my life. Since the day we met, you have supported me, tolerated my messiness and endless craziness. At the end of the day, you are my hero. This dissertation stands as a testament to your unconditional love and encouragement.

Introduction

After the distress hit the financial system in 2008, at the London Summit in April 2009, the G20 leaders all agreed that the current system in the whole world is vulnerable. Globally appropriate steps shall be taken to overcome the discrepancies. The biggest concern related to the regulatory framework was that it was incapable of preventing imbalances and spillover of distress among entities or even countries. As a result, over the past decade, structural changes were applied in the financial system. Recent regulatory initiatives aim to enforce the system by proposing more substantial prudential requirements and improved protection rules.

Besides implementing new regulatory frameworks, a market infrastructure has gained high importance in the financial world. Over the last years, this area became the dominant institution in the "non-banking" field. The central clearing, performed by central counterparty clearing houses (hereinafter CCP), is a crucial feature of global derivatives markets. The G20 leaders recognized the benefits in risk management offered by CCPs, so they agreed in 2009 that standardized over-the-counter (hereinafter OTC) derivative transactions should be centrally cleared (G20 2009). The aforementioned prudential requirements were for CCPs themselves also established to strengthen their resilience to promote systematic stability. Global standards not just for the resilience but for the recovery of CCPs have been implemented and continuously adjusted and improved since the crisis. Coeuré (2017, p. 97.) presents the high attention authorities put into strengthening central clearing activities' global safeguards. The primary role played the approval of the CPMI-IOSCO Principles for Financial Market Infrastructures in 2012, a complementary CPMI-IOSCO report on the recovery of financial market infrastructures in 2014. The Financial Stability Board also gave guidance in 2014.

In 2015 further comprehensive work plan on central counterparties was put in force targeting resilience, recovery, resolution, and clearing interdependencies. Additional CPMI-IOSCO (2017) requirements were published in 2017, 2019, and 2020 as well. The latest issue for consideration

was regarding the default management auctions (CPMI-IOSCO, 2020). For resolution planning, guidance has been set out by FSB (2014) and FSB (2017), and a framework developed for supervisory stress testing specifically for CCPs (CPMI-IOSCO (2018)).

As mentioned, this regulatory "redesigning" is a global plan in progress. Every financial institution around the world is subject to the newly approved frameworks. Guidelines present in the Dodd-Frank Act (DFA) are rules to be applied for institutions operating in the United States of America. At the same time, European entities are subject to the Basel Committee's proposal, knows as Basel III, applicable for banking institutions, for regulatory reform, and the European Market Infrastructure Regulation (EMIR). Asian entities are regulated too by the Hong Kong Monetary Authority (HKMA). There are CCPs established outside the European Union, which applied for recognition of EMIR. Among these CCPs are listed several Asian institutions as well.[1]

Authorities and regulators emphasize the importance of transparency, and they also cast CCPs as "pillars of the new global financial architecture" (Paisley, 2017).

To measure the resilience of these kinds of new infrastructures, among others, regulators call for the application of stress tests. The quality of management and the stability of the financial system are also the subject of several tests. A particular element of CCP's daily function is the default waterfall guarantee system. The quantification of clearing member contribution is based on, among others, on results of stress tests. While calibrating the stress test method to determine the proper contributions for the clearing members must consider two points of view: the default waterfall shall be prudent enough, so, in case of extreme distress, a CCP could survive. On the other hand, if the clearing service becomes too expensive, market participants will be burdened to join the system. This would have an adverse effect, so the primary goal of clear OTC trades through CCPs making markets transparent and safe would fade.

[1] https://www.esma.europa.eu/sites/default/files/library/list_of_applicants_tc-ccps.pdf

Before the sub-prime crisis of 2007-2009, only about 25 percent of OTC transactions were cleared through a central partner (Hull, 2018). The regulatory response to the crisis aims to enhance the stability and transparency of the financial system. The Dodd-Frank Act adopted by the US Congress and the European Market Infrastructure Regulation (EMIR) stipulates that a regulated CCP will regulate a standardized OTC deal between all significant players. These markets have become more regulated, and OTC trades have become subject to central clearing. In 2009 only one-third of interest rate derivatives and one-tenth of credit default swaps were cleared through CCPs, while in 2019, these ratios increased to almost four-fifths and 50%, respectively (Aramonte and Huang, 2019). As of the first half of 2020, about $388 trillion notional amount of interest rate derivatives were cleared by CCPs, with a gross market value of about $6 trillion (BIS, 2020).

This research aims to give an overview of the regulatory framework proposed by the relevant authorities and to identify the most suitable default waterfall design that suits the profile of the CCP, but it avoids distorting the competition on the market among clearing members. The study connects with authorities' steps mentioned earlier and contributes to the existing literature in two ways. Firstly, the proposed model for defining the optimal level of default fund contribution by calibrating the applied stress tests will give a practical overview of the default waterfall's optimal calibration. The trading incentives concerning the amount of capital a CCP is willing to contribute to the default waterfall based on a proposed model are also essential for the study. On the other hand, regulatory constraints on this topic are emphasized, giving examples of how inadequate or highly regulated environments can harm the system and its participants.

Therefore, the research question focuses on the design of the default waterfall in two cases: **How does the default fund contribution of the clearing members take shape if the CCP manages its default fund separately, merged on the spot and derivatives market.** The amount of CCP capital in the system plays an important role, so its size can define the system's riskiness, but it can also alter incentives. This reasons why the other question of the study is related to it: **What should be the size of the CCP's**

contribution in order to avoid using the non-defaulting member's default fund contribution? What should be the size of the CCP's capital just to have a default waterfall that covers the losses of the defaulting member without triggering the recovery plan?

The document is structured as follows: In the first chapter, I introduce the reader to the world of central clearing by defining its function in the economy. The chapter first familiarizes historical aspects of central clearing and the significance of multilateral netting. Lingering further on history, in this chapter, I present the default and near-fail events related to central counterparties, followed by the detailing of CCPs' risks. CCPs are often confused with banks, but I analyze both institutions' balance sheet structure and risk profile in the second chapter to prove how different they are. The third chapter focuses on the development of the regulatory background concerning the European and US frameworks. Chapter IV. contains the analysis of the default waterfall's three layers: margins, default fund contributions, and the CCP's capital contributions. The relevant regulatory background is described in this chapter, along with literature overviews. The second layer detailing contains the importance of stress testing. From a theoretical point of view, I dedicate one last chapter to introduce the possibilities CCPs and authorities have to avoid a dramatic failure of the infrastructure if the default waterfall is proven to be inadequate. The document's final chapter contains the proposed methodology and baseline research model, unfolding a Monte Carlo simulation that analyzes the amount of capital a CCP has to risk when providing clearing and settlement services on the market while operating different guarantee systems setups. I used a theoretical model to show how credit risk is altered depending on the four guarantee system setups. Finally, I analyze the results to show what benefits and dangers the four operations have from the viewpoint of the CCP's own capital. This question is also crucial from the regulators' point of view since the more vulnerable a CCP is, the larger the systematic risk. The limits of the model and a sensitivity test is also presented.

During my doctoral studies, I was a member of a research group, supported by EFOP-3.6.3.-VEKOP-16-2017-00007 számú "Tehetségből fiatal kutató"

– A kutatói életpályát támogató tevékenységek. (“Talented young researcher” – Supporting activities of researcher career). The work of the group was flourishing, and the model we built is incorporated into my research. A part of the theoretical model results were part of an MSc thesis of one of the research group members. The co-authors’ statement is annexed to the thesis.

Some elements of a study prepared with Csilla Szanyi and Kata Váradi are used. The co-authors’ statements are annexed as well.

I. CCP's function in the economy

The presence of the CCPs in the financial markets is undeniable. Many researchers pointed out the benefits these infrastructures provide, nevertheless, learning the path that led to the growing importance of CCP is indispensable.

Before entering into the detail of the CCP analysis, it is crucial to clear the notions of CCPs and clearinghouses.

1.1. Clearinghouses vs. central counterparties

The primary role of clearinghouses and central counterparties is the clearing and the settlement of trades. The first significant difference is that a clearinghouse operates on exchange markets, while CCPs can operate on exchange and OTC markets. Regarding the risk-overtaking mechanism, the CCP takes over the counterparty risk during trading, so there is a novation process by becoming the seller to every buyer and every seller, while a clearinghouse usually does not do this. So in the case of OTC CCPs, the two trading parties are no longer exposed to each other but only to the CCP, providing insurance against bilateral default risk (Biais et al., 2016). The netting of the transactions is different since a CCP always nets transactions, while clearinghouses do not necessarily. Another striking dissimilarity relates to the fact that in OTC CCPs, the trades are not necessarily cleared daily (Berlinger et al., 2016b). Overall, every CCP has the activity of a clearinghouse, while not every clearinghouse can be regarded as a CCP (DNB, 2013). However, this difference is in the clearing activity is continuously eroding and disappearing (Berlinger et al., 2016b).

With my supervisor, Kata Váradi, Ph. D., we analyzed the difference between clearinghouses and central counterparty by analyzing their risk management efficiency on a margin level. We used EMIR and DFA regulations' requirements when developing the models. We used **futures margin as the margin calculated by clearinghouses** only in exchange trading, and **CCP margin calculated by the CCPs** and can be used in the markets it clears (both exchange- and OTC trading). In both cases, the trader becomes a member of the system, and it

will be a clearing member having an obligation to pay margins imposed by the entity. Our results show that calculating the margin balance with the futures margining or the CCP margining can lead to a much different margin account balance, although the initial margin requirements were calculated the same way. The simulation was run 1 000 times. The main result was that from an everyday liquidity management point of view regarding cash flow movements and overmargining, the futures margining is better from the clearing members' perspective. Moreover, also from a procyclicality aspect, the futures margining proved to be better. Nevertheless, the overall results show that the CCP margin was better from the model adequacy perspective. Namely, it performed much better on the backtest, so from a prudency perspective, it is superior. Therefore, the significant difference appears on an operational level, while both institutions' goal is the same.

1.2. A brief history of central clearing

In the following, I will present the history of central counterparties by pointing out the major turning points in their evolution, increasing resilience, and importance.

1.2.1. Cheque clearing

Cheque clearing was one of the first forms of clearing services. This service is defined as "*movement of a check from the bank in which it was deposited to the bank on which it was drawn, and the movement of its face amount in the opposite direction*." (Business dictionary, 2021). This is a so-called clearing cycle, and its purpose is to net the credit and debit accounts with the same pre-agreed amount. If there were insufficient funds in the account at the time the cheque arrived, it was being rejected and returned to the issuing bank. The payee in the transaction was the person to whom the cheque was drawn. This allowed the owner to the issuing bank, present the cheque, and receive the payment. Before payment, the drawer's bank would examine the check's basic requirements regarding the administrative criteria like signature, dates, and any other details as requested. The payee was empowered to deposit the cheque with their bank, which helped it to be introduced to the responsible bank for installment (Lloyd, 1899).

Cheques became popular in England in the 1600s, but until around 1770, this "clearing" was performed personally by clerks. London originated the clearinghouse. London private banker clerks formed this very initial clearing activity. The primary purpose of these meetings was to save themselves the trouble and time of going to each bank, so they got into the habit of meeting in a room to settle their mutual claims. The French merchants had a similar practice. They gathered to balance their debts, pay the differences, and make their bills payable at the great annual fair at Lyons. They visited all other banks to exchange cheques until they settled with each other (Lloyd, 1899; Nevin and Davis, 1970). In 1832 Charles Babbage described how the Clearing House operated (Babbage, 1832). In the 19th century, the first organization for clearing cheques was the "Bankers' Clearing House." Lubbock's Bank founded it on the famous Lombard Street, needing only a single room for the clearing activity. Clerks from London banks met each day to exchange checks and settle accounts.

After every cheque was collected, each clerk of the debtor bank paid in cash to the Inspector of the Clearing House, the amount one bank owed to other banks. Lastly, when the debtor clerks had paid the Inspector, each clerk for the banks that were owed money collected the amount they were entitled. The end-of-day balance was zero, as the debtor banks' amount of cash must have equaled the creditor banks' total money. At the end of the day, the netting amount was zero. If the received and the distributed amount did not match, the paper trail of documents helped to identify the numerical errors, so those could be found and corrected as soon as possible (Matthew, 1921).

The growing volume of checks required more efficient sorting methods to be developed. As the automation of cheque processing improved, electronic payment systems excluded the need for paper-based tools.

1.2.2. Financial clearing history

As automation improved, the latter part of the 19th century was characterized by the innovative processes implemented in financial exchanges. This improvement meant that commodities futures markets and stock exchanges began to use clearinghouses.

In Europe, London was, and nowadays, it is still one of the most important financial centers. Not surprisingly, as late as 1899, the London Stock Exchange was the first and the only stock exchange in Europe using a clearinghouse at the time (Lloyd, 1899).

The New York Stock Exchange (NYSE) is the most crucial in the United States of America, but the Philadelphia Stock Exchange was the first to use a clearing system. Founded in 1790, it played an influential role in America's financial and economic development, facilitating the accurate settlement of securities transactions, including buy-sell activities and deliveries (Guarino, 2015).

Brown et al. (2008) and Bernstein et al. (2019) give a historical overview of the clearing activity focusing on the United States' markets. They highlight the Consolidated Stock Exchange (CSE) as the most significant exchange that competed head-to-head with the Big Board[2]. It traded many NYSE-listed securities, and as noted by Brown et al. averaged more than a 50 market percent share during the 1890s starting from 1886. The NYSE netted its stock transactions through a clearinghouse only from May of 1892. (Bernstein et al., 2019). At this point, the risk-mutualization of trading and highly sophisticated guarantee funds were not implemented yet. The primary goal was to facilitated multi-lateral netting across all members by centralizing clearing. The New York Coffee Exchange and the Chicago Mercantile Exchange started using clearing houses to settle their transactions from the second decade of the 20th century, despite being considered significant stock exchanges. The New York Coffee Exchange began using clearing houses in 1914. The Chicago Mercantile Exchange started providing clearing services later in 1919 (Labuszewski et al., 2010).

Bernstein et al. (2019) examined the benefits of establishing the NYSE compared to the CSE. Their findings show the benefits introduced by the clearing, highlighting the reduced annualized volatility of returns by 90-

[2] The Big Board is an auction market where brokers and specialists buy and sell securities for people by matching the highest bidding price with the lowest selling price. One of the most distinguishing characteristics of the Big Board is -- unlike the Nasdaq or other electronic exchanges, it has an actual trading floor at 11 Wall Street in New York.

173bps and increased asset values. Before clearing, "*shocks to overnight lending rates reduced the value of stocks on the NYSE, relative to identical stocks on the CSE, but this was no longer true after the establishment of the clearing.*" (Bernstein et al., 2019, p. 719) They also point out that a decrease in contagion risk drives at least half of the average reduction in counterparty risk. They indicate that clearing can significantly improve market stability and value to decrease network contagion and counterparty risk.

The benefits of central clearing are undeniable. It can significantly improve market stability and increase asset values by reducing network contagion and counterparty risk.

1.2.3. CCPs in the modern era

The main idea of CCPs is that trading through a CCP, a bilateral OTC derivative trade between two counterparties, is replaced by two symmetric transactions between the CCP and each counterparty. Cont (2010), Iyer and Peydro (2011) point out an essential function and benefit of these market infrastructures, namely preventing adverse effects and spillover of a defaulting counterparty. Compared to bilateral trading, where the default of one entity can spread throughout the system leading to a chain of contagious defaults, by multilateral netting among market participants, there is higher transparency, risk-sharing among members of the clearinghouse is achieved. Also, there is no need for duplicative monitoring, and mitigation of counterparty risk is managed through the CCP as members of the system are insulated from each other's default, reducing friction in commitments (Nosal, 2011).

It is undeniable, and we have already determined that the prime role of the central clearing counterparty is to manage risk achieving this by various techniques to manage the exposures taken by not just its clearing members but also the non-clearing members too.

Central counterparties were not in the spotlight as they are nowadays. The turning point in their importance was on the 14th of September 2008. This day was significant in current history as well. The day before Lehman

Brothers declared bankruptcy, they tried to limit the damage and the losses of other financial institutions resulting from its default by working to net counterparty risk in their bilateral over-the-counter contracts. Lehman Brothers Holdings in 2012 reported that their global OTC derivatives position at the time was estimated at $35 trillion in notional. If this would not be enough, the company also was included being a counterparty in over 900,000 derivatives transactions, amounting to a total of $24 billion in counterparty liabilities. The company had 209 registered subsidiaries in 21 different countries, so Lehman's bankruptcy and financial debugging were among the most significant and most complicated cases in history. Creditors filed about $1.2 trillion of claims against the Lehman estate (Fleming and Sarkar, 2015; Bernstein et al., 2019).

Unfortunately, their move of clearing to reduce damages "was described by market participants as "a bust," with very little successful netting before Lehman's bankruptcy filing" (Bernstein et al., 2019). The consequences are already known: counterparty risk has increased dramatically, leading to contagion and financial instability among global financial market participants. The uncertainty amplified counterparty risk. This uncertainty's essential indicators were the dramatic increase in the credit default swap-bond basis and covered interest rate parity deviations. (Bernstein et al., 2019).

The collapse of one of the "too-big-to-fail" institutions and the never seen spillover it caused raised concerns about the stability of the whole financial system, and it also pointed out the need for a more robust counterparty risk management.

Before Lehman's collapse, market participants relied on bilateral agreements and ad-hoc margin requirements among them. Moreover, the regulatory background in OTC derivatives did not require traders to move their activities and use multilateral netting through a centralized clearinghouse. With the lack of a central counterparty and, therefore, the lack of proper risk management, traders were exposed to increased counterparty risk through contagion, since if one trader defaults, he can set off a domino effect leading

to additional defaults among market participants, but also amplify the spillover effect to other segments of the markets or even other countries.

The most significant benefit of multilateral netting is the gross notional exposure reduction. Cecchetti et al. (2009) estimate that the exposure can be reduced even by 90 percent. Policymakers use the Lehman's bankruptcy as a piece of evidence to show the need to enhance the transparency of the OTC traded transactions, pointing out the ex-post netting benefits. The primary goal is to reduce the counterparty risk arising from contagion and to avoid the domino effect induced by a market participant unable to meet its requirements.

1.2.4. Bilateral trading versus multilateral netting

The end-to-end analysis of trade has three significant levels to be considered: the platform where the trade is initiated, the actual clearing of the transaction, and of course, the settlement of assets. The process is presented on an existing example through the capital market infrastructure of the Hungarian market for trades cleared by the Hungarian CCP, KELER CCP:

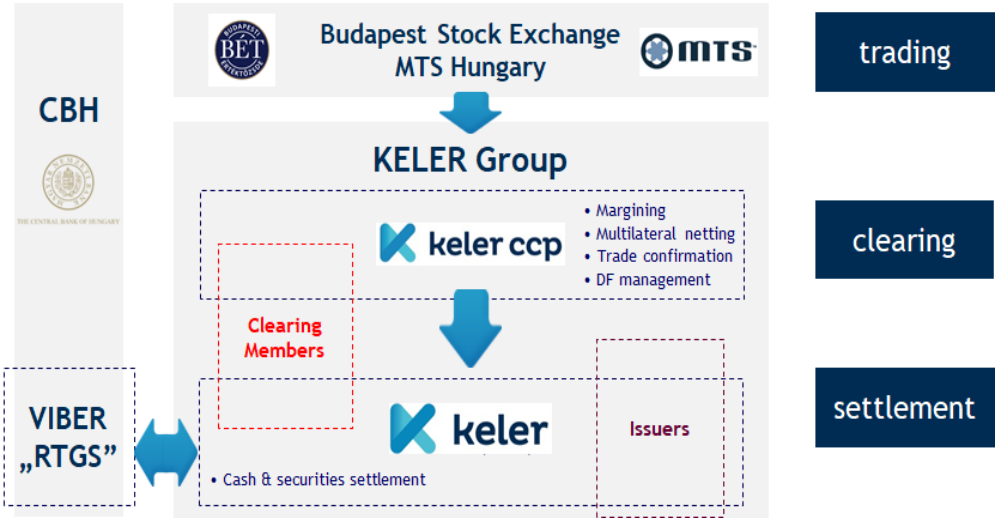


Figure 1: Capital Market Infrastructure in Hungary

Source: KELER CCP (2021)

The deal is made on a trading platform - in this case, the Budapest Stock Exchange or the Multilateral Trading System (MTS platform)[3] – This is the first level where market participants buy or sell assets. KELER CCP performs the clearing, KELER CSD – the central securities depository – performs settlement of assets. Nevertheless, the cash side settlement of the trade can be performed by the central securities depository, not only by the central bank but also by the CSD with banking-type ancillary services. Béres (2018) points out the undeniable positive effect of CCPs. He analyzes both central securities depositories and central counterparties, and he highlights that the two infrastructures can determine the efficiency of the financial and capital markets by having an indirect effect on the performance of the whole economy.

CCP clearing concentrates on trade management, position management, collateral and risk management, and delivery management. There are two forms of CCP inclusions: first, the CCP becomes the original buyer and seller's counterparty. Second, the CCP is a facilitator, in which case the original buyer and seller remain legal counterparties to each other. The CCP will validate and match the delivery instructions, the result of which is forwarded to settlement. The clearing is performed first by the CCP, then the CSD's turn is to perform the settlement. It is also possible for CCPs to be involved in the activity of clearing and in the settlement.

The process when the CCP imposes itself a "central" party between traders and, therefore, "*becoming a buyer to the seller, and a seller to the buyer*" is called novation (CPSS, 2004). The CCP will provide insurance against the bilateral default risk for the two parties. They are no longer exposed to each other but only to the CCP (Biais et al., 2016). Although Lopez and Saeidinezhad (2017) have shown the risks in the growing importance of CCPs, they point out the significant benefits CCPs shall bring. First of all, the CCP takes market participants' trading exposures onto its balance sheet, relieving multilateral risk exposures' counterparties. This action reduces

[3] MTS is an electronic fixed income trading markets trading platform suitable to conclude different market products - cash, repo and swaps. The MTS platform supports electronic European fixed income markets for issuers, primary dealers and the secondary market.

counterparty risks among market participants, and the multilateral netting gives further benefits to the members. By the process, assets are released for participants to use them elsewhere. The model of central clearing compared bilateral trading is represented below:

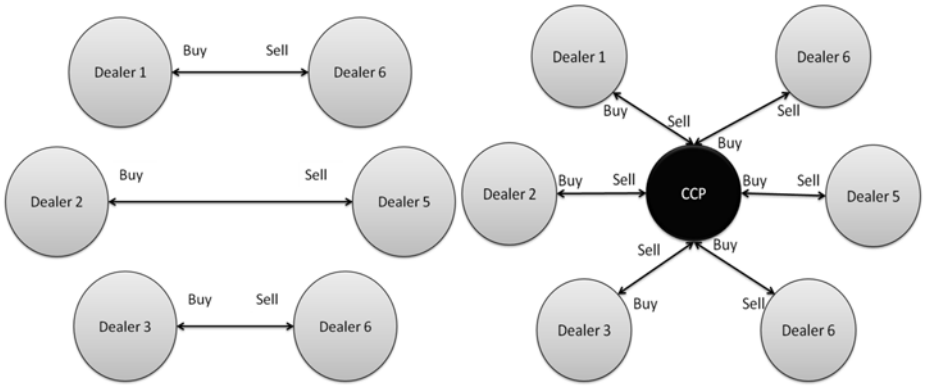


Figure 2: Bilateral and multilateral netting

Source: Cont, (2015, p. 366)

When the number of market participants is numerous, central clearing leads to a reduction of exposures through multilateral netting across counterparties, thus reducing counterparty risks:

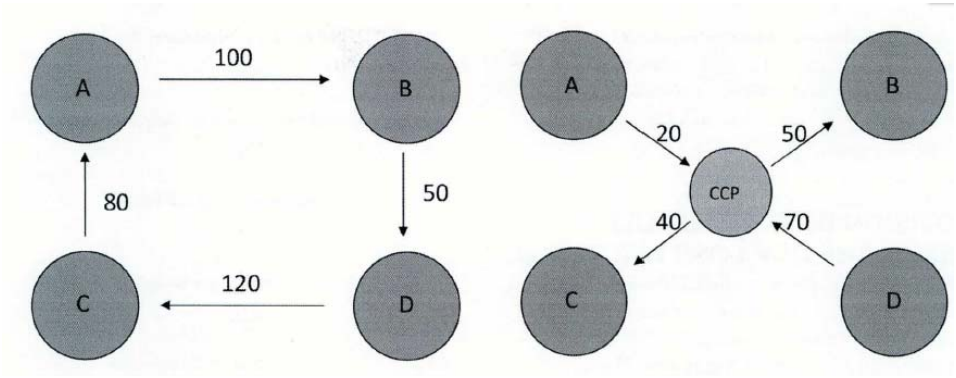


Figure 3: Exposure reduction

Source: Cont, (2015, p. 367.)

CCPs incorporate sophisticated risk management systems that contain the exposures arising from trading positions from a risk management perspective. Transparency walks hand in hand with better price information for traders, so this is also an advantage that cannot be omitted. Cont and Kokholm (2015) applied a stylized model of OTC exposures with multiple asset classes, and they have compared the effects of bilateral netting across classes with those

of multilateral netting across counterparties. Their findings show how efficient CCPs are if proper model parameters are used to take into account the differences in riskiness across asset classes.

Generally, margins that members provide are the primary risk management tools adopted by CCPs. Collateral is used to cover losses and protect both the clearinghouse and the market it clears from the severe movements in the cleared assets or commodities' price. The change of prices in the traded assets can be so significant that it creates liability or obligation the member cannot meet, leading to default. There are two other main components of the financial resources the CCP can use in case of default. The default fund contribution and its own funds as well. Altogether, they are called the default waterfall. The thesis details the components of the default waterfall contribution in chapter IV., where all components are described and presented.

1.3. Central counterparty defaults and near-fails[4]

To understand why a CCP must have a resilient and transparent operation, we must first see what happens if proper governance lacks these two elements. The 2008 crisis triggered the need for a robust financial environment, and the under-regulated era of OTC markets has ended. This chapter will present the issues and the main lessons learned from the most feared event, namely the default of a CCP.

We may think that the biggest fails in history come from the money markets, but the truth is, commodity markets were the first ones being hit by the breakdown of CCP. Since 1973, there were three events of this type and some near-fail circumstances as well (Kiff, 2014). At first, I present the three fails, followed by the near fails in modern history.

[4] A study regarding this topic was published and were used in this chapter: Friesz M., Váradi K. (2019), The role of central counterparties on the energy market International Journal Of Multidisciplinarity In Business And Science (1849-0581): 5 8 pp 48-56 (2019) https://issuu.com/tvranes/docs/ijmbs_vol_5_-_no_8_-_2019

1.3.1. The failure of the Caisse de Liquidation des Affaires et Marchandises (CLAM), Paris, 1974

Bignon and Vuillemey (2020) analyzed the fail of the French CCP from 1974. The CLAM was a cocoa, coffee, and sugar futures market, being the only CCP on the Paris Commodity Exchange. 1970-1974 was a turbulent period worldwide: the oil crisis and the stock market crash were all significant events that set out to settle the development. In Paris, the so-called sugar crisis hit the markets in 1974. The sugar's price has been multiplied by six in a one-year timeframe, peaking from 1,300 to 8,100 FRF/ton. Meanwhile, several countries experienced shortages of sugar and the combination of structural and exceptional factors lead to expectations of a long-lasting sugar shortage (Bignon and Vuillemey, 2020).

Overall, the unmet margin calls were the primary cause leading to the breakdown of CLAM—due to the sharp drop in sugar prices on the FX markets. The CCP's mistake was that it did not increase the margin requirements due to the higher market volatility. The high level of concentration against one single trader has not managed appropriately; authorities should have ordered reducing such a single party's exposure. Lacking transparency in the loss-allocation also aggravated the clearinghouse's situation. The lack of proper risk management is pointed out as well. Severe discrepancies were identified as soon as sugar prices collapsed, and the concentration level had a substantial downward effect as well. It is also shown that "*the interests of the CCP and those of the member in distress became closely aligned, which induced the CCP to delay the declaration of default and attempt manipulation of settlement prices.*" (Bignon and Vuillemey, 2017, p. 37). The regulatory framework was proven to be inadequate to mitigate the conflicts between managers and the supervisor, which ultimately led to misreporting. This spilled over between managers and creditors (risk-shifting) as well. (Bignon and Vuillemey, 2020).

1.3.2. The failure of the Malaysian Kuala Lumpur Commodity Clearing House (KLCE), Kuala Lumpur, 1983

In 1983 the Malaysian Kuala Lumpur Commodity Clearing House was closed down. The reason is similar to the CLAM's; the margin calls were not met after a crash in palm oil futures prices as the local CCP required. Concentration is present in this case as well since six large brokers had accumulated huge positions. The price volatility generated huge losses that ended with the default of the counterparties. The dedicated task force reported poor management and unwieldy rules leading to the fall of the four-year-old entity.

The crisis flared up by a Chinese millionaire named Loo Cheng Ghee. He was the Kentucky Fried Chicken franchise holder for Malaysia and Singapore. He made the speculative move by trying and failing to corner the palm oil futures market by legally selling short. Before speculation began, the trading volume on the KLCE averaged 800 lots of palm oil per day. Unfortunately, contract defaults and trading suspensions triggered speculations too, and its aftermath paralyzed the market. Due to unexpected bad weather, palm oil prices grew. Despite the Palm Oil Refiners Associations' warning regarding possible speculations and market manipulation, KLCE claimed to watch but not take action. Loo Cheng Ghee and his traders increased their trading activity, and although the crisis seemed to be outlined, it did not permit the statement of emergency powers. Rather, the exchange agreed to increases in good-faith deposits. After a few days, the first step the exchange did was to identify forced "*brokers to identify non-exchange members who held more than 100 open contracts in a month*" by invoking emergency regulations of limiting trading. Lee's brokers defaulted as well the next day on 5,150 lots and were suspended (Robinson, 1984).

Again, we can highlight the supervising authority's lack of proper timing of involvement and delayed response to the clearinghouse's market volatility. The suspension of trading was deferred also, deepening the situation. The connecting reports show a less transparent trade confirmation and registration

resulted. This sloppy management resulted in long delays in sorting out who owed what to whom (Kiff, 2019).

1.3.3. The failure of the Hong Kong Futures Exchange, Hong Kong, 1987

In 1987, worldwide stock markets faced immense falls, followed by the crash at Wall Street. The collision also hit the Hong Kong stock market. The Hang Seng Index fell, losing 11.1% of the market capitalization. The market was closed for the next four days. The crisis was mainly due to the lack of observation in maintaining initial margins, the negative trait of the market system, and some lack of proper knowledge of contracts. The Clearing House did not respond appropriately to the fluctuating process on the market. It only required its clearing members to deposit their net margins instead of gross ones. "*The protection to either its member firms or investors was way below the expected level. Some steps were taken; people were prohibited from short-selling shares. People, longing index futures, could not short index constituent stocks in the stock market to hedge their risk. Their long positions in the futures market were speculative*." (Lui Ho-chung, 1992, p.11.) The illusions of bullish markets lead traders to speculation (Lui Ho-chung, 1992). The Exchange needed the government's help asking it to provide loans for a bailout.

"*During a four-day market closure initiated by the stock exchange, clearing member performance failures were of sufficient magnitude to overwhelm the solvency of the guarantor of the clearing house's trades*." (Cox, 2015, p. 1.) In this case, researchers also point out the dramatic loss of confidence. The Hong Kong government put a resolution plan in place, this being the only known example in the CCP world (Cox, 2015).

1.3.4. Near-fails of CCPs

Near-fail defaults may seem less exciting, but these events are momentous events pointing out the system's discrepancies.

In October 1987, two entities faced near-fail events. The Chicago Mercantile Exchange (CME) and the Options Clearing Corporation (OCC) faced

difficulties in collecting the margins from the market. The CME handled the stress event when the Continental Illinois Bank advanced the clearinghouse $400 million just minutes before the opening bell in order to complete all the $2.5 billion in principal variation margin payments. (Kiff, 2019) The primary lesson for CME was that they should change their policy because "*clearing members retained too much discretion over the timely payment of margin*," leading to a critically small amount of time for the clearinghouse.[5]

In the case of the OCC, the issue again was the high level of concentration. The exposure towards a large clearing member who had difficulties meeting its requirements in the form of margin calls was excellent. The member reached out to an emergency loan from its bank to avoid suspension and default (Kiff, 2019).

Since the 1987 crash, there have been no significant issues among clearinghouses with such enormous stress to cover. Regulators and authorities learned from the past, and policies were adopted to avoid the financial system's domino effect. Along with the regulatory side's resilience, technology helped automate the payment system, so institutions are on the path to mitigate arising risks.

As these significant events show, **transparency and cooperation among parties** are crucial to avoid exacerbating systemic risks that CCP fails may cause.

1.3.5. CCP related market events in 2018

It is questionable if the current system is prepared for distress. However, reaching back to the fails tales, there was smaller distress in 2018.

In 2018 the electricity market was hit by distress. We can call the event a near fail or as **a test to the current systems** as well. This event is the first one

[5] History Of Central Counterparty Failures And Near-failures ..., https://www.theotcspace.com/content/history-central-counterparty-failures-and-ne (accessed August 09, 2021).

since the 2008 subprime crisis, when CCPs gained an essential role in establishing still working and transparent markets.

This specific event is related to the energy market. In this particular case, the issues are mentioned above: the member could not meet its margin requirements, so the member was declared in default. A Norwegian trader Einar Aas blew a €114m hole in the buffers. This trader earned millions of kroner in the previous years, but a way too risky and speculative trade ended this success. He bet that the spread between the Nordic and German power would narrow. Carbon emission allowances, the best performing commodity during the period, were on a tear. This event helped push up the German market, while at the same time, wetter weather forecasts sunk the Nordic next-year contract. His positions were massive compared to the liquidity on the market (Paulsson and Hotler, 2018). On the same day, he was declared defaulted for not meeting the margin requirements.

From the Nasdaq Clearing point of view, the defaulted portfolio contained a large spread position between Nordic and German Power that was negatively impacted by extraordinary fluctuations. Aas could not meet its margin calls, so within 48 hours, all of the positions had been closed through an auction, but the losses to be covered exceeded the defaulting member's collateral and default fund contribution. New capital needed to be injected, and the Nasdaq Clearing has decided to increase margin levels too. (Nasdaq, 2018).

This event endorsed the CCP and its advantages (King et al. 2020). Huang and Takáts (2020a) analyze the event from a model risk perspective since the event took place during a considerably calm market environment. They also point out the potential causes of such an event, like considering a long enough look-back period for the price changes, overestimating the correlations across markets, or underestimating the period needed to close the failing portfolios. Incentives must be aligned on the skin-in-the-game level.

1.4. Risks of CCPs

A CCP's primary role and purpose are to centralize counterparty risk management in the financial markets that operate (Pirrong, 2014). To

understand a CCP's risk profile, Hughes and Manning (2015) compare it with banks'. In their view, the most significant financial risk of a CCP stems from the likelihood that the CCP can execute the replacement trades in its matched book at a disadvantageous price. Consequently, liquidity risk arises in the case of a defaulting member. The two also point out that the risk profile of the CCP is "*conditional on the default of one or more of its participants. This underscores the natural interdependence between the risk profile of a CCP*". Banks have quite different activities; therefore, they are exposed to various risks, mainly their borrowers' credit risk. Moreover, banks face liquidity risk as well that arises from the mismatch between their funding sources and assets. (Hughes and Manning (2015)).

Researchers (including Murphy 2012; Pirrong, 2014, Hughes and Manning 2015) identify the vulnerable points by which a CCP could trigger or amplify systemic risk, namely:

- **Liquidity risk creation:** improper models for margin or collateral haircut and procyclicality calculation or even default fund contribution can burden the market participants by requiring excessive liquidity provision. In this case, the CCP can absorb liquidity from the market.
- **Transmission of stress:** if the required amount of collateral is inadequate and the CCP's pre-funded resources prove insufficient to cover losses of one or more clearing members, the domino effect can enhance.
- **Risk shifting:** as netting of cleared trades frees members' balance-sheet capacity to take risks elsewhere.
- **Wrong-time risk:** if the CCP imposes raise on the market it clears, due to the mutualized loss allocation, timing is crucial, as the CCP must avoid taking actions when members are least able to bear it.
- **Information and incentive issues:** The mispricing of individual members' contributions to risk can increase speculative behavior, triggering distress on the market. These factors are crucial factors affecting CCP risk but are also exogenous to the clearinghouse. The

volume of the trades on the market a CCP clears ultimately depends on its clearing members' activity.

Having the risk-reducing benefits of the CCPs, but also the potential risks are carrying through the transmission of stress, there can be potential positive and negative externalities on a systemic level. The positive side is that each trade cleared contributes to the opportunities for multilateral netting of exposures, thereby reducing the amount of risk to be managed relative to non-centrally cleared ones (Duffie and Zhu 2011). Consequently, the CCPs clear more trades and market processes concentrate around it, increasing its importance and reliance as well, so a potential spillover in the system should be managed correctly and in time. Primarily, by multilateral netting and exploiting the many other benefits of the clearing activity CCPs provide benefits by the more trades a CCP clears, but by increasing its operation, it also increases the potential impact of CCP stress. The risks mentioned above stemming from a given CCP design can amplify because the CCP will be unable to accomplish its primary role and cannot absorb the shock, leading to its materialization or the distress, due to liquidity shortage will result in transmitting the damages into the broader system. King et al. (2020) argue that CCP liquidity requests could strain banks and other market members from a liquidity risk perspective, increasingly posing a threat to the system. Their research focus shifts from potentially disastrous consequences of a failure or severe disruption to the difficulty that may occur if the CCP requires liquidity from large banks and other market participants. While the counterparty risk is mitigated, liquidity risk will appear instead. In addition, since assets will probably be called for by a CCP on occasion when bank liquidity positions are under pressure, they are innately procyclical in this environment.

Based on the same indicators identified by the FSB in the banking system, Hughes and Manning (2016) analyze the operation of CCPs and their influence on the network. They focus on the size, substitutability, resources, complexity, and scope and, nonetheless, the depth of its system-wide interconnections on domestic and cross-border markets.

Current regulatory and market requirements are leading CCPs to implement sophisticated practices to manage the default of one or more clearing members. Nevertheless, the management of non-default losses (NDLs) is also essential from the resilience perspective. The PFMI establishes standards for managing NDLs, with specific principles for legal, business, investment, custody, and operational risks. NDLs are not discussed in detail; however, this topic will be covered minimally regarding resolution and recovery planning. However, we shall not deny the importance of these factors, as the CCP's design choices can influence the cost of clearing and members' trading activities and decisions. The clearing activity and the conditions put by the CCP will be ultimately affected, and it will determine the balance of positive and negative systemic externalities that the CCP imposes on the financial system. A poor decision of the CCP and the design they apply may have severe consequences because their fundamental design can alter the loss allocation arrangements, and they also have the power to determine how stress could potentially be transmitted in the event of distress. As more and more trades are becoming subject to a CCP's clearing activity, members may seek to reduce their dependent exposures to the CCP by restructuring their businesses to avoid mandatory clearing obligations or managing their trading activity to reduce their allocation. This change can shift the market participants' behavior, which may prove systemically significant.

The potential threats mentioned can be managed by proper risk management tools, and let us not forget that regulators aim to prevent the development of inadequate managing systems by offering a prudent and rigorous legislative background. The primary goal of both money and commodity markets is to reduce risk and enforce the financial system's resilience by avoiding burdening the market participants. Central counterparties do mitigate counterparty risk and are prepared to withstand under "extreme but plausible market conditions." However, CCPs are no panacea, as if distress hits the financial system, CCPs are not an exception to harsh aftermath. While CCPs provide protection against idiosyncratic counterparty risk and serve as safeguards for the system as a whole, they offer no essential protection against aggregate risk and may even encourage risk-shifting (Biais et al.,

2012). Another risk arises in current circumstances, namely the default of the CCP itself. The default of a CCP, however, becomes a systemic risk. This event can trigger the collapse or weaken an industry's or economy's resilience (Duffie, 2011). Duffie (2011) claims that this event would dramatically affect the stability of the financial markets, as delineated in the previous chapter. There are further concerns regarding the systematic importance pointed out by Markose et al. (2012). The most prominent lesson learned from the global financial crisis is that the too-big-to-fail problem may cause headaches for everyone; CCPs also have a similar issue, the *too-interconnected-to-fail*. This is similar to the other phenomena tightly related to the moral hazard problem. This means that in the case of distress, and if CCPs failed, the adverse effects would be so wide-ranging that they could become prime candidates to expect bailouts.

Kubitza et al. (2021) show that not all market participants benefit from central clearing, and some are worse off. The loss-sharing divides the participants into losers and winners. They focus on the allocation of losses caused by the default of clearing members to survive clearing members. The loss-sharing effect can differ across market participants and is highly dependent on the derivatives market network structure, the rules of loss sharing, the directionality of the derivatives portfolios, and the correlation of derivatives prices.

Compared to banks, the number of failed CCPs is modest. While there were three significant failures of clearinghouses as seen in chapter 1.3, for example, since 2000 in the United States, more than 500 banks have failed[6]. To overcome these issues, regulators took a closer look at the fails and near-fails in history. Many of the past issues are now thoroughly regulated and supervised by competent authorities. Although many researchers welcome the new regulations, some are skeptical, as mentioned before. Many of them criticize the lack of regulatory framework, while others argue against overregulation. Not only the regulation of CCPs is subject to intense debates,

[6] The Federal Deposit Insurance Corporation is often appointed as receiver for failed banks. Their database includes information on the acquiring bank (if applicable), how accounts and loans are affected

but the money market itself. (Dewatripont and Tirole, 1994; Goodhart et al., 1998; Acharya and Bisin, 2014; Lopez and Saeidinezhad, 2017). Acharya et al. (2010) show that excessive regulation has costs, but at the same time, its effects, causing any severe disaster, can only be observed afterward. Lopez and Saeidinezhad (2017) criticize the new CCP regulations because they evaluate the individual CCP's resilience in isolation without considering potential spillovers on the rest of the financial system. They point out the shift of trading behavior and risk-taking willingness of the clearing members. Omitting this situation is way too optimistic. If the spillover effect is not handled in time, the expected resilience will fail, and CCPs will underperform. Therefore current regulatory frameworks shall implement further guidelines in several aspects to assure foreseeable financial stability.

Experts advise that clearinghouses can be thought of "*as a set of institutional arrangements that are designed to enhance contractual performance*." (Nosal, 2012, p. 1.).

II. CCPs are not banks

By analyzing the risks and the systematic importance of the CCPs, many draw similarities with banks. Laics may think of CCPs as banks. However, there is a resemblance between the two types of financial institutions; it is crucial to emphasize that CCPs are not banks. It is challenging even for regulators and policymakers to establish standards for CCP risk management, especially when they view them from the perspective of the bank regulatory standards. CCPs' risk-taking mechanisms and their full function bear a small resemblance to banks. They can be called unique in the meaning that they are not payment systems, depositories, insurance companies or exchange platforms, nor trading platforms, although they have characteristics that be similar to insurance because of their "guarantee mechanism." This guarantee mechanism is why a clearinghouse's inclusion may lead to seeing the CCP as an insurer rather than a principal to cleared trades (Cox and Steigerwald, 2017).

Moreover, CCPs may have an extensive network, connecting with other domestic or cross-border market infrastructures. Cox and Steigerwald (2017, p. 5.) state the following: "*While both serve an intermediary function, the similarity ends there.*"

Cox and Steigerwald (2017) analyze the most significant differences between CCPs and banks and the relevance of those differences, including their business models and risk profiles. In particular, they highlight the differences in the roles that capital and collateral play in connection with CCP and bank risk management, as *CCPs are acting as risk managers* – therefore subject to credit and liquidity risk of clearing members default - *while banks are risk-takers*. However, the mechanism of socialization of losses bears a striking resemblance to ex-post funding of deposit insurance, which punishes the surviving banks

According to Corrigan (1983), banks are considered to be special institutions, but among others, Berlinger et al. (2016a) also point out the exceptional role of CCPs. Both institutions are deemed essential and peculiar, but we can agree that they are unique in very different ways.

Due to the role the CCP plays, the implications of counterparty substitution are often misconstrued. Cox and Steigerwald (2017) point out how experts tend to see the clearinghouse as an agent of the original counterparties to cleared trades in the academic and policy literature, but the CCPs are the principal to the trades. This misconception is referred to as the "persistence of the bilateral." Let us note that the bilateral relationship is irrevocably terminated when the trade is accepted for clearing by the CCP. The CCP is the central party between the actors, guaranteeing the trade's fulfillment even if one of the parties fails to meet its obligations.

Ghamami and Glasserman (2015) give an example through a pair of clearing members holding offsetting "long" and "short" interest rate futures positions. He assumes a hypothetical situation where the two members simultaneously fail to meet their obligations. In a bilateral agreement, the loss would be zero because their obligations would be mutual and offsetting. In case the trade is cleared by a clearinghouse, the original trade counterparties no longer have

any continuing relevance because novation terminates the mutual relationship between the original counterparties. The researcher also points out that the presented simultaneous default is rare, but these offsetting positions might leave the CCP without any loss.

2.1. Balance-sheet structure

A bank's balance sheet contains the primary information for creditors and other institutions, as this is the basis of finding out about the bank's financial conditions. In particular, it provides a high-level view for both creditors and regulators regarding the bank's ability to meet its ongoing obligations in the short and long term. Moreover, it contains information about its capital status, the amount of capital buffer available to meet its obligation if the bank faces difficulties and fails.

The CCP's balance-sheet is inadequate and will not provide a basis for its resilience and capital strength analysis. The most significant factor is that CCPs have obligations to their clearing members so that these items will appear in their financial statements. It is not just clearing members, but the whole market cares about the ability of the CCP to meet its obligations and assure a smooth day-to-day operation and enforce resilience. The matchbook is the primary tool for a CCP that shall maintain because this ensures the CCP's ability to meet its obligations to clearing members (Cox and Steigerwald., 2017).

Faruqui et al. (2018) analyze the CCP-bank nexus, focusing on the two-way interactions between them. Along the balance sheet interlinkages and the structure of the CCP default waterfall, they show the nexus between them and highlight that the levels of stress change these interactions, even leading to a "*destabilising feedback loop with potentially system-wide effects*" (Faruqui et al. (2018, p. 1)) and also highlight the endogenous build-up of risk that these connections may trigger.

Along with a simple OTC derivative transaction, the changes of the balance-sheet of two banks (from the CCP's point of view, they are clearing members) and a CCP, and the mechanics of a central clearing action is represented below (Faruqui et al. (2018)):

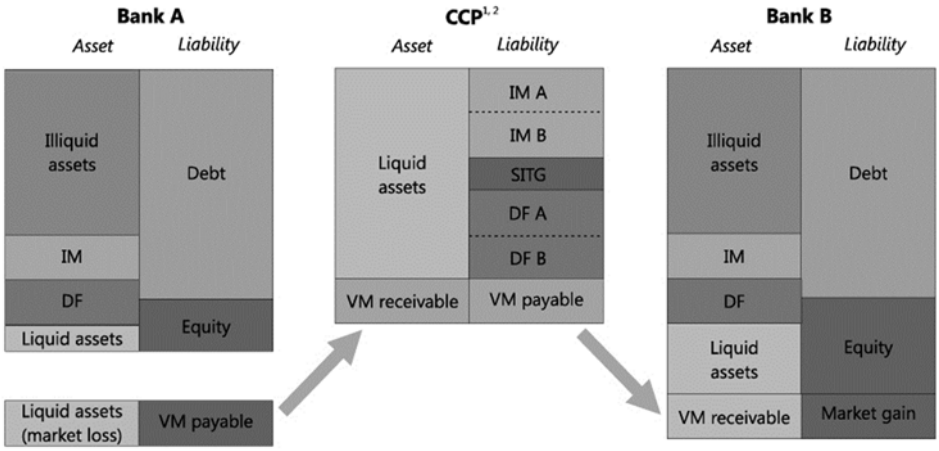


Figure 4:Balance sheet of Banks and CCPs
Source: Faruqui et al. (2018, p. 79.)

The role of the CCP, one can see precisely how the clearinghouse becomes a "central" party: it becomes a link between its clearing members.

If we take the layers of the default waterfall step by step, they all appear in the balance-sheet of the CCP, but it is worth analyzing the sources thoroughly. The CCP requires its clearing members, in this case, the two banks, to post initial margins for the transaction. The initial margin appears as a liability for the CCP, while it is an asset from the bank's perspective. The initial margin value would be repaid for clearing members at the transaction's maturity only if there was no need to exhaust it due to quiet periods without market distress (Faruqui et al., 2018). Variation margin, the financial resource to minimize losses from market movements that affect the asset's price, also has its place in the balance sheets (Cont, 2015). The clearing member shall post the variation margin that did incur a mark-to-market loss (Murphy, 2017). The member facing the loss draws down its liquid resources, writing off a similar amount of capital on the liability side, while the other clearing member receives the variation margin amount from the CCP. This movement will appear in the statements of the three parties. (Faruqui et al., 2018, p. 79.).Variation margin requirements may appear daily in order to prevent the build-up of exposures (Murphy, 2017). Let us not forget that every clearing member shall contribute to the CCP's default fund. From an accounting point of view, this appears as a liability on the CCP's balance sheet, while on the banks' balance sheets will appear on the asset side. Although the cleared

transaction has zero market value for the CCP, the trade's value will appear in the balances of all three institutions (Faruqui et al., 2018).
The most significant difference cannot be unseen in the example mentioned above, namely the ratio of liquid assets. Although the banking regulatory background has put considerable effort into making a safer banking system, through maintaining a certain proportion of liquidity, CCPs are designed to support liquidity. CCPs do not have illiquid assets as many as a bank may have because banks have different services, such as less liquid loans, than the assets a CCP requires from its clearing members or the investments the regulatory requirements allow, according to Article 47 of EMIR (EMIR, 2012).

The presence of both institutions has an impact on each other. While CCPs manage counterparty credit risk through the different layers of the default waterfall and enhancing transparency by operating a matched book (Cecchetti et al., 2009, Pirrong, 2011), banks must take into account CCPs' activity and its requirement that may alter their risk-taking behavior, therefore influencing each other in several ways.

The movement of assets among the financial statements of the CCP and its clearing members is highly dependent on the positions members take, but the contribution requirements to the CCP's default waterfall impose costs for its members. Faruqui et al. (2018) agree with Pirrong (2014), Murphy and Nahai-Williamson. (2014) that the size of the initial margin affects the cost of derivatives trading, among other things, these costs can also affect the clearing members' risk-taking and decision-making processes.

2.2. Risk profile

Banks are risk-takers. Their risk stems from intermediating deposits and short-term funding against longer-term credit provision. This feature is why banks run mismatched books: their assets from credit provision do not match their liabilities to their funding sources. Risk mitigation comes from the appropriate capital adequacy standards, so this is how the inherent mismatch is required by the regulatory standards to be handled.

Contrary to banks, CCPs are risk managers. Through novation, they become a seller to the buyer and the buyer for the seller after a transaction has been consummated and cleared. While banks operate a mismatched book that has its risks mentioned before, CCPs run matched books. The risks stemming from having a mismatched book do not appear at a CCP. CCPs face the risk of the default of their clearing member (**credit and counterparty risk**), which ignites them to perform their obligation to manage the positions' risks in order to prevent the domino and spillover effect on the market. However, temporary mismatched exposures appear due to margins and mutualized default resources from clearing members. Coeuré (2015) also argues that "*CCPs are not leveraged and (…) do not actively take the risk: barring the default of a member or an operational incident, their net risk exposure at any point in time is always equal to zero.*" As a conclusion and agreeing with Hughes and Manning (2015) and Lin and Surti (2013), both institutions face the risks stemming from credit, liquidity, operational and systemic risks. Regarding credit risks, while banks deal with long-term exposures due to their intermediation between short-term funding and long-term credit provision, CCPs face short-term exposures, mostly intra-day and overnight ones stemming from the member defaults.

Liquidity risk in banks' cases arises from intermediating between short-term funding and long-term credit provision, causing an issue in meeting current obligations by liquidating assets (Faruqui et al. (2018). CCPs manage liquidity issues with the help of the available financial resources offered by the default waterfall. To assure the resilience of CCPs, the regulator imposes several prudential requirements on the investment policy regarding financial resources enhancing liquidity. More specifically, EMIR mandates that the financial resources of a CCP should be invested in cash or highly liquid financial instruments with minimal market and credit risk.

While **systemic risk** appears in both institutions having armageddon-like consequences, their management is entirely different if it occurs. Banks are, therefore differentiated by their systematic importance. Based on the 2011 G20 Leaders' Cannes Summit, the risks of the global financial system from systemically important financial institutions (SIFIs) shall be set. Since then,

an integrated set of policy measures were approved and put into force. The endorsed specific standards aim to regulate globally and/or systematically important financial institutions that bear a higher risk to the system. Besides the methodology of identifying these institutions, the authorities' aim to resolve failing finances was strengthened, and more intensive supervision was applied. The requirements for resolvability assessments, recovery and resolution, and for additional loss absorption capacity above the Basel III minimum (i.e., different buffers, capital requirements) were also part of the reform (FSB, 2011).

In 2020, 30 G-SIFIs were identified (FSB, 2020). The total number of Credit Institutions in Europe only, according to Eurostat (2021), is 4,289. The United States government reports 4,983 in the USA for 2021[7]. Compared to this, CCPs do not need identification. In the vast majority of European countries, the market has none or a maximum of two CCPs[8]. Oliver Wyman (2019) identifies a total of 74 CCPs globally.[9] The relatively small number of CCPs does not mean less risk: if the CCP is not managed rigorously, in a theatrical scenario, a country's whole market can crash, spilling over to other markets if cross-border trades are included. This explains the special attention of the regulators.

Operational risks in the case of banks rely on strict policies (Articles 312 to 324 of CRR). The definition is straightforward: "operational risk: *the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events, and includes legal risk.*" Throughout the years, conduct and information-communication-technology risks were defined. A CCP's operational risk is slightly different, especially for not having the services that include physical money (ATMs, cash registers) and interaction with the retail sector. The operational reliability and operational capacity are the critical aspects to be handled through formalized processes.

[7] https://www.fdic.gov/
[8] The List of Central Counterparties authorised to offer services and activities in the Union can be accessed here: https://www.esma.europa.eu/sites/default/files/library/ccps_authorised_under_emir.pdf (accessed: 22 august 2021)
[9] This number may be slightly higher, as the researcher lists Global CCPs.

To enhance the transparency, operational and technical requirements associated with the communication protocols and message designs it implements shall be disclosed (Article 38 of EMIR, 2012).

Occurring losses from their business activities have some meaningful distinctions as well. Banks must have robust capital available to absorb the potential losses. Information on capital adequacy is the primary source to analyze the viability of the institution. Contrary, CCPs' capital is not the primary resource to exhaust in case of absorbing losses, although it may play a minor role, being part of the default waterfall through which losses are mutualized. It also gives minimal information about the CCP's resilience. Testing the resilience of the institutions is also performed differently. Stress testing for CCPs is exceptionally crucial to analyze how a CCP would perform in extreme market conditions, focusing principally on member default possibility and consequences. Banking stress tests focus on capital resilience (ECB, 2021).

III. A high-level overview of the regulatory framework

In the past 2 decades, market resilience has become one of the most important goals. Since 1998 the analysis of OTC markets and the trading activity was subject to discussion. In 1998 a study group coordinated interviews from G10 countries on OTC deals. The report indicated that the trading practices for processing trades and managing counterparty risks were broadly similar in all the G-10 countries. The legal background analysis shod that standard legal agreements and confirmation templates were used for documentation. At the time, the increasing automation of transaction processing, from data capture to confirmation and settlement, was beneficial, but manual intervention was still a significant part of the process. In their report, they highlight that "*netting and, to a growing extent, collateral agreements are used to mitigate counterparty credit risks*." (Parkinson, 1988, p. 3.) Trades settled through clearinghouses were infinitesimal, bilaterally settled trades were more specific (Parkinson, 1988). From 2001 onwards, the activity of the Committee of Payment and Settlement Systems (CPSS) and the Technical Committee of the International Organization of Securities Commissions (IOSCO) has been more and more focused on market infrastructures. In November 2004, the CPSS and Technical Committee of IOSCO issued 15 Recommendations for CCPs, which addressed the significant types of risk faced by CPSS and a methodology for assessing a CCP's observance of each recommendation.

Váradi (2018) points out that the recommendations' publication can be linked to the Lamfalussy report of 1990. This report focuses on the central bank's oversight activity concerning the risk-integrating nature of CCPs. As SWIFT (2017) stresses, the emergence of international recommendations meant a single set of international operational criteria that central banks sought to enforce through moral influence and local regulatory tools. In order to properly follow up and apply the recommendations, the national authorities and the institutions had to be involved and were responsible for the implementation process.

The current regulatory framework is not just the evolution of historical events but a former of best practice recommendations of the industry. The subprime crisis in 2007-2009 has pointed out the vulnerabilities of the financial system. Therefore, steps were taken to improve and to increase the resilience of the system. CCPs have become more and more critical, so their regulation had to be strengthened too. Until the 2008 financial crisis, the functioning of CCPs, and more specifically its regulation, was not a priority for legislators. During the liquidation of defaulted institutions, especially the Lehman Brothers, the analysis showed that transactions cleared through CCPs and the related exposures were closed relatively quickly due to its high-level transparency, having all necessary information to act effectively, i.e., having the so-called pricelist of the time (Bernstein et al., 2018).

Meanwhile, OTC transactions' were hard to match and close, leading to significant international impact. Before the Dodd-Frank Act and EMIR became into force and properly outlined, private market actors created futures clearinghouses to manage the credit risk associated with trading futures contracts. Rules were not established to prevent the buildup of losses or risky behavior until the termination of the contract. This could have been triggered by the deterioration of the participant's creditworthiness, which could also make a shift in its incentives leading the participant to take higher risks while having limited resources. Accordingly, informal groups/clubs of traders developed, implementing the multilateral netting of trades among members who had "*agreed to accept each other's contracts as substitutes*." (Baker, 2016, p. 17). The need for rules to manage credit risk among futures exchanges has increased. The rules implemented hindered defaulters from further trading. If concerns arose regarding the trading firm, the new policy allowed the review of its books and enabled it requiring to post margin for its deals.

The Chicago Board of Trade established a clearinghouse in 1883 that reduced the costs of netting contracts and the posting of margin, but it did not have a guarantee function. In the USA, the Minneapolis Grain Exchange (futures exchange) assumed a guarantee role in 1891, along with several small exchanges in the country. In 1925, the Board of Trade Clearing Corporation

became a central counterparty. In Europe, several clearinghouses had assumed a guarantee function by the late 1800s. Baker (2016, p. 17) explains the historical delay with the "*reluctance of large institutions to give up the competitive advantage of their credit strength*." The Chicago Mercantile Exchange had an internal clearinghouse. (Baker, 2016).

3.1. Regulatory background during 2007-2009

In January 2009, a working group was created to guide implementing these recommendations to CCPs that clear OTC derivative products (FSB, 2010). The financial crisis significantly contributed to the enhancement of cooperation at an international level to establish and regulate CCPs, particularly the positive experience related to the resolution of futures portfolios in the Lehman default (Bernstein et al., 2019). The G20 (Pittsburgh, September 2009) confirmed the importance of strengthening the International Financial Reporting Standards (IFRS), expanding the scope of regulation and oversight, and stricter OTC derivatives regulation. The primary goal was to head trades for electronic trading platforms, where appropriate, and by end-2012 at the latest, the transactions should be cleared through central counterparties, except the ones stipulated by the DFA and EMIR. Trade repositories got an essential function because the OTC derivative contracts should be reported to them. The remaining trades that are not centrally cleared should be subject to higher capital requirements. (Bella et al. 2018; and FSB, 2017)

3.2. CPSS-IOSCO 2012

In 2012, the CPSS and the IOSCO issued the principles for financial market infrastructure in order to achieve the desired transparency and system resilience. (CPSS-IOSCO, 2012) The newly implemented jurisdictions have set the basics for CCPs, but it also brought changes to the trade repository activities as well. (Tompaidis, 2018) Since the regulation accommodates the clearing obligation for derivatives and the establishment of CCPs, the implementation process has been under constant monitoring. (Cox and Steigerwald, 2017)

The G20 in Pittsburgh decided in 2009 that it would be worthwhile to clear as many transactions, including OTC transactions, through CCPs as it could reduce the risk to the financial system as a whole (G20, 2009). However, this concentration of transaction risk necessitated the development of CCP regulation. The regulatory framework of the United States' clearing activity was established relatively late, in 2010, the so-called Dodd-Frank Act, which EMIR followed in 2012, the jurisdiction applicable in the European Union (Nabilou and Asimakopoulos, 2020).

3.3. The Dodd-Frank Act regulation

It is undeniable that the EU and the US play a leading role in shaping the global financial systems, with more than two-thirds of all financial services based on transaction volume. Although the relationships between the two money markets are almost organic, many issues are approached in a fundamentally different way (Biedermann and Orosz, 2015). As already mentioned, the tools regulators and leaders have in their hands are correctly implemented prudent regulations. It was also noted before that the changes are made globally, but the differences in regulatory approaches in the US and the European Union are relatively different. While the American Dodd-Frank Act is a more comprehensive law, the EU regulates each sector systematically separately (Biedermann and Orosz, 2015).

In July 2010, the US Congress enacted the Restoring American Financial Stability Act of 2010 , called the Dodd-Frank Act, as the legislative response to the financial crisis that implements measures adopted by the G20 at the international level and improved by the Financial Stability Committee and the Basel Committee on Banking Supervision (Sabel, 2012). In 2010 the Dodd-Frank law was supplemented with the Wall Street reform and consumer protection. The legislation aims to strengthen the United States' financial stability by improving the accountability and transparency of the financial system and eliminating the 'too big to fail' system. With this step protecting US taxpayers by closing state rescue operations, protecting consumers against unfair financial service behavior was also a goal. The major financial reforms have also been sharply criticized: some say its provisions are insufficient to prevent a similar financial crisis, while others

say regulation is too rigid and undermines US financial companies' competitiveness. Nwogugu (2015) argues that the act is inefficient and inadequate and has not resulted in significant economic growth. In his view, the transaction costs and compliance costs have increased for both government agencies and financial services companies.

Simultaneously, it is not a simple task but this general norm into practice, as companies can continue to conduct counseling and self-proprietary trading at home lawfully. The Dodd-Frank Act (along with other legislation) introduced a "diluted" version of the Volcker Rule[10]: banks can only invest in high-risk investments up to 3 percent of their Tier 1 capital. Also, banks may not hold more than 3% in any private equity or hedge fund. The 3% capital threshold is probably not strict enough to limit banks' risky activities and self-trading. The Dodd-Frank Act also introduced transparency reforms in the derivatives market, comprehensively regulating swaps, but the possibility of excessive leverage remained. Baker (2020) proposes changes in the industry by adopting a model that can serve as a minimum safeguard for protecting customer margin from fellow customer risk.

[10]The Volcker rule's primary goal is to discourage banks from taking excessive risks by prohibiting certain investment activities with their own accounts, and by limiting their any type of connection (i.e. ownership) with hedge funds and private equity funds.

3.4. EMIR

The regulation for CCPs in the European Union was published in 2012. The regulation is called European Market Infrastructures Regulation, abbreviated as **EMIR**. Regulatory technical standards supplement the text of EMIR; these are the so-called "technical details." I will devote more detail to the EMIR regulation, as my research is based on this framework. Knowledge of the regulation is therefore an essential part of the thesis.

Váradi (2018) represented the EMIR in detail. A total of 9 Regulatory Technical Standards – RTSs are supplementing the EMIR, while the 3 ITSs (Implementing Regulations) assist the implementation of the law. Additionally, they are complemented by guidelines helping the interpretation of the law and their application. Moreover, Q&A (questions and answers) are also issued regularly by ESMA.

As mentioned before, trade repositories have also been analyzed, so EMIR gives significant changes in trade repositories and mandatory reporting. Of course, its essential role is to regulate CCP activities, leading counterparty risk towards them. Again, we must mention that CCPs are risk managers and not risk-takers. The stringent regulatory framework aims to manage the increased risk of the CCP to avoid default and to protect the financial system.

EMIR requires that OTC derivatives (with certain exceptions) must be reported and cleared. It also introduces additional security standards for CCPs and trade repositories (ESMA, 2013). EMIR focuses on the post-trade regulation of OTC transactions but has also reviewed the pre-trade and trading aspects of OTC trades. (Biedermann and Orosz, 2015). The regulation also suggests that OTF (Organized Trading Systems) concept should also extend to unregulated platforms. The overall goal is to limit automated trading and excessive speculation in derivative commodity markets and strengthen consumer protection for retail investors buying financial products (ESMA, 2019a).

The EU had more challenges to take during the stabilization of the regulatory background, since the United States system is more or less homogeneous and uniform, the EU had to deal with the very different interests of the 28 Member

States. Due to this diversity, the EU experienced a slowing down in the legislative processes, and it also made the outcome more fragmented (Biedermann and Orosz, 2015).

In 2012, the Financial Infrastructure Recommendations were consolidated, and a framework for their evaluation was created –under the name Principles for Financial Market Infrastructures (PFMI). The recommendations contained in the PFMI were later supplemented by further recommendations aimed at the restoration, stability, and transparency of CCPs. The main difference between the two is that EMIR regulates in more detail. However, the PFMI Recommendations have evolved since 2012 in areas that are currently not fully covered by EMIR. Váradi (2018) points out why the gap between PFMI and EMIR has widened in recent years).

The regulation aims to increase resilience and transparency by using tools designed explicitly for CCPs. **Resilience** is achieved by properly managing the default waterfall, assuring available SITG, using non-defaulting member's resources when necessary. **Recovery** tools can be used, such as pre-defined cash assessments, variation margin gains haircutting, partial or full tear ups. The ultimate step being the **resolution** (EMIR, JPM report).

Current EMIR frameworks rely on ex-ante measures that prevent or aim to minimize the possibility of a CCP failing. The measures consist of compliance provisions on capital requirements, margin and haircut standards, loss-sharing arrangements, investment policies applied by the CCP, liquidity requirements, and clearing membership standards. The requirements cover both micro, macro, and structural stipulations as well. It may seem extremely strict and unflexible, but CCPs often have their own risk management toolkit to customize their rulebook to manage their exposure stemming from counterparty risks due to its core operation, the clearing activity.

Besides the robust safeguards of the legally mandated prudential requirements, EMIR's Article 16 calls for a permanent and available initial capital of at least EUR 7.5 million (EMIR, 2012). Article 35 (2) of the technical standards supplementing EMIR mandates central counterparties to set the minimum level of the CCP's skin-in-the-game at 25% of its capital

requirements, which shall be revised regularly every year. However, CCPs can decide to increase their skin-in-the-game, but this is not a proper tool to use for the assurance of daily operations. For instance, the skin-in-the-game can be divided into two by keeping the mandatory 25% as the dedicated own resources of the waterfall and allocating additional financial resources of the CCP. The Hungarian CCP applies this approach (KELER CCP, 2021.)

CCPs operate on a matched-book basis because the changes in the value of entitlements of one clearing member are precisely matched by an opposite variation in the opposite direction in the value of its claim against another clearing member. This is where margins requirements appear as a crucial risk management tool at the micro-level. A CCP should impose margin requirements both on its clearing members. The regulatory text, Art. 45 (4) EMIR (2012) states that margins should be sufficient to cover potential exposures, specifically for potential losses originating from "*at least 99% of the exposures movements over an appropriate time horizon*." The CCP is allowed to manage its portfolio, but it is prohibited to exhaust the margins of the non-defaulting clearing members to cover the losses generated by a defaulting member.

The macroprudential type ex-ante regulations include the use of countercyclical margins. Due to the procyclical nature of the margin requirements, regulators emphasize regulating them properly to mitigate the potential risks. The primary aim of the approach is to help CCPs avoid the burdening of clearing members in times of distress. Overall, EMIR requires CCPs to include procyclicality in its margin calculation methodology to enforce its margining policy. The European Central Bank (ECB) also supports the inclusion of macroprudential intervention tools in the daily operations (ECB Financial Stability Review, May 2016).

The inadequacy of margins may occur, but CCPs are required to be prepared for such events. Art. 43(1) of EMIR (2012) requires that the CCP ensure that additional sufficient prefunded financial resources cover arising losses exceeding the damages not covered by margin requirements. These other financial resources consist of the CCP's freely available dedicated resources

but are only feasible to cover losses. The default fund and other financial resources should enable the CCP to withstand defaults under *extreme but plausible market conditions*. According to Art. 42(1) of EMIR (2012), it is required that these financial resources help limit the CCPs' credit exposure to its clearing members. Again, EMIR does not set minimum requirements, but it mandates the CCP to set a minimum amount for the default funds. It is the focal element of the thesis, and in the latter part, I will detail its calculation, but now, I will only highlight its most substantial features, as the CCP is allowed to establish several default funds for each type of financial instrument that clears. Every clearing member is obligated to contribute to it based on risk-based and pro-rata. The resilience is ensured by the requirements of EMIR, stipulating that the fund must be flexible enough to withstand the most extensive exposures of the highest or the sum of the second and third largest members' exposure (Nabilou and Asimakopoulos, 2020).

The CCP may also require the non-defaulting clearing members to provide additional funds, but this step could potentially result in the socialization of losses because the CCP can require this contribution to cover losses of a clearing member (Menkveld, 2017).

Article 46 of EMIR (2012) requires CCPs to collateralize their exposures to all its clearing members fully. If the CCP establishes links with other CCPs, it should cover those exposures as well. The flexibility of EMIR only sets qualitative standards for collateral to be accepted by the CCP so that the CCP can decide the range of collaterals it accepts. However, the exposures should be covered with only highly liquid collateral with minimal credit and market risks and proportional to its risk profile (Art. 46(1) EMIR, 2012). The liquidity and credit exposures are to be assessed on a near to real-time basis.

Article 50 (1) of EMIR (2012) also gives a tool to mitigate potential counterparty risk to the extent possible, so a CCP should use central bank money for settling its transactions or by using appropriate measures to limit its cash settlement risks, it can use other resources as well. Nabilou and Asimakopoulos (2020) consider that the need for liquidity is more relevant in

providing clearing services by non-bank CCPs, or CCPs not affiliated with banks. Firstly, intraday funding needs are the primary risks to ensure arising daily payment obligations. The second instance would be under stressed circumstances or during systemic events leading to liquidity problems, wherein a liquidity backstop from a central bank would be needed.

Art. 47(1) of EMIR (2012) mandates that financial resources of a CCP should be invested in cash or highly liquid financial instruments with minimal market and credit risk; otherwise, it cannot be taken into account for dedicated own resources as part of the default waterfall. The regulator also prescribes in Art. 47(3) of EMIR (2012) the full protection of the financial instruments, more precisely the margins or default fund contributions. These must be deposited with operators of securities settlements systems, while acceptable concentration limits shall be applied to a single obligor. It is worth mentioning that liquidity is essential to be assured, so CCPs should have access to credit lines or similar arrangements to meet their liquidity needs if their available financial resources are not immediately available. Nevertheless, as mentioned before, concentration is a must to be taken into consideration, because as per Art. 44(1) EMIR (2012) only up to 25% of the credit line can be provided by a single clearing member, parent undertaking, or subsidiary of the clearing member.

Canini (2021) formulates a constructive critique of the 2019 CCP Supervision Regulation. According to EMIR, the fiscal responsibility and day-to-day supervision CCPs are at the national level, but there are possibilities to lift key decisions to the national supervisors. Murphy (2020) presents new evidence of the distribution of risk in client portfolios and draws attention that clearing policy should be improved. He recommends that the mandate to clear should be phrased in terms of initial margin.

Moreover, in the case of inadequate financial resources, CCPs often have a recovery toolkit. The loss allocation rules are also specific that aim to ensure that the CCP returns to a matched book. The layers and the structures of the default waterfall, supplemented with the stipulations the regulators expect CCPs to comply with, are discussed in detail in the upcoming chapters.

3.4.1. R&R by EMIR

The objectives of the recovery and resolution framework aim, among others, to ensure the continuity of CCP core services in case of stressed conditions by "*avoiding the use of public funds, avoiding interference with property rights, protecting financial stability, and enhancing public confidence in the financial system*." Nabilou and Asimakopoulos (2020, p. 82).While banks' recovery and resolution plans prioritize the use of private funds within a resolution, a CCP's recovery does not stipulate a hierarchical order among the listed objectives. Recovery plans are linked to the setting up of loss allocation mechanisms, establishing the trigger points of implementation of the plan if financial resources are exhausted and proven to be insufficient. An entity's failure would imply that the internal risk management framework has come apart, including policies and procedures and mandatory regulatory safeguards. In the case of CCPs, the contagion of default is the most significant risk that may trigger a whole system's default. While in the case of banks, this is unlikely since the bank resolution allows banks to be resolved without bailing in certain liabilities that could generate contagion, but such liabilities could be the banks' obligations to CCPs.

Nabilou and Asimakopoulos (2020) point out a study that shows the concerns regarding interdependencies among CCPs, which may increase the probability of systemic failure. The study also highlights that the default of the CCP's top two clearing members could result in further default due to the high level of interconnectedness of entities and affiliates. This reasoning also enforces the idea that CCPs should be prepared for disastrous events, reinforcing the current EU regulation that requires CCPs to have recovery and resolution plans. However, the regimes for these plans differ across jurisdictions. The fragmentation of the regulatory framework brings uncertainty to the treatment of a failed CCP. However, CCPs have established different variations of recovery and resolution measures and are already in place. Researchers, among others Plata (2017) and Nabilou and Asimakopoulos (2020), Peters and Wollny (2018), highlight that if the failure of a CCP is an outcome of a systemic crisis, markets being under pressure, bailing-in the clearing members could be harmful to financial stability, and it

would amend incentives. The creditworthiness of the CCP might erode. Authorities face a considerable challenge on when and how to implement the plans while preserving the different critical functions of a CCP within strict time limits. (Nabilou and Asimakopoulos, 2020)

In December 2019, the EU ambassadors approved the European Council's position on a proposed framework for CCPs and their authorities to prepare to put in place a harmonized framework for CCP recovery and resolution (European Council Council of the European Union, 2019). In 2020 the CCPRRR (Recovery and resolution of central counterparties) regulation entered into force, but in 2021 it was still under review. ESMA set out a consultation paper on the measures to be taken in the case of any member default, to specify the range of scenarios, and on obligation for the CCP's competent authority regarding the review of the plan (ESMA, 2021b).

3.4.2. EMIR Refit

Since 2012, the EMIR did not change, but as with every legislation, it has become subject to the European Commission's regulatory fitness and performance program (Refit). The review aims to remove unnecessary obstacles and improve regulation by amending and simplifying compliance costs, transparency issues (i.e., increasing reported data quality), and insufficient access to clearing for certain counterparties. The EMIR Refit entered into force on June 17, 2019, but not all provisions will apply from that day. (ESMA 2019b).

Sykes and Karsten (2019) gathered the EMIR Refit changes in twelve summative points, explaining each point separately. EMIR Refit addresses (1) financial counterparty amendments, (2) the financial counterparty category, (3) non-financial counterparty calculation and clearing (4) mandatory clearing timing, (5) pension scheme clearing exemption, (6) reporting obligations – immediate provisions, (7) reporting obligations – delayed provisions, (8) suspension of clearing obligation, (9) initial margin information, (10) insolvency law provision, (11) risk-management RTS, (12) accessibility of clearing services.

This thesis will not cover more of the new regulation since it is still under consultation and the potentially relevant parts are not in force yet.

IV. The default waterfall system setup

"The law of property determines who owns something, but the market determined how it will be used" – Ronal Coase

Since the Lehman crisis, many scholars have researched this field, targeting every aspect of central clearing. The default waterfall is an essential part of a CCP, so its layers were and are analyzed by many. In order to give more space to recent academic publications and to present research more closely related to empirical research in a systematic way, I will follow the five questions systematically outlined by Berndsen (2020).

Before 2007, there were slightly few studies on CCPs, but especially in the past five years, CCPs gained blooming literature that focuses on the following (Berndsen, 2020):

The first perspective considers the effects of a CCP's introduction in the system that replaces bilateral clearing. ***To Clear Centrally or not to Clear Centrally?*** The literature approached answering the question in three different ways, on a qualitative and theoretical model-based concept, but on a study-specific approach as well. One approach is the effect on **netting efficiency**, which reduces the amount of aggregate counterparty risk exposure compared to the gross amount. A second perspective approaches it from the side of the **amount of collateral** posted on the initial margin and/or variation margin level based on aggregate counterparty risk exposures. Articles based on a **study-specific** approach provide more detail and sharper conclusions but are limited since the given specifics of the analyzed circumstances. Overall, results show that central clearing is beneficial, but it has its conditions to work as expected. The specifics of the markets can affect how sound central clearing is (i.e., the number of clearing members – preferably high, the number of asset classes – preferably low, high bilateral margin requirements, relatively low number of SIFIs outside the CCP, or a combination of those factors).

The second question addressed is ***If there is a CCP, what is the optimal number*?** Articles on this topic analyze CCPs interoperability. There are more

than one CCPs on the market; they co-exist and are interconnected. From a systemic risk perspective, it can be interpreted as a move towards the optimum of one CCP. Proof in the literature for permitting interoperability is blended. Since more than one CCP creates competition – one CCP is not optimal from this point of view. According to Zhu's (2011) findings, clearing expenses decrease substantially with three CCPs on the market, yet there is no proof regarding lax risk management. In sum, from a systemic risk view, the optimal number of CCPs is one. If multiple CCPs clear the same products, it is recommended to reduce the number of infrastructures. Certain conditions can lower systemic risk if connecting multiple equity-clearing CCPs through interoperability links.

The third area is related to the default waterfall and the CCP's risk management practices. This question outlines a historical look-back on the 1987 crisis, methodology of setting margins, procyclicality, stress-testing, and improvements in the default management process. My research also contributes to this area as well, where the focal question is: ***Is the size of the prefunded waterfall sufficient?*** Berndsen (2020) answers this question from three different aspects. The first answer provides a relative answer by recommending improvements in the prefunded waterfall, but it does not use a benchmark. These results lead to or imply an increase in financial resources. The articles using a normative benchmark provided by the regulator or by law show that financial resources are adequate in complying with the rules. From a third perspective, the answer is retrospective: financial resources were adequate as long as no CCP has gone into resolution after several member defaults.

The third answer is only complete if we answer another one: ***What happens at the end of the prefunded waterfall?*** The literature, in this aspect, is more of a qualitative nature since the fail of a CCP is not an everyday event on markets. The academic answers to handle the negative impact of the total exhaustion of the default waterfall generally recommend variation margin gains haircutting, and cash calls are preferred. Initial margin haircutting is less preferred, while access to liquidity from the central bank based on eligible collateral can facilitate a CCP's recovery process.

The fifth question is related to SITG, asking ***What is the role of Skin-in-the-Game?*** In this area, the incentives are the main target since the primary goal is to assure financial stability rather than the private goal of profit maximization. In this case, the CCP's own capital is incorporated in the waterfall, is under debate. Academics recommend pursuing a prudent risk management strategy that aligns with the public policy expectations, and CCPs will continue to operate in even the most extreme market events. It is highlighted that the SITG's primary aim is not loss-absorbing. However, there is a trade-off between increasing the level of SITG and the cost of clearing.

All in all, this reasearch area is blooming, and it contributes to the soundness of CCPs' activity since they are crucial pillars of the financial system, so its prudential regulation is indispensable. The prudential requirements provided by EMIR imposes the regulatory framework for the European CCPs. Its goal aligns with market participants' and stakeholders' expectations, which is the viability of the CCP and, nonetheless, the stability of the financial system. The measures detail the requirements regarding the financial resources available for managing default events and how the CCP should handle these resources to fulfill its role.

To understand the requirements and the reasoning behind the imposed framework, the current chapter details the rules CCPs must comply with according to EMIR and the concerns raised by researchers and CCP experts in this regard.

Murphy (2017) explains how the default waterfall system is built up and details its origin. The first area waterfalls became common was the capital markets. They were commonly used in mortgage-backed securities (MBSs). "*In early tranched structures, the risk that flowed down was prepayment risk: the top tranche was typically prepaid first. Latterly, private-label MBSs were developed where default risk flowed in the other direction, i.e., with defaults eroding tranches from the bottom up.*" (Murphy, 2017, p. 58.). This concept is the base on the default waterfall CCPs currently use. A general default

waterfall setup used by the European CCPs adhering to the EMIR requirements is presented below:

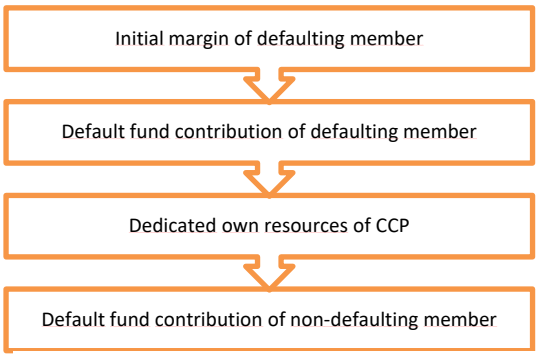


Figure 5: Default waterfall of a CCP

Source: Edited based on EMIR (2012), Article 48., own edition

The exhaustion of the above-listed resources is far from random. Regulations require using the available balances in a preordered sequence, margin requirements being the first resources available. According to Figure 5, a CCP can only use the margin to cover the defaulting member's losses, but not the margins provided by surviving members. EMIR (2012) Article 41 and chapter VI. of the regulatory technical standards (2013) set the margin requirements level, which stipulates that it shall cover potential market losses in the clearing members' positions in normal market conditions based on the calculation of a statistical model. The parameters of the statistical model must comply with the following criteria in case of non-OTC financial assets: confidence level at least 99%; lookback period is 250 days that includes a stressed period, liquidation period is at least two days – since the settlement on the stock exchanges is T+2 days. Procyclicality shall also be taken into consideration (Illés et al., 2019).

The second layer of protection is the default fund contributions from the clearing members (EMIR (2012) Article 48). Regulators ask CCPs to implement an internal policy framework for defining the types of "extreme but plausible" market conditions that could expose it to the most significant risk. As Figure 5 shows, this layer of the default waterfall is to cover losses to extreme market turbulence and a cross-guarantee between clearing members.

The third layer is the own funds of the CCPs, also called **skin-in-the-game, which** will be the next to be exhausted if all the defaulting members' resources are not enough. Afterward, non-defaulting members' assets within the default fund will be used, too, in order to protect the whole system. There is **a second skin-in-the-game** as a resource if the resources are not enough to cover the losses. This second skin-in-the-game is not part of Figure 7, as the regulator does not impose its existence. However, as mentioned earlier, during the EMIR regulatory overview in chapter 3.2.2, there are CCPs, which include their own additional resources in the default waterfall[11]. Recovery and resolution regimes will be triggered if the default waterfall resources do not cover the occurred losses (Cont, 2015).

The default waterfall has a vital role in identifying liquidity risk as well regarding the default of the clearing members. Principle 7 CPSS-IOSCO (2012) and the EMIR regulation (2012) states if a CCP has a complex risk profile or if its function is systemically important, the CCP should consider meeting more stringent rules regarding its liquidity to be able to manage simultaneous member defaults (Parkinson, 2014).

Further, I will present the main drawn up by researchers and professionals related to the default waterfall resources by focusing on the above shown general default waterfall elements: the different margin requirements, the CCP's capital, the skin-in-the-game, and the default fund related contributions. Afterward, the tools and possibilities available for the CCPs will be presented in detail.

4.1. The first layer of the default waterfall: margins

Clearing members are obligated to pay for the services the CCP provides and to maintain the resilience, margin requirements arise. In the form of collateral, clearing members shall meet their expectations. Cox and Steigerwald (2017) make the distinction between the initial margin and collateral. The initial margin is a requirement set by CCP based on rigorous

[11] The Hungarian KELER CCP's default waterfall setup: https://english.kelerkszf.hu/Risk%20Management/Derivatives/Default%20waterfall/

calculation methodologies. The amount depends on the member's obligations and the changes in the value of positions held. Collateral is the underlying instrument provided by the clearing member to the CCP to meet the initial margin requirements. CCPs announce the high-quality liquid securities and/or currencies that are acceptable. Market risk considerations fundamentally determine the initial margin requirements, including price volatility, concentration, and market liquidity. Besides the initial margin, another type of margin can be posed, namely, the variation margin. It is "*paid with cash, and reflects changes in the position values based on new mark-to-market. Collected from those who have lost due to the new marks, variation margin is in turn paid by the CCP with finality to those who have won.*" (Cox and Steigerwald, 2017, p. 8.). If there is an unfavorable price movement in the underlying asset in which the market participants have open positions, it is collected. The calculations are performed daily. On T, it is the difference between the trade price and the same day closing price; on the following days, it is the difference between the closing prices of the previous settlement day and the actual settlement day (KELER CCP, 2021).

As presented during the fails of the CCPs in history, the failure to meet the variation margin requirements is most likely caused by the member's default. Variation margins are not part of the CCPs' default waterfall. Intraday variation margins may accumulate, but these are only available for a limited timeframe.

The regulators' primary objective is that market participants' margins determined by the CCP shall be prudent, stable, and reproducible. PFMI's Principle 6 (2012) details the most critical features of the initial margin:

- the exposure must be fully covered by collateral on a daily basis;
- market liquidity and any risks associated with the product needs to be considered;
- liquidation period: five business days for OTC derivatives, for other products two working days;
- significance level: 99,5 percent shall be applied for OTC derivatives, and 99 percent in all other cases;

- a portfolio-based basic security definition, with a discount (spread), may be given in duly substantiated cases, which may be based on an appropriate correlation and economic justification;
- the lookback period must be at least 12 months that includes stress events too;

Figlewski (1984), Fenn and Kupiec (1993), and Koeppl et al. (2012) examined the margining methodologies for a single asset under a given price process. Lam et al. (2004) investigated the margining procedures from a prudential and opportunity cost point of view, comparing three methodologies. Barker et al. (2016) modeled credit and liquidity risk considering a feedback mechanism between the clearing members' default and market turbulences. Béli and Váradi (2017) present a methodology for determining the initial margin requirement based on a value-at-risk model, fully complying with EMIR requirements. It is important to note that the regulatory requirements do not exclude the use of other risk-based calculation methodologies, i.e., expected shortfall is another accepted approach. Berlinger et al. (2019) analyze risk-sensitive and anti-cyclical margin strategies. Lopez and Saeidinezhad (2017) form their point of view based on Brunnermeier and Pedersen (2009) and show that margin requirements may have destabilizing feedback effects in times of market distress. The argument is that "*under these conditions, meeting margin requirements implies raising more collateral at a time when market conditions are already illiquid. This induces a pro-cyclical excess demand for liquid funds at a time when liquidity is scarce*" (Lopez and Saeidinezhad, 2017, p. 5.). Huang and Takáts (2020b) show how the Covid19 affected the margin requirements, leading to large margin calls, highlighting that CCPs remain resilient. The high margin is not a surprise during high market volatility, but the extent of the procyclicality of margining depends on the design the CCP chooses.

Margining methodology is supplemented with further additional elements. Procyclicality is required to be implemented to strengthen the resilience of the system. Procyclicality is defined as the tendency of any financial variable to move with the economic cycles. This is a troublesome property when it intensifies financial stress (FSB, 2009; Szanyi et al., 2017). High procyclical

movements harm market liquidity resulting in difficulties for market participants concerning funding (Brunnermeier and Pedersen (2009), Heller and Vause (2012)).

Authorities designated under Article 22 of EMIR (2012) CCPs apply the margining requirements to limit procyclicality under Article 41 of EMIR (2012) and Article 28 of the Regulatory Technical Standards (2013) as follows:

a) Applying a margin buffer at least equal to 25% of the calculated margins allows for temporary exhaustion in periods where calculated margin requirements are rising significantly (RTS, Article 28.1a, 2013).

b) Assigning at least 25 % weight to stressed observations in the lookback period calculated by Article 26 (RTS, Article 28.1b, 2013).

c) Ensuring that its margin requirements are not lower than those that would be calculated using volatility estimated over a ten-year historical lookback period (RTS, Article 28.1c, 2013).

Szanyi et al. (2017), Murphy et al. (2016), point out that the relevant articles for CCPs' referring to procyclicality may be imprecise; consequently, its application lies on several presumptions. Due to the high level of uncertainty regarding the proper application of the propositions, there is a chance that the calculations can lead to a procyclical margin or unreasonably high margin requirement without any further assumptions. Szanyi et al. (2017) also define the discrepancies. For instance, the definition of stress, the timeframes of exhaustion, and the re-building of buffers are crucial to be defined. If stabilization is the primary goal, it should be carried out on the margin level, not on the risk measure level. If point a) is applicable, the method of exhausting the margin buffer should be defined: in one step, gradually, because the main point of finishing the buffer should be to stabilize the margin, not to decrease it. This is an essential shortage of the regulation for two reasons: on the one hand, it threatens the financial stability of a CCP; on the other hand, in case of stress, if a CCP decreases margin would cause an

increase in the value of the default fund, especially in stress periods. From the market participants' perspective, this is not necessarily a favorable scenario because the default fund contribution can be used to cover losses of another clearing member, while margins are used in case of the market participants' own default. This contribution can be "taken away" by the CCP.

Moreover, it would be beneficial if the regulation would state that "*the buffer can be exhausted when the risk is increasing – when the volatility is increasing – not when the margin would increase notably*" (Szanyi et al., 2017, p 7.). While handling the effect, the focus is on the margin increase. Szanyi et al. (2017) recommend that the change in the margin value should be on the stability. This would fend off dramatic increase and decrease too.

The second point misses the definition as well. According to Szanyi et al. (2017) and Murphy et al. (2016), a certain percentile of the last ten years' data is advised to be considered; otherwise, the floor would always be the margin value. Although the initial margin follows the market cycles, it turned out to be 'too' stable in percentage terms.

The third option is no different. To handle this, the authors suggest applying a certain percentile, and, according to Szanyi et al. (2017), a uniformly applied percentile should be set by the regulator. This method has a less flexible nature, therefore different tools shall be introduced to avoid over and under margining.

Gurolla Perez (2020) analyzes the performance of standard initial margin models during the Covid19 events and quantifies the different trade-offs. Results show that margin calls are driven mainly by variation margin, not initial margin, and analyzes the inherent risk sensitivity of margin models

Overall, the regulatory background is highly specific for margining methodologies, but there is still space for researchers and experts to develop the most suitable one for a CCP. However, as highlighted above, some aspects of the framework raise the need for further clarification to avoid over- or undermargining the market.

4.2. The second layer of the default waterfall: default fund

The default fund's primary goal is that as members contribute to it, there is loss-mutualization among them. If the loss exceeds the initial margin of the defaulting member, its fund contribution will be exhausted to be used to outweigh the additional losses.

As mentioned before, a member's default losses that exceed its initial margins and default fund contribution are absorbed first by the CCP's equity capital and then by the default fund contributions of surviving members on a pro-rata basis. In other words, the default fund contribution is calculated on a pro-rata basis, so stress is hitting the system that requires further liquidity members are needed to increase their obligations towards the clearinghouse. For additional liquidity, the CCP may be forced to request a contribution from selective members, for example, based on the proportion of open position or volume (Capponi et al., 2018). Although France and Kahn (2016) point out that the clearing member is not legally obligated to provide these additional amounts. The default fund size is calculated by the CCP, considering its exposure to each clearing member's default by evaluating the potential liquidation cost of the member's portfolio across a range of plausible stress scenarios.

The regulatory framework (EMIR, 2012 and RTS, 2013) details the most critical features of the default fund:

- A CCP shall set the minimum size of contributions to the default fund (Article 42 of EMIR, 2012);
- Must comply with EMIR max (1;2+3) concept, detailed below
- CCPs must identify the "extreme but plausible" scenarios as per Article 30 of RTS (2013) by customizing it to reflect the risk profile of the CCP. The conditions shall be based:
    - Historical scenarios containing extreme market movements
    - The lookback period is 30 years or the availability of reliable data

    - Hypothetical future scenarios shall be included that contain presumptions with respect to showcasing market volatility and price correlation across markets and financial instruments
    - Qualitative and quantitative criteria must be set.
- The scenarios must be reviewed regularly, at least annually, and its adequacy, too, should be subject to monitoring.

Definition of Cover II

Article 43 of EMIR (2012) stipulates that a CCP shall maintain sufficient financial resources to cover potential losses even after exhausting the defaulting member's available margins. These pre-funded financial resources shall be freely available for the CCP, provided as part of the default fund contribution. In the second paragraph of the mentioned article, the regulator states that the default fund contribution and other financial resources shall "*at all times enable the CCP to withstand the default of at least the two clearing members to which it has the largest exposures under extreme but plausible market conditions.*" Researchers call this rule **Cover II.**

Capponi et al. (2018) point out in their research that the system cleared by a clearinghouse with a sufficiently large number of clearing members can calibrate an optimal level of default fund that could cover potential losses, and at the same time, it provides its services at a not too high price. This level of safety will over fulfill the requirements of the Cover 2 rule, but it would incentivize traders to "*choose safer investments and avert negative externalities on each other"*

Definition of EMIR max (1;2+3)

The extent of the default fund has another rule set in EMIR, which shall not be confused with rule Cover II. Article 42 of EMIR (2012) sets the minimum of the default fund at the level where its size enables "*the CCP to withstand, under extreme but plausible market conditions, the default of the clearing member to which it has the largest exposures or of the second and third largest clearing members, if the sum of their exposures is larger*." In this dissertation, this will be referred to as **EMIR max(1,2+3)**.

Murphy et al. (2014), Capponi et al. (2018), Poce et al. (2018) argue that the Cover 2 standard is not prudent enough. In line with other studies, they point out if the cost of funding collateral is too high, it requires a default fund that could be too expensive for members, and while members risk-taking incentives increase, the clearinghouse will be in a vulnerable position Capponi et al. (2018) provides a new approach for the optimal default fund requirement that mitigates inefficiency.

Researchers also examined the loss mutualization role of the default fund, which has some disadvantages that shall not be neglected. The dependency among members may have negative consequences when members take excessive risk in the hope of higher returns. The effect of this risk-taking by the members affects the size of the default fund. The trade-off regulators face while collecting the default fund contributions. The goal is to prevent members from unreasonable risk-taking, but at the same time, though aiming to keep low funding costs, they direct the incentives towards safer investments (Capponi et al., 2018).

As noted before, the default fund is a mutualized guarantee fund that aims to cover market risks not covered by the margins, assuming that one or more clearing members cannot meet its obligations. The default fund is determined through regularly performed stress tests that should demonstrate that the CCP has sufficient resources to withstand extreme but plausible market conditions. The calibration of the stress test is a focal point of quantifying the default fund and the contributions in the following chapters, I will present the most important aspects of stress testing in central clearing activities. However, I will also compare the methodologies, groupings, or practices banks use in the upcoming chapters. Some features and approaches of the two institutions' stress testing are similar, therefore it is worth presenting it from both perspectives. Moreover, one chapter is dedicated to the stress test methodologies applied in the USA, imposed by the Dodd-Frank Act. The thesis' priority topic is the assessment of stress testing, the own research is built on stress testing, so the results of the equally strict but slightly different regulation of EMIR, the United State's framework, deserves a short, high-level presentation.

4.2.1 Stress testing

Researchers have defined stress and systemic stress in several ways. Systemic stress is a set of circumstances that leads to the failure of a significant part of the financial sector, resulting in a reduction of credit availability that has the potential to affect the real economy adversely (Acharya et al., 2010). The toolkit of financial institutions has its own limits, but with the benefits of stress tests, rarely occurring events can be measured that the basic toolkits usually cannot (Madar, 2010). By defining an independent event system, traditionally made by institutions or regulators – risk factors can be outlined. As a result, the extent of losses suffered in different scenarios gives a holistic overview of the stress-tested entity or industry. The empirical literature has aimed to capture systemic stress and risk more generally. In some views, systemic stress is from the perspective of interdependence between individual institutions.

Before current regulations were adopted, empirical studies focused more on banking activities. The interdependencies between banks, resulting from credit claims, were the researchers' primary area. Elsinger et al. (2006) build a matrix of interbank connections for the Austrian banking system and conclude that the probabilities of contagious default from interbank relationships are tiny. Iori et al. (2006) simulate potential contagion within theoretical banking systems and conclude that the vulnerability to systemic instability stemming from the interbank market is greater when banks are more interdependent. Having a too secure connection, failing riskier banks can drag safer banks down (Naceur, 2018). Nagy et al. (2016) measure systemic risk across the Romanian financial system, considering the foreign exchange market, bond market, money market, equity market, and banking sector to assure a holistic representation of the whole system.

The effect of bank capital on bank-lending activities has been widely debated since the 1988 Basel accord. Since the sub-prime financial crisis, the Basel Committee has suggested tightening capital requirements and implementing a simple lever-activity on all fronts. Additional capital requirements have been introduced under the Basel III regulatory framework regarding the capital base's quality. Tier 1 capital aims at better quality capital, and it is

expected to lead banks toward managing the components of their regulatory capital differently (Faruqui, 2018).

In the case of central counterparties, positions are stressed in order to estimate losses arising under “extreme but plausible” market conditions, represented by historical or simulated yield scenarios that are more conservative than those covered by ordinary margins. The magnitude of the shock is set to a situation, which rescales the stress due to the increase of margins to values comparable to clearing members’ equities (Poce et al., 2016)

The great benefit of stress tests is that they are able to promote the services of providers through a standard risk management toolbox and thus provide a financial-institution-wide coverage of possible shock effects. However, the relevance of the results can only be maintained if we create extreme but still conceivable scenarios that could jeopardize the solvency or liquidity of the financial institution. Such scenarios could be historical shocks from the past.

The downside to this is that it is unable to keep pace with fast-growing financial markets, technology development, so it ignores specific contexts and may underestimate or, the opposite, exacerbate certain risks. According to Hull (2018), a multiplication of risk factors can be used in the historical approach to producing more severe effects. However, this results in the loss of the correlation between risk factors, and in the event of shocks, the role of co-movements in financial markets increases (Hull, 2018).

Hypothetical scenarios are set up to resolve the retrospective view. Creating a single fictitious market scenario requires a variety of approaches and creativity, meaning that appropriate institutional risk profiles need to be explored based on management (BCBS, 2009a). Both quantitative and qualitative criteria can be used in the assessments.

Financial institutions facilitate the calculation of all risk factors so that stress test models can be built if the hazards are fully taken into account. As I mentioned earlier, stress tests also need to be focused on risks that are not directly related to them to detect the institution’s weaknesses. These risks can only be taken into account indirectly or made with simplistic assumptions but

not strayed away from reality. This limitation is both an advantage and a disadvantage, as it retains the focus of the test (Bella et al., 2018). On the other hand, systemic events that are far from reality create an artificial environment, and their plausibility cannot be defended (Cox and Steigerwald, 2017).

The assumption, which further simplifies reality but is often used, refers to the static nature of balance sheets and positions. Simply put, this means that the composition of the balance sheet at baseline remains unchanged over the time horizon of the stress period. No further risk management measures to reduce exposures should be reflected during the test on the balance sheet in the same form and will remain there. New instruments cannot be involved either. Deteriorating capital positions tend to provoke a reaction from institutions, which can mostly manifest in raising capital. No such measures are possible along the stress trajectory. Although this approach is far from reality, a system-wide stress test can better guarantee comparability between individual institutions (Bella et al., 2018)

There are still many simplifying assumptions in practice, but they have in common that they push stress tests into a framework isolated from reality. However, due to their excessive complexity and impracticability, they are needed. In addition to the many disadvantages, stress tests are a useful tool for the risk management practices of both banks and CCPs in the case of an appropriate framework, an appropriately consistent stress scenario, and correctly interpreted results.

4.2.2 Stress test grouping

Stress tests can be grouped according to their complexity, that is, the number of risk factors subject to shock (BCBS, 2009). These are mostly defined for banks, but the methodology can be applied for CCPs as well.

The most standard test to perform is the sensitivity test. Only one risk variable becomes stressed during this method, ceteris paribus, so the other factors remain unchanged. The advantages of this method are straightforward: the implementation and the interpretation of results are transparent. (Frey and Patil, 2002)

At the same time, financial institutions have much more complex profiles and activities, so many risk factors play a role in their profitability and liquidity situation, and these factors are closely related, strongly correlated. It is, therefore, unrealistic to assume that a change in a factor does not cause the other factors to change. The solution to this problem, for stress tests based on classical scenario analysis, have been developed, which try to model the reality as much as possible, taking into account correlations and synergies between risk factors (Buch and Duges, 2018).

The other dimension along which grouping of stress tests can be achieved is the source of the scenarios. Not just in the case of banks, but CCP regulators require historical events as input for testing. Examples of such a shock include the 2008 global economic crisis, the Dotcom crisis, or any event where changes in risk factors built into the model are well observable and clearly describe the relationships between them (Hull, 2018). This historical approach also raises some problems. Firstly, past events rarely recur, as market players and regulators strive to learn from past mistakes.

Furthermore, market conditions are continually changing. In this particular case, the CCPs' role and current regulatory efforts are just one example. Only in over a decade, several elements of the economic environment from 2008 are not applicable anymore. Secondly, market products and actors are constantly changing, too. Financial innovations and the expansion of fintech companies can generate new approaches and relationships that may not yet appear appropriately in a historical scenario (Buch and Dages, 2018).

Due to this uncertainty regarding the past, pessimistic events are implemented in the systems. Under current market conditions, past events can be a threat to the solvency and liquidity of financial institutions. These are called hypothetical scenarios, the preparation of which requires serious creativity, analysis, and a wide-ranging approach (Hull, 2018). EMIR's "extreme but plausible scenarios" can be listed here.

Stress tests can focus on only one risk, such as market risk, credit risk, or liquidity risk, but there may be more risks at the same time during distress. The Central Bank of Hungary presented its stress testing practice in 2013

(Banai et al., 2013), in which two different scenarios examined the resilience of the Hungarian banking system. Liquidity stress testing and market risk, credit risk stress testing segregation were carried out because the two risks cause problems in banks' lives with different effects and different time horizons. Differentiation is not only about risks but also about the products being tested. Stress tests can only be carried out on a few asset categories, such as mortgage loans, but can either be the portfolio of a particular institution or the system as a whole. Its purpose always determines the way the test is performed (Banai et al., 2013).

Stress tests may also differ from each other in terms of the time horizon being studied. One of the most important aspects of selecting a test period is the length of the mechanism of exposure to the financial institution. For example, in the case of liquidity risk, it is common that the time horizon is only a few days. This timeframe is sufficient to test the resistance to losses from the liquidity source markets and the difficulties in selling liquid assets (BIS, 2019). For example, in the case of credit risks, the rise in the default rate of loans is a long process; these problems may not be reflected in the financial institutions' balance sheet and profit and loss accounts over one week. The time horizon of direct market risk losses also depends on how fast the asset is repurchased on the market, but the mechanism of its effect can also be realized quickly as market prices fall. In banking practice, testing the capital position usually takes 2-3 years, while the testing of liquidity is typically one week or one month Bella et al., (2018). CCPs are required to complete stress testing daily. For example, KELER CCP performs the tests at the level of the clearing entity for the pre-defined scenarios. The results are consolidated at the clearing member and group level without netting, and the open risks are considered two days (KELER CCP, 2019).

Stress tests can be made with a so-called bottom-up and top-down approach, both of which have advantages and disadvantages. The two methodologies are primarily relevant to stress tests prepared and prescribed by the regulator. The main difference is that in the bottom-up case, the scenario created by the regulator is run individually by the banks on the model used in their risk management tools, and the results are communicated to the authorities. In

contrast, in the top-down approach, the regulator checks the banks' resilience in its framework (DNB, 2017).

Financial institutions are familiar with the composition of their portfolio and the parameters of their contracts, so they can more efficiently model their expected losses from changes in risk factors. The bottom-up approach thus takes better account of the specificities of individual institutions, whether it is possible to incorporate a difference in their future strategy or business model into the system. However, the comparison of the results becomes much more difficult for the regulator, and for this type of test, there are often certain constraints, such as the assumption of static balanced composition. Another problem is that auditing the models also takes up a lot of time and effort on the part of the authorities, as they must also make sure that the results obtained are relevant and plausible. That is why bottom-up stress tests only take place with the participation of the most important banks (Banai et al., 2013).

In the top-down approach, there is no or only limited possibility for the regulator to be acquainted with the portfolio of the investigated institutions. Of course, the necessary data can be retrieved from the data services, but their detail is far from being such that individual, institutional features can be considered in the modeling. However, it has the advantage of a bottom-up approach. (Cihák, 2007).

As opposed to low-resource demand, testing can be performed on the entire banking system, so besides individual banking effects, the financial system's vulnerability as a whole can be measured. Contrary to the bottom-up methodology, this can be done quickly so that institutions can respond more flexibly to changes in the economic environment, and the potential effects of new risk factors can be rapidly measured. Therefore, stress tests are suitable for examining vulnerabilities in both individual institutions and entire financial systems (Cihák, 2007).

Váradi (2018) points out the weaknesses of the stress test performed in adherence with EMIR for CCPs. The purpose of the stress test is to identify exceptional but realistic market situations by examining historical and

hypothetical scenarios and consolidating the Guarantee Fund's definition under Articles 42 and 49 of the EMIR and Section 4 of the RTS. Hull (2018) emphasizes that the 2007/2008 crisis has highlighted the need for much less emphasis on VaR models in risk management and much higher stress testing, as VaR look backs, while looking at the future in risk management is essential. However, many CCPs, instead of realistic tests, build a hypothetical scenario that is inconceivable from many economic perspectives and performs stress calculations based on these scenarios (Szanyi et al., 2017).

The excess stress testing is also harmful, as Váradi (2018) argues. As stress does not need to be taken into account in the calculation of underlying collateral, it is also necessary to avoid creating unrealistic scenarios in practice. Backstress tests are used to test them where they look at the market circumstances in which the full recovery of certain items in the guarantee scheme could occur.

4.2.3 Applying stress test – methods for central counterparties

Regulators, researchers, and experts have developed a wide variety of models to determine the adequate stress testing methodology. At first, I will briefly present the current findings in this field, followed by the general view of stress test methods and their types.

The default fund adequacy can be tested from several aspects, one of which is from a network-based stress test point of view, as analyzed by Poce et al. (2018) tested the adequacy of the default fund, where they explored the network of clearing members on the fixed income market. Their analysis focused on the fixed income market, and the main results showed that calibrating the default fund to comply with the Cover 2 rule and not more, may not be satisfactory. Only very conservative default funds, covering several clearing members' losses from the default, can face the costs resulting from distress spillovers. It was also proven that "*financial distress spreads among financial institutions through direct exposures and indirect exposures through common assets ownership*" (Poce et al., 2018, p. 1.). Battiston et al. (2016) and Iori et al. (2006) also analyzed the interconnectedness of the financial markets. Capponi et al. (2018) provide evidence about studies that

aim to analyze the framework's effectiveness regarding its loss-absorbing capacity during stressed market scenarios and highlight the equilibrium and socially optimal risk-taking choice. Paddrik and Young (2017) also prove that the simultaneous failure of two members could cause network contagion, leading to the exhaustion of the CCP's available resources, which may be insufficient. Menkveld (2017) points to the fact that crowded trades of dealers could amplify losses of CCPs in stressed scenarios. Campbell and Ivanov (2016) indicate that the losses could be more substantial if the exposures of large CCP members are positively correlated than if they are independent.

Ghamami and Glasserman (2017) found that lower default fund requirements reduce the cost of clearing but make CCPs less resilient.

Baker et al. (2016) analyze the distribution of losses to default fund contributions and contingent liquidity requirements for each clearing member identifying wrong-way risks among defaulting parties. Their main conclusion suggests that liquidity is the most important for members assessing the risks and costs.

Paddrik and Zhang (2020) analyze the variation margin calls following a shock and conclude that CCPs do not amplify the propagation of shocks in networks but instead limit them.

Menkveld and Vuillemey (2020) summarize current CCP researches, and by discussing multilateral netting, the insurance against counterparty risk, the effect of CCPs on asset prices and fire sales, margins setting, the default waterfall, and CCP governance, they conclude that CCPs may potentially be a source of additional risks, which are still to be comprehended.

4.2.4. EU wide stress test

Both banks and CCPs are considered systematically important financial institutions and based on this, regulators regularly carry out EU-wide stress tests for both types of institutions. Compared to banks, the "specialties" of CCPs are presented by Berlinger et al. (2016b). It requires a particular setup in its risk management system. This includes considering a high degree of specialization, symmetric exposures, balanced position, cross-guarantee

system, deposit dependency, and dynamic risk management. Although the two methodologies are similar in many ways, there are also significant differences, mainly due to the risk characteristics of the institutions. In the EU-wide stress test of CCPs, the focus is on counterparty risk and liquidity risk. In contrast, the stress test coordinated by the European Banking Authority for banks, the effects of almost all threats, such as credit risk, operational risk, or even market risk, were also measured against the bank's result and capital adequacy.

One of the objectives of EMIR is to promote central clearing and ensure safe and resilient CCPs. For CCPs, the European Securities Market Authority (ESMA) initiates and coordinates EU-wide stress tests at least annually. ESMA released the fourth CCP stress testing framework in June 2021 (ESMA 2021), while the last stress test results were published in 2020 (ESMA 2020). Together with local authorities, ESMA applies standard methodologies for assessing the effect of different stress scenarios and identifying the shortcomings in the resilience of the institutions.

The stress tests include credit-, operational-, concentration risk, and reverse credit stress. The results published in 2020 communicated by ESMA show the resilience of the system. Overall, since the first stress test, the performance of CCPs has improved during the second stress testing period; the third had even more promising results. The latest report highlights that the credit stress test pointed out differences in resilience between CCPs, but no systemic risk has been identified. The liquidity stress test enforced this and showed that EU CCPs are resilient under the defined scenarios and, more importantly, did not reveal any systemic risk. The framework included a new concentration component and highlighted the need for EU CCPs to account for liquidation costs within their risk frameworks accurately. The report also mentions the additional environmental situation during the testing, namely the COVID19, a significant and unprecedented crisis. In coordination with the NCAs, ESMA "*closely monitored the impact on EU CCPs, which remained resilient through the crisis, despite the increased market volatility and operational risk. ESMA's stress scenarios were found to be overall of comparable severity with the most recent stress events.*" (ESMA, 2020)

4.2.4.1 Scope and components of ESMA's CCP stress tests

ESMA performs the stress test in cooperation with National Competent Authorities and the European Systemic Risk Board (ESRB). The test scenarios comprise of '*extreme but plausible market conditions*' to achieve the purpose of the stress tests for CCPs in participating in the event. CCPs' resilience will be determined by using a combination of multiple participant defaults and simultaneous market price shocks. The purpose of the stress test looks beyond compliance with minimum regulatory requirements. The most crucial objective is to assess CCPs' resilience to macro-economic scenarios involving the whole European Union.

The scope of the whole exercise developed over the years. During the first exercise, counterparty credit risk was the main focus, testing the effects of a clearing member default and simultaneous market price shocks. The second stress test introduced methodological improvements, incorporating an assessment of liquidity risk. The third exercise included a concentration risk component that was used to adjust the losses arising from the credit stress test to account for the costs of liquidating concentrated positions. This fourth exercise will pause the liquidity risk assessment, whereas the scope will include operational risk as a new component. Also, the integration of concentration with credit is an important new development in this fourth exercise that will further improve the detection of vulnerabilities in the EU system of CCPs. (ESMA, 2021)

The next stress test exercise comprises of the following components:

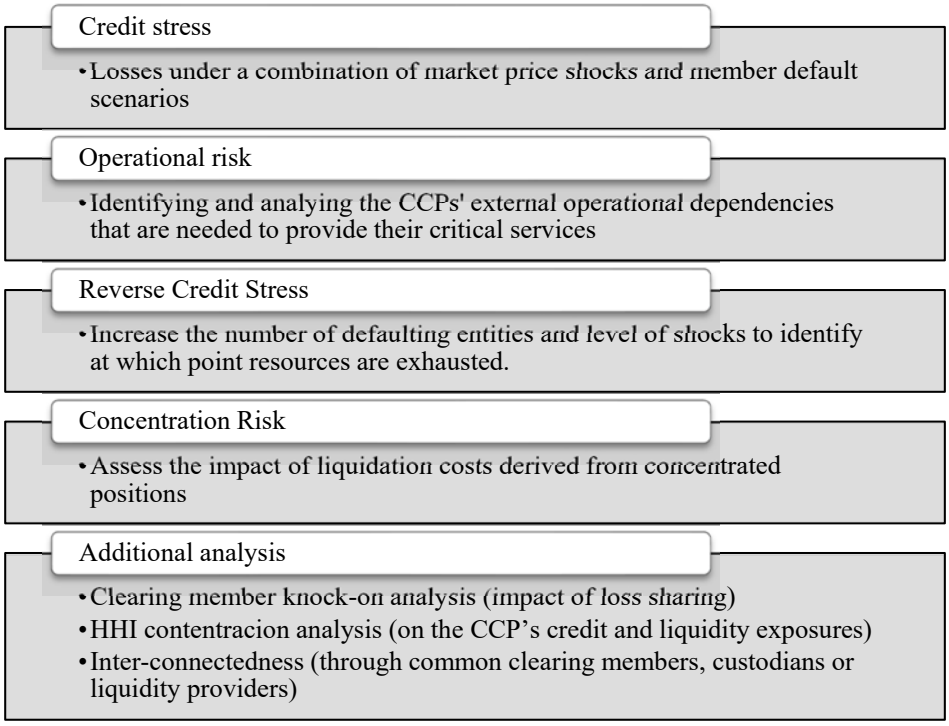


Figure 5: ESMA stress test components

Source: ESMA, 2021, own edition

4.2.4.2 Credit stress

The credit stress comprises of member default scenarios and market stress scenarios. The member default scenarios define the conditions that are utilized to choose the entities that are viewed to be in default. The credit risk scenarios differ in the methodology for determining defaulting members. Two scenarios will be applied for the Member Default Scenario exercise, a Full scope Cover-2 groups and Cover-2 groups per CCP. In the first one, the scope is to identify the two clearing member groups with the highest aggregate exposure under a particular market stress scenario. All clearing members that belong to an identified corporate group are assumed to default across all CCPs. Because this scenario will not test every CCP, the second scenario is introduced. Cover-2 groups per CCP will work with the defaulting clearing members as the members belonging to the top-2 groups of clearing members for each CCP. The defaulting clearing member groups are selected per CCP, and they may be (and in most cases will be) different for each CCP, and they are not considered to be in default in other CCPs. (ESMA, 2021).

The market stress scenario contains a methodology that considers the joint empirical distribution of historical observations of the risk factors deemed relevant to CCP. "*The scenario has been obtained by choosing the mean response for each conditioned variable in an adverse scenario where the triggering variables are stressed over a two or five day horizon depending on the asset class. The sample chosen for the calibration spans the period from January 2005 to December 2020.*" (ESMA, 2021).

Other components were introduced to assure the coverage of every impacted element of a stress situation. These aspects are presented in the third stress testing:

- Account-level reporting: CCPs will report data at a more granular level. The stress P&L and corresponding collateral will need to be reported at the clearing member and account level and the concentrated positions only at an account level.
- Intraday Exposures: the default event will be modeled as a weekend default, allowing the testing of the intraday risk management procedures of the CCPs, including margining and settlement procedures
- The wrong-way risk for cleared positions where the issuer is the clearing member or an affiliate: in order to identify wrong-way risk, CCPs must incorporate in the P&L calculations for each member of this specific clearing member or its affiliates issue the instruments.

4.2.4.3 Operational risk

The primary goal of this exercise is to identify risks from operational risk events affecting third-party entities on which CCPs rely. The objectives cover external third-party entities or systems, which may cause disastrous aftermaths if they have some disruption. It also aims to identify risks in case of an operational risk event that may affect the third-party service provider. The exercise shall assess the risk management tools that CCPs use to manage risks from these external third-party entities. Due to their high level of

interconnectedness, an analysis this network must be assessed to avoid business disruption or system failure of a potentially systemic nature.

The operational risk analysis will cover risk identification processes, assessments, risk mitigation and monitoring steps, and the interconnectedness analysis mentioned above.

4.2.4.4 Reverse Stress Test

CCPs will are required to recalculate losses after sizing the shocks and cannot mount to P&L directly. The reverse stress analysis is limited to the credit stress component. It does not cover liquidity risk to limit the effort required, as the data to be used can be very complex and demanding. The report suggests considering expanding the scope to liquidity risk.

This type of analysis aims to determine the likely combinations of market stress scenarios and members' non-performance scenarios that involve systematic risk. The study focuses on systemic risk rather than individual CCPs. The results of each CCP shall be analyzed only when necessary for the source of events that may be of systemic importance. This is also a sensitivity test. A twodimensional analysis will be performed depending on the absorption capacity of the system of CCPs. This is achieved by stepwise increasing the quantity of defaulting entities and the severity of the market movements.

***4.2.4.5** Concentration risk*

The regulatory framework suppresses concentration risk. Under Article 53(3) of the RTS (Commission Delegated Regulation EU No 153/2013), it is required that the potential losses stemming from the clearing member positions shall be thoroughly assessed. This analysis also includes the impact, and the risks that liquidating concentrated positions could have on the market and the CCP's margin coverage level. CCPs must include a so-called Concentration component that will model the expansion at the expense of liquidating an enormous position in a short period of time in the market. The

CPMI- IOSCO (2017) stipulates that a CCP's margin model assumptions incorporate estimates of market liquidation costs, including bid-ask spreads.

The price at which the CCP sells off the defaulting member's portfolio can be worse since an extended position is spilled on the market, resulting in the movement of prices. The CCPs would incur transaction costs. This should be taken into consideration by implementing the market scenario described in the Credit Component. The inability to perform market transactions without price movements the Market illiquidity risk component is to be used by considering the size of the position and the depth of the market.

Market illiquidity can appear as an exogenous factor: the relative size of the bid-ask spread, a cost that would be incurred even for small positions. The endogenous factor represents the fact that when positions are excessively large, they cause the market to move against them. The market impact depends on comparing the size of the position and the market depth, which is the ability of the market to absorb a substantial amount without materially impacting the mid-price.

CCPs take the aggregated positions and compare them to specific thresholds to determine which ones are categorized as concentrated positions. Liquidation costs should be estimated as the asset classes they clear. A liquidation activity will have an impact on the market, so the liquidation cost should reflect its effects.

Menkveld and Vuillemey (2020) note that the design of stress testing exercises is not the same as those used for the banking sector, it must capture the specificities of CCPs, and policymakers should take this into account. Regarding the potential recovery and resolution of CCPs, the consequences are still largely unexplored.

4.2.5. Dodd-Frank Act Stress Test

As discussed above, the Dodd-Frank Act regulates central counterparties in the United States. After the financial crisis in 2008, Congress enacted the Dodd-Frank Act, which, among others, requires the Federal Reserve to

perform an annual stress test on the system. This provision includes the stress testing of clearinghouses as well. Besides banks and clearinghouses, the supervisory test also applies to LISCC firms, large and complex firms, and large and noncomplex firms.

In 2012, the Board of Governors of the Federal Reserve System adopted rules implementing frameworks and programs. These supervisory frameworks and programs are assessed to measure if the institutions subject to the regulation are sufficiently capitalized to absorb losses during stressful conditions. The aim is to reveal discrepancies in the system to assure that obligations to partners and creditors are met. Moreover, they should be able to continue lending to households and businesses. The methodology is a forward-looking quantitative evaluation of the impact of stressful economic and financial market conditions on firms' capital. The Dodd-Frank Act Stress Test (DFAST) besides identifying the weaknesses of the system, it serves to inform regulators and all participant, and the public too of how the stressed entities perform under a hypothetical set of stressful economic conditions and how their capital ratios may change. The other part of the test is the Comprehensive Capital Analysis and Review (CCAR). This includes a quantitative assessment for all firms subject to the supervisory stress test. The CCAR is a quantitative assessment as well that uses supervisory stress test results to evaluate the entities' capital adequacy and planned capital distributions. Compared to the previous exercises, projected provisions for loan losses are smaller since firms included large allowances in response to the COVID19 event and due to changes to accounting rules.

The latest stress test consisted of two supervisory scenarios, one called baseline and the other called severely adverse. The baseline scenarios are the unstressed scenarios, while the others are hypothetical ones designed to assess the strength of the banking system, especially their own individual performance and their resilience during stressed conditions. The scenarios include trajectories for 28 variables, including "*16 variables that capture economic activity, asset prices, and interest rates in the U.S. economy and financial mar- kets, and an additional three variables (real GDP growth,*

inflation, and the U.S./foreign currency exchange rate) for each of four foreign country blocs. (DFAST, 2021, p. 13.)

The severely adverse scenario is based on the deterioration of the global economic conditions, which is supplemented by a period of heightened stress in commercial real estate loans and the corporate debt market. The scenario contains additional essential features, assuming that the corporate loan market will be more intense for lower-rated nonfinancial firms. Regions with rapid house price gains should be assumed to be concentrated. The commercial real estate prices should be assumed to be affected by the COVID19 event.

Besides, albeit the shortcoming in euro-region financial conditions mirrors a broad-based contraction in euro area demand, this compression ought to be more extended in nations with less capacity to utilize fiscal policy to incline toward the stoppage in the economic activity. Conditions across Latin American economies should be considered tantamount to the abrupt stoppage in the United States. The growth slowdown in emerging Asia should be assumed to be illustrative of conditions across many developing economies.

The stress test is performed on firms with large trading and private equity exposures, a total of 23. A counterparty default scenario component was applied in case of 12 firms also having substantial trading, processing, or custodial operations. The market shock being global.

The Federal Reserve has a separate scenario pack for the largest counterparty default (LCPD) called *Global Market Shock and Counterparty Default Components*. This component assumes massive market distress and the default of a firm's largest counterparty. It considers the system's interconnectedness by default of the CCP to the same ten firms and two other firms with substantial trading, processing, or custodial operations. These components are additional factors to the scenarios specified in the adverse and severely adverse scenarios.

The global market shock also consists of hypothetical scenarios using a large set of risk factors that accurately reflects general market distress and increased uncertainty. The risk factors are triggered at a given time.

Risk shocks are calibrated to the time within stressed market events, which vary depending on the expected liquidity of the various types of risk but are applicable to the situation of the companies at a given time. Every year, companies with significant trading activity are required to apply global market shocks prescribed by the stressed scenarios. They are also required to recognize trading and counterparty mark-to-market losses in the first quarter of the planning horizon. The company that "*is subject to the supervisory stress test and has aggregate trading assets and liabilities of $50 billion or more, or aggregate trading assets and liabilities equal to 10 percent or more of total consolidated assets, and is not a large and noncomplex firm under the Board's capital plan rule*" (DFAST, 2021, 12 CFR 225.), must apply the global market shock and counterparty default component. These institutions are most highly exposed to a potential failure of a CCP, and most importantly, they can amplify the stress on the markets. In order to cover the most at-risk firms, certain large and highly interconnected firms had to implement the LCPD component in their stress-testing framework.

The 2021 global market shock component has a sharp shortening in the global economic activity as financial conditions are declining. Specifically, with rating agencies downgrading enormous areas of outstanding obligation, corporate bond spreads enlarge forcefully as ratings-sensitive financial backers sell their assets.

Moreover, suppose a company has some characteristics that may be somehow outstanding, for instance, its financial condition, size, complexity, risk profile, the scope of operations, or activities, or bears risks to the economy. In that case, the Board may require to include one or more additional components in the severely adverse scenario. This component can involve the prompt and unexpected default of the firm's largest counterparty[12].

[12] The report also mentions that some entities are excluded from the selection of a firm's largest counterparty, including Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

Firms are also required to estimate potential losses and effects on the capital associated with implementing the component. If a firm has a connection with more than one counterparties, the largest is determined by net stressed losses. The estimation is calculated based on the global market shock. Non-cash securities financing activity assets posted or received are revalued. The shock is also applied to the value of the trade position and non-cash collateral exchanged for derivatives.

From a US perspective, the risk of the global market shock component for the severely adverse scenario stems from a significant weakening of the European economy and its adverse effects spillover to the home markets that lead to sell-offs in financial assets more broadly to global market disturbances. Due to the spillover risk will negatively affect the U.S. and developing Asian and other emerging markets. The stress is based on the sudden increase in implied volatility, a substantial drop in industrial and energy commodity prices, and a reduction in market liquidity. This latter factor has the most severe and broad effect on the whole system. Having a stress test designed on major macroeconomic movements, the occurrence of flight-to-quality capital is inevitable. Therefore, affected countries experience currency appreciation, while European and emerging market currencies experience currency depreciation against the U.S. dollar.

Results project that the firms as a group would experience $474 billion in losses on loans and other positions. The following losses are included:

- $353 billion in accrual loan portfolio losses;
- $4 billion in securities losses;
- $86 billion in trading and counterparty losses at the 12 firms with substantial trading, processing, or custodial operations; and
- $31 billion in additional losses

The two largest losses stem from accrual loan portfolios and the trading and counterparty positions subject to the global market shock and counterparty default component. Ninety-three percent of the losses originate from these two types of losses.

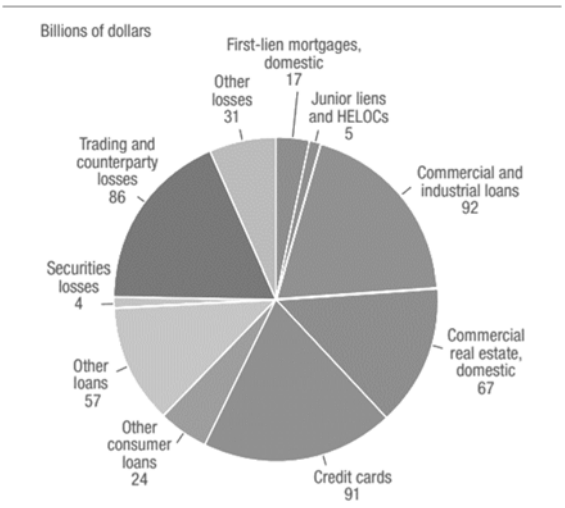


Figure 6: Projected losses of DFAST 2021

Source: DFAST, 2021

The $86 billion in trading and counterparty losses generated from the global market shock and LCPD components for the 12 firms subject to one or both components losses ranged from $0.5 billion to $21.1 billion. The values may vary depending on the specific risk characteristics of each firm's trading positions. Given that the stress is performed on a specific day, the results may be different for another day since the basis of the stress test are the trading positions they had on the 9th October 2020.

It is worth highlighting that results show how the default of a central counterparty could affect the market. It would have a severe impact, resulting in the second-highest loss in distressed conditions. It is instructive for regulators and firms as well, since the transparency, proper management, and resilience of CCPs play a significant role in strengthening the financial system.

4.3 The third layer of the default waterfall: skin-in-the-game

The central concept of CCPs, as discussed so far, the primary goal is to protect clearing members and the whole system from a potential domino effect that could crack financial markets. Central counterparties' capital, therefore, also plays a significant role. The third layer of the default waterfall system is the CCPs' own capital, the so-called skin-in-the-game.

Due to the inadequacy of the defaulting member's contributions, the CCP jumps in the game with the **junior tranche** of its own resources before exhausting the non-defaulting member's financial resources.

The current regulatory framework requires a considerable fraction of the CCP's equity at 25 percent, according to Article 35 of EMIR (2012), to provide as skin-in-the-game in the default waterfall system. It is related to incentives too that the CCP management and not just the shareholders should bear the consequences if it is inevitable to reach out for the CCP's capital buffer (Cont, 2015). Cont (2015), Murphy (2017), and McPartland and Lewis (2017) point out that in case the waterfall is exhausted, both contributions of faulty and non-faulty members' contributions are proven to be inadequate, and before entering the recovery phase of the CCP, there should be another tranche, which is known in the literature as another part of the skin-in-the-game, the **senior tranche**. The senior tranche is not mandatory, but several CCPs opt to avoid using more drastic recovery tools. (Muratov-Szabó et al., 2019) They suggest that regulators are the ones who can answer by asking "*what level of skin-in-the-game would be sufficient to generate the amount of clearing they consider necessary, were market participants free to choose whether or not to clear any particular trade*" (Murphy, 2016, p. 69.) Cox (2015) suggests that supervising authorities are the ones who should have the responsibility in reaching an objective and favorable decision, and he does not give a precise answer to the question. The junior one is serving as "*an auction inducement and a nuisance-avoidance deductible*" (McPartland and Lewis, 2017, p. 3.). The senior tranche has the "*ability to replenish the junior tranche immediately with resources from its senior tranche should help the CCP to maintain public confidence*" (McPartland and Lewis, 2017, p. 4.).

The amount of skin-in-the-game can be harmful if its scale does not fit the risk profile of the CCP by being too high or too low. Murphy (2017) highlights the cases of the CCP's capital contribution: if this is too small, the system participants will identify high risk in the clearing activity, so instead of joining the system, they would rather seek to engage in OTC trades that are not subject to clearing. Carter and Garner (2015) also maintain that the CCP's skin-in-the-game value determining factor, because "*the CCP's incentives for prudent risk management are likely to be optimized by requiring its skin in the game to be a material portion of its own capital – and this would be true irrespective of the size of the CCP's skin in the game relative to the size of its total default waterfall.*" (Carter and Garner, 2015, p. 85). Huang and Takáts (2020a) analyze the SITG from a model risk perspective, asking if the SITG is a game-changer? They conclude that the CCP's SITG bears a low model risk, and the capital not linked to credit risk does not reduce model risk.

Overall, the studies point out how the amount of skin-in-the-game can indicate the risk profile and the incentives of the CCP, and its purpose is not limited to a loss-absorption function. This way, the layers may alter the incentives and risk perception of clearing members.

4.3.1. Debate against high skin-in-the-game

High skin-in-the-game has an uncertain impact on clearing activity. Collateral is costly, and a higher level of capital requirement means that traders must bear higher collateral costs, but an adequately capitalized CCP is more resilient, so it gives higher certainty for surviving traders, and it imposes lower or nil loss for them (CPMI-IOSCO, 2012). This leads us to the next topic: there is a constant debate between regulators and CCP practitioners on the amount of skin-in-the-game.

Regulators impose strict rules for CCPs regarding the amount of skin-in-the-game with the purpose of loss-absorption and loss-mutualization. Let us not forget, this layer also motivates the CCP to apply proper risk management in order to protect the system it clears. Including their own financial resources can discipline the CCP to avoid lax risk management and to prevent the pile-

up of risky positions without proper collateral security. Transparent processes and policies can only achieve a resilient and resistant system.

CCP experts show their dissenting opinion to the regulator regarding the amount of the skint-in-the-game. CME highlights that "*Skin in the game doesn't protect end client*." The high skin-in-the-game can encourage moral hazard among clearing members if the CCPs contribute more substantial financial resources to the default fund. They highlight that **concentration risk** is the most prominent fear CCPs can have. To deal with concentration risk, Surprise (2015) and CPMI-IOSCO (2019) proposes to handle the most significant exposures by requesting the clearing member causing it to pay additional collaterals for the risk it generates, so if the worst happens and it fails to meet its obligations, the extra fund will serve to cover the losses it caused (Surprise, 2015). Otherwise, if this were not handled, the end clients, even other market participants, would also suffer from the CCP's financial resources collapse. This would benefit neither the CCP nor the end clients in the long run, especially if the default events accumulate. In the CME's point of view, the protection of the end client is not assured by the investments in the guarantee fund by the CCP. It can "*be used to close shortfalls in client account, thereby protecting non-defaulting end clients.*" (Suprise, 2015). Experts explain their standpoint against high skin-in-the-game proportion with the high cost of capital and the incentives of clearing members they are willing to take. However, they agree on the necessity of the junior tranche because it indicates the first line of defense, and therefore is a strong incentive to promote adequate risk management conventions for clearing activity.

The CCP12 [13] also states that "*SITG not a significant loss-absorbing resource*." Their justification points out that neither CCPs nor international standards expect it to be the essential loss-absorbing tool of the guarantee system. However, they agree on the previously presented concept; namely, a too high value of the SITG "*will weaken market participants' incentives to*

[13] CCP12 is a global association of 37 members who operate more than 50 individual CCPs globally across EMEA, the Americas and the Asia-Pacific region. CCP12 aims to promote effective, practical and appropriate risk management and operational standards for CCPs to ensure the safety and efficiency of the financial markets it represents.

participate in the default management process, as they will consider CCP skin-in-the-game and the potential for their own mutualisation when constructing bids in a default management auction" (CCP12, 2019, p. 12.).

Daly (2015) gave a reason that skin-in-the-game contributions are significant because a potential solution for CCPs to stop a considerable default from happening is to have access to ample resources, and "*clearinghouse contributions would be a perfect place to start*." Based on the different markets and guarantee funds reported in 2014, the separately managed guaranty funds dedicated to cleared interest rate and credit-default swaps, CME Clearing, ICE Clear Credit, and LCH. Clearnet's SwapClear US contributed $150 million, $50 million, and $2 million to their guaranty funds, representing 2.2%, 2%, and 0.3% of their guaranty fund's total assets. In Europe, under EMIR, the minimum contribution is 25% of their own capital resources if they have a minimum capital requirement higher than 7.5 million euros. The difference is outstanding between the European and the US clearinghouses' financial situation. According to CME, in 2018, in the UK, the clearinghouse contributed $75m, or 25% of its own capital, while in the US, the exchange contributed about $375m, or roughly 5.25% of its capital. Daly is on the opinion that "*increased clearinghouse contributions may raise the morale of those suffering losses, but in actuality, it is as productive as trying to fill in the Grand Canyon with a garden trowel. It's all about scale.*"

During an Online Workshop on CCP Risk Management that the European Association of CCP Clearing Houses (EACH) organized jointly with the Journal for Financial Market Infrastructures, EACH (2020) aimed to discuss the concept of SITG, its purpose, compare it to the purpose of other default management resources available at the CCP as part of the default waterfall. EACH believes that the current calibration of SITG as included in EMIR is adequate. Their empirical assessment concludes that overall, increasing the SIG would not make much difference. Statistics show that in 2019 the SITG of EU and UK CCPs represents, on average, less than 0.15% of the total resources of CCPs (i.e. initial margins, SITG, default fund, assessment powers). The SITG is not explicitly designed for loss absorption. Regarding the small percentage of the SITG EACH admits, that it is not a big number,

but „*it is high enough to ensure that CCPs are well incentivised to perform robust risk management because, as we have already seen, exhausting the SIG would mean on average burning 1.6 years of profits for European CCPs*" (EACH 2021, pp. 10).

According to David Murphy (Lisney, 2021) the increase of SITG creates an imbalance between the impact on small and large institutions, "*If you're going to ask clearing members to replenish their deposits in the guarantee fund…the probability of being successful at doing so would be increased if the CCP were at risk to the same degree as the clearing members themselves are at risk*." "*It's not meant to be a large loss absorption resource, because that would shift the balance of the incentives for clearing members to not only manage the risks that they bring to the clearing house, but also to participate in things like default management*" (Lisney, 2021.)

Another related to the skin-in-the-game is "Where is it?". McPartland and Lewis (2017a, b) analyze the ownership and the related incentives of the design of the default waterfall and its components. They get to the conclusion that no matter what the ownership structure of the CCP is the „skin-in-the-game should be pre-funded and on deposit with the appropriate central bank." (McPartland and Lewis, 2017b, p. 4.) They explain that this gives relief to every participant in the system: to prudential authorities, clearing members and other, market participants because, in this way, the financial commitment from the CCP is in a pre-funded form, and it is available immediately under the most adverse of circumstances.

The collaterals and contribution amounts that shall be provided has an impact on the incentives of every character on the market. Based on McPartland and Lewis (2017b) research, the incentives and the size of the default waterfall components adjust to it as follows:

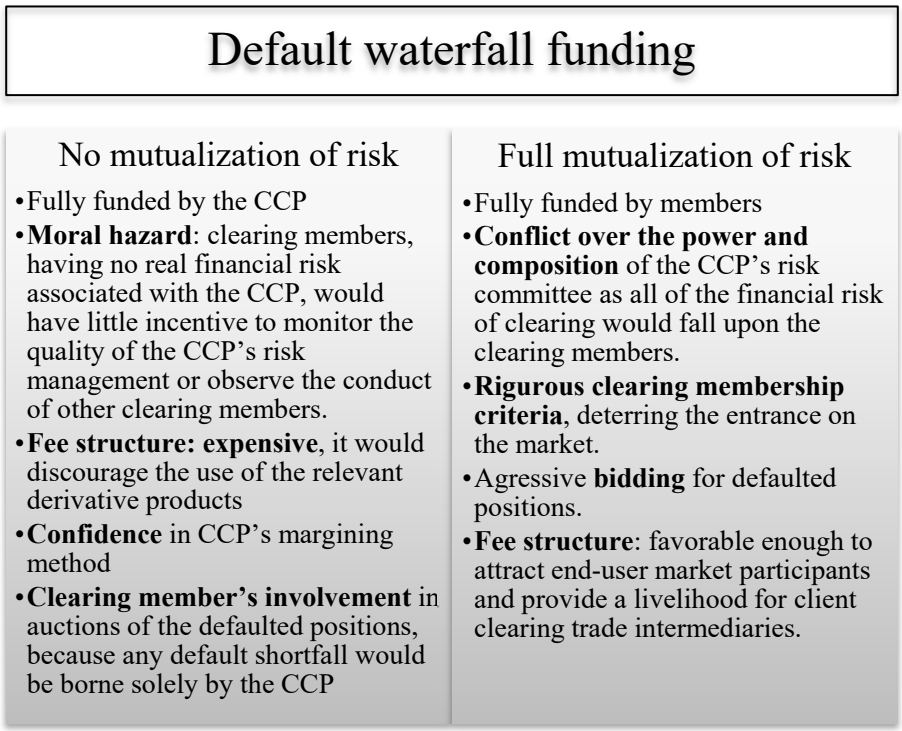


Figure 7: Default waterfall funding

Source: McPartland and Lewis (2017b), own edition

The CCP's ownership and contribution to the guarantee system also impact the incentives of members.

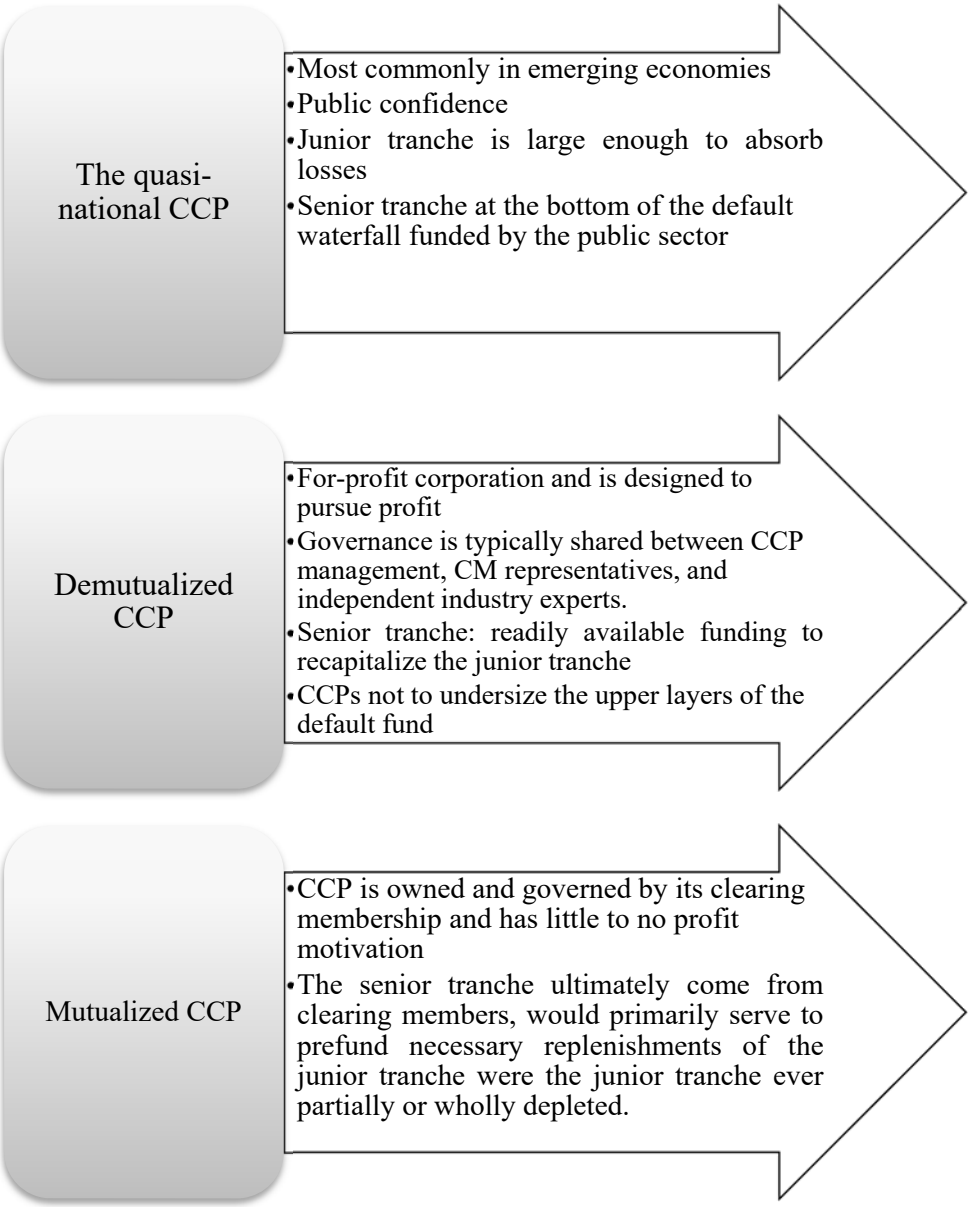


Figure 8: Ownership structures and their effects

Source: McPartland and Lewis (2017b), own edition

Huang (2019) also analyzes the theoretical and regulatory background of the skin-in-the-game. Proving the effects of the different skin-in-the-game in the default waterfall of a CCP, he uses actual data from the clearing industry, a total of 16 CCPs at the group level and 44 CCPs at the entity level, numbers enough to cover most of the field. His results suggest that a CCP with more capital requires more collateral from its clearing members. As mentioned before, this gives higher certainty for the system by lowering the number of defaults and losses arising from a potential default of a clearing member. However, this certainly has its price because it causes profitable trades to be

relinquished, resulting in reduced fee income. From the CCP's point of view, the higher capital included raises concerns originating from a clearing member's losses. This also explains why a higher collateral requirement is set, aiming to disincentivize defaults. His results show a significant correlation between the CCP skin-in-the-game and the required initial margin. A 1% increase in the skin-in-the-game results increased by more than 0.6% in the required initial margin. It must be noted that the ownership of the CCP has a significant impact on the skin-in-the-game amount a CCP is willing to add to its default waterfall. This is why in the following, I will present the two cases of CCP incentives: first, the incentives regarding **for-profit CCPs**, and secondly, the CCP that is **owned entirely by its clearing members**. Huang and Takáts (2020a) take a step forward from Huang's (2019) approach, and their focus shifts from analyzing the role of STG, including its association with the aggregate amount of collateral or initial margin, to explicitly focusing on the model risk of CCP. Their results suggest that higher SITG does not reduce the model risk of CCPs.

4.3.2. Incentives regarding for-profit CCPs

The amount of CCP capital contributions is a focal point of the system. The owners and users differ and so have responsibilities toward one another, and their interests certainly pole apart. The for-profit CCP's key intention is to maximize its own expected utility. A for-profit CCP's default waterfall can have two sources: it can either be funded solely by the clearing members or by the CCP. It does not matter which ownership does it have, and it will affect the incentives of every market participant while both involving benefits and drawbacks. (Huang, 2019; McPartland and Lewis, 2017a, Cox, 2015)

A completely clearing member-funded waterfall's danger is that it favors a better yield on value rather than safety, conceivably prompting limited exposure to default risk, resulting in sloppy risk management practices. The inappropriate management concusses and limits the credibility of the CCP, prompting skepticism in its function in satisfying robust risk management obligations McPartland and Lewis (2017b).

The other setup of the waterfall contribution, when the CCP entirely funds it, raises several concerns that can alter incentives. As the clearing members also compose the Risk Committee (regulated by Article 28 of EMIR, 2012), they have an essential role in the risk management of the CCP and their policies as well. If a clearing member had no contribution to the default waterfall, their interest in the proper risk management of the CCP would be limited, and monitoring its risks would not be a prime aspect. Generally, the CCP liquidates the defaulter's positions in case of a default and seeks clearing members to accept them. (CPMI-IOSCO, 2019). This liquidation process is beneficial for the CCP due to its prompt action for loss absorption. If the CCP were responsible for absorbing all default losses, clearing members would be more hesitant to accept clients or support in liquidation. In this case, the clearing members would accept clients or bid for positions they would likely require terms undesirable to the CCP. The no capital added scenario would also induce lower margining models. The less creditworthy clearing members could also quickly join the clearing system, "*since unless a default were large enough to lead to the failure of the entire CCP, they would not bear any of its cost"* (Lewis and McPartland, 2017a, p. 64). Coeuré (2015) reasons that this model does not fit with the role and character of a CCP because they "*are risk poolers, not insurance providers."*

From a financial point of view, as noted before, fees posed by the CCP have a significant role in the incentives of the clearing members. Huang (2019) analyses the fee structure from a social point of view, and he concludes that a "*for-profit CCP needs to take into account the per-unit clearing fee"* (Huang, 2019, p. 3.). While a higher fee increases the temptation to increase trading volume, he points out the level of the fee threshold effects in two ways: if it is too high, the collateral requirements will be lower, resulting in a boost of the trading volumes. In this case, the capital requirement serves as a loss-absorbing layer. The lower fees expect higher capital requirements. The trading volume will drop because the amount of collateral due to the CCP will increase. This is a practical ex-ante step in pushing the CCP to abolish the counterparty credit risk it is exposed to. Cox (2015), too, discusses the effect of CCP skin-in-the-game on the incentives, and he also points out that

increases in the size of CCP skin-in-the-game could lead to increases in clearing fees and harming the liquidity of the cleared markets. However, as Murphy (2017) evaluates, a CCP can achieve the optimal balance between the components of the default waterfall, leading to maximizing the return on equity.

To sum up, a for-profit CCP must focus on the return on equity if the contribution of the default waterfall is large. This will bring expanding clearing activity expenses, creating a disincentive to clear transactions, expanding systemic risk. Besides, as Cox (2015) clarifies, the too-high commitment of skin-in-the-game included in the waterfall could jeopardize the CCP's drawn-out presence if there should arise an occurrence of an extraordinary default occasion. Since the lesser junior tranch absorbs losses, clearing members would be urged to abstain from helping a default member's management. The higher the junior tranche, the likelihood of funds collected from the non-defaulting members declines, also decreasing incentives to be part of the default management (Lewis and McPartland (2017a).

4.3.3. Incentives regarding clearing member-owned (user-owned) CCPs

Huang (2019), Cox and Steigerwald (2017), and Lewis and McPartland (2017a, 2017b) study the different ownership structures of CCP, and they point out another type of ownership structure worth analyzing is the mutualized CCPs: This type of ownership structure implies that the clearing members and exchanges own them, which are the same that use their services. Following their use of concepts, mainly owned by a few large clearing members, collectively call them **user-owned CCPs.** From this structure, there could be misaligned motivating forces between members, as the smaller ones would have less impact on the choice of the approach the CCP would apply. (Lewis and McPartland (2017a, 2017b)

Compared to the for-profit model, the CCP aims to maximize the total welfare surplus. Another distinction the two specialists call attention to is how these CCPs hold extra capital, and the necessary collateral amount is low. Nevertheless, because the proprietors are equivalent to the clients, the money

related assets in the default waterfall system have the same financial source: market participants' capital (Huang, 2019; Lewis and McPartland, 2017a).

Lewis and McPartland (2017a, 2017b) draw attention to one exception why the mutualized CCPs should include skin-in-the-game in the system – not only margins –because of the role it serves. Including a junior tranche can prevent some default losses from reaching the mutualized part of the guarantee system, and this way, the refill of the clearing member contribution could be avoided. This being beneficial for all members of the system. Because the resources are coming from the members' capital, they can decide whether to refill the junior tranche after a default that exhausted it or reach out for the retained earnings of the CCP. This latter option can take a longer time, so for regulatory compliance, a CCP would instead call capital through its clearing members during the replenishment of the default waterfall (Carter and Garner, 2015)

User-owned CCPs have different policies on capital contributions to the default waterfalls. For instance, the Options Clearing Corporation (OCC) does not include any capital in its default waterfall, but the retained earnings "*are discretionary at any stage of the default*" (Options Clearing Corporation, 2016). Another example is EuroCCP, not including capital contribution in its waterfall. Nevertheless, it has an equity capital layer that can be used once the default fund is exhausted; however, the scheme is designed not to call upon that layer (Cox and Steigerwald, 2017).

As seen above, the amount of skin-in-the-game has a remarkable overall impact on the default waterfall system. The for-profit CCPs tend to have significantly lower skin-in-the-game than the user-owned ones.

The size does not serve only as protection for the fail of the system, however, it likewise creates incentives for both CCPs and its clearing members. Each party's capital contribution to the fund creates incentives to seek prudent risk management practices, so every member bears a portion of the loss caused by default. Carter and Gardner (2015) acknowledge the presence of free-rider in the system, but problems created can be mitigated with loss-mutualization and prudent risk management incentives. The free-rider, in this case, would

be the lack of participation in risk-bearing by not contributing the costs their associated positions generate.

The potential for less stringent risk management would also make it difficult for the CCP to credibly demonstrate to its clearing members that it was fulfilling its risk management responsibilities. Information asymmetries can also lead to heightened risk because the CCP does not have ample information about all the trading activities of its clearing members outside the CCP; therefore, it will be unable to assess the probability of the participant's risk profile to measure the risks associated. On the other hand, if the participants lack information about the CCP's risk management frameworks, incentives can alter emerging to degrade the CCP's credibility (Menkveld et al., 2016).

Despite the different opinions on the components of the default waterfall, CCPs apply the waterfall similar to the one presented in chapter IV. Figure 5: margins being the first line of defense, followed by the defaulting members' default fund contributions. Finally, the remaining losses would be covered from the CCP's contribution. The mutualized contributions of the surviving clearing participants being the ultimate source to be exhausted. Any remaining losses would be covered using the CCP's recovery tools, discussed in the next chapter. Many CCPs, including Chicago Mercantile Exchange Inc., LCH. Clearnet Limited–showed below, apply this type of default waterfall.

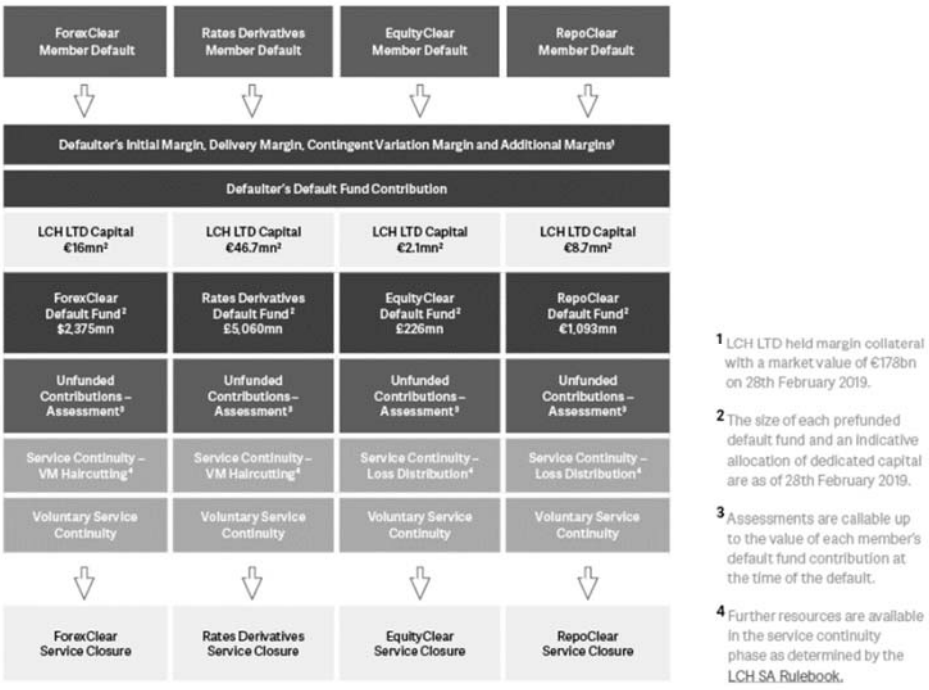


Figure 9: Example of DFW with an only junior trench of SITG for several markets

Source: LCH, 2021

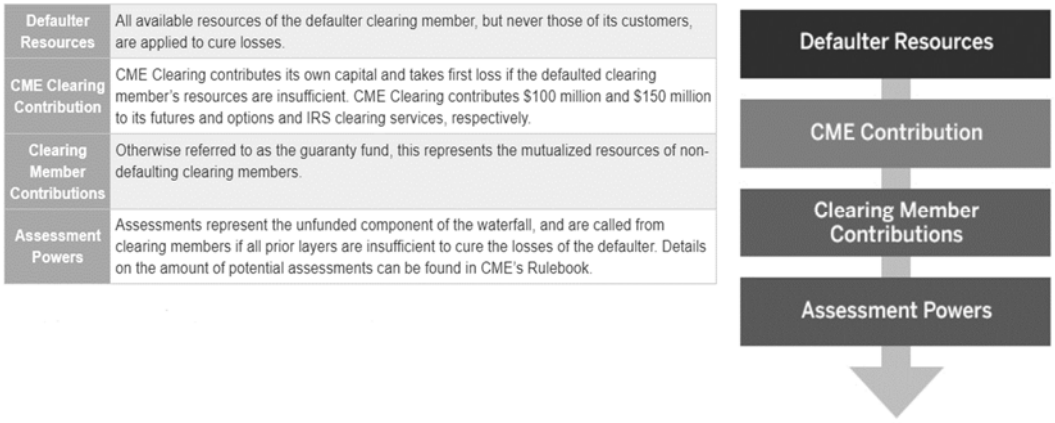


Figure 10: Example of DFW with an only junior trench of SITG

Source: CME, 2021

However, the default waterfall presented above is not applied universally. Several CCPs build on the typical waterfall, but they apply additional layers, mostly a second skin-in-the game tranche. For example, both KELER CCP and ECC (Figure 14) include another layer of own funds after all member

contributions, including non-defaulting member default fund resources, were exhausted and proven to be inadequate.

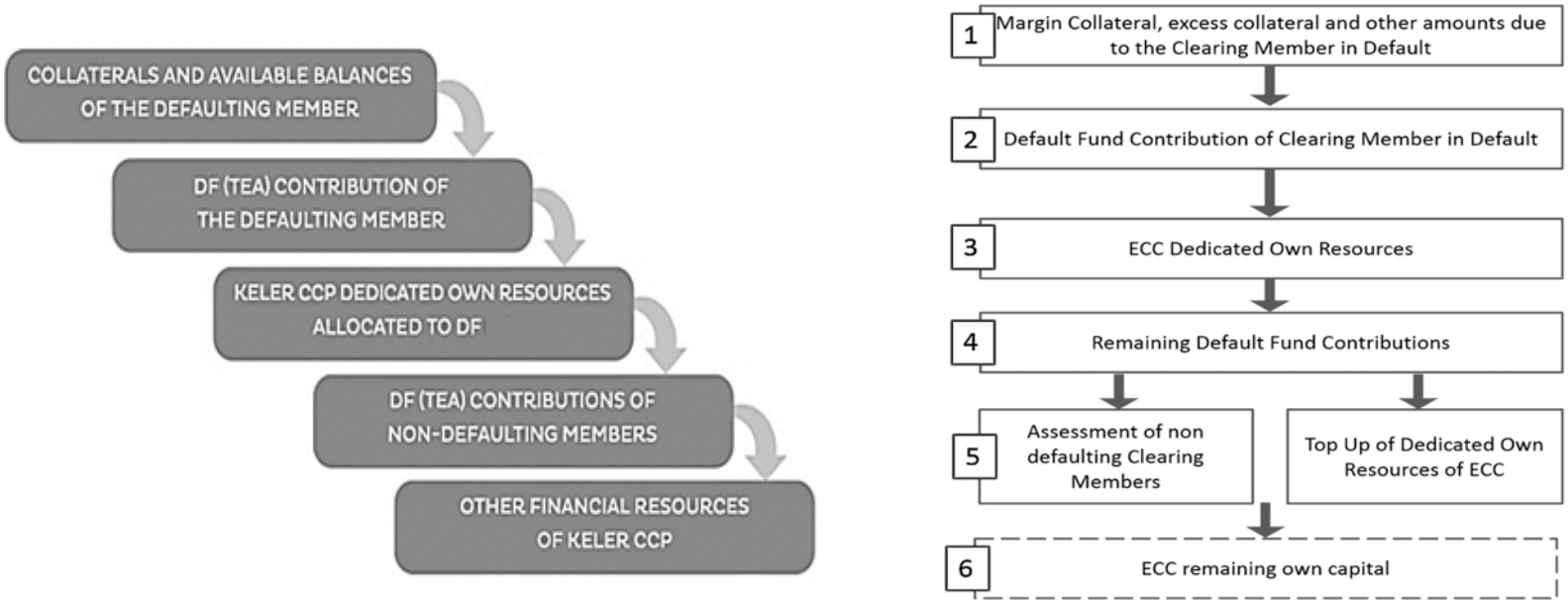


Figure 11: Example of DFW with junior and senior tranches of SITG: (left: KELER CCP, right ECC)

Source: KELER CCP (2021), ECC(2021)

Until 2019 the ASX Clear (Futures) had more than two layers of own resources: it divides participant contributions to the default fund into two tranches; it applies additional rounds of own capital after each tranche was exhausted, but from 2020 this changed and the own resources (consisting of the restricted capital reserve, equity and recovery assessments) are exhausted in the shown below:

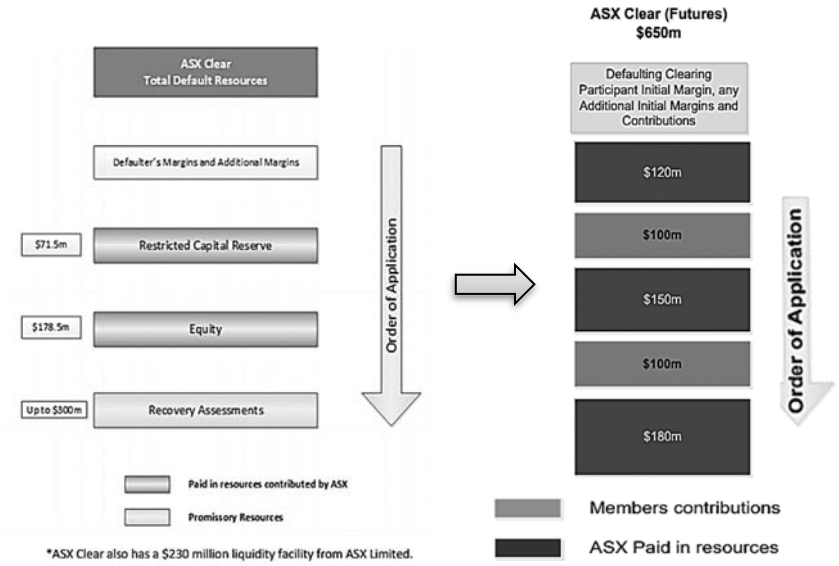


Figure 12: Example of DFW with more than two SITG

Source: ASX, 2019 and 2020

Depending on the nature of the market a CCP clears, the default waterfall setup can also differ. ISDA (2014) reported a default on the Korean Exchange (KRX) in December 2013, which resulted in losses that exceeded the defaulter's collateral. At the time, KRX's rules stipulated that the remaining losses should be absorbed by the default fund contributions of the surviving members. As discussed above, the inclusion of own capital can modify incentives and prevent non-faulty members' contributions. This event triggered the Korean Financial Services Commission to make changes to legislation to ordain that CCP capital would be introduced in the waterfall before exhausting non-faulty participants' resources (Financial Services Commission, 2015).

V. The inadequacy of the default waterfall: resolution and recovery

"Money's only something you need in case you don't die tomorrow."

Carl Fox (Martin Sheen) Wall Street

The market, regulators, and stakeholders all expect CCPs to withstand extreme market conditions, but the shock event may be so immense that the CCP's prefunded and callable resources are exhausted and still not enough to cover the losses. In this case, the CCP could have no other option but to enter into resolution and fail. As pointed out earlier, the failure of a central counterparty may have system-wide effects, so clearing participants might face difficulties in managing their positions afterward. A substitute solution for market participants would be to search for alternative ways of closing their open positions. This extreme situation would trigger immense uncertainty, altering the underlying exposures' value, heightening the associated market and counterparty risk for the whole system (Domanski et al., 2015). The general framework is laid down in Bank Recovery and Resolution Directive (BRRD) (BRRD, 2014)

The advancement of a particular framework for the resolution of failing is still advancing. Many European jurisdictions, notably the United Kingdom, have been adopting autonomous legislation governing the recovery and resolution. The main goal is to introduce a fully harmonized European regime that was released in 2016 has been formally adopted in December 2020, named CCP Recovery and Resolution Regulation (Binder, 2021).

The newly developed approaches for the banking sector can serve as a model for CCPs, but CCPs' specifics shall be considered, so significant modifications must be made to match their business models and risk profiles. The model provided by the Bank Recovery and Resolution Directive of 2014, EU law, in the form of a Regulation adopted in 2020, now provides a separate comprehensive framework for treating failing CCPs (Binder, 2021).

5.1. Recovery planning

Another critical component the regulation has addressed other than the sound risk management practices is the recovery and resolution regimes for CCPs. Both are to assure consistency of the clearing services to achieve systemic stability and to give guidance for an orderly resolution of the CCP (CPSS-IOSCO (2012), CPMI-IOSCO (2014), FSB (2014a)).

Peters and Wollny (2018) bring up the significance of preparation. A recovery plan is a pivotal tool for both CCPs and regulators to be set up to distinguish the critical services; the stress scenarios in case of default and non-default events prevent the CCP from offering its core services. The measures to be distinguished are both quantitative and qualitative, which could activate all or part of the recovery plan; and would require the use of recovery tools in case of diverse events. The plan should indicate conceivable outcomes the CCP has in different circumstances. The relevant supervising authority must periodically review the plan and assess its adequacy. In case of significant change on the market or in the regulatory background, the deficiencies caused should be considered implementing. This requires a flexible implementation of the plan (Peer and Lewis, 2018). However, the set of supervisory intervention is limited; the execution of the plan is solely the responsibility of the CCP. To facilitate the quantification of potential exposure to the CCP, regulators endeavors to enhance transparency by elaborating the impact in the recovery plan for clearing members. (Priem, 2018)

The general framework of recovery tools provided by the regulator refers to tools to be used in case of a defaulting member and tools to allocate losses not caused by a participant default (CPMI-IOSCO, 2014). The following table contains the type of tools to be used in different events and their characteristics.

Type of tool	Characteristics
Tools for uncovered losses caused by participant default	
Cash calls (Assessment powers)	In a going concern, CCPs can require non-defaulting clearing members to provide additional financial, but only for covering losses due to default. These calls to

	clearing members should be proportionate to the pre-paid default resources or the market-to-market value of the positions the clearing members bring to the CCP on a given day. In order to enhance transparency while mitigating uncertainty of the callable cash amount, the European Parliament opts for the possibility of several cash calls, maximized by the resolution authority. The aim is to reduce the maximum loss that would fall on any individual non-defaulting clearing member by mutualizing the loss in proportion to the risk that the clearing member brings to the CCP. Even more, this approach would provide ex-ante incentives for clearing members to limit the risk they bring to the CCP. (Peter and Wollny, 2018).
Variation margin haircutting by the CCP	This is a limited-time tool that involves reducing haircutting - in any variation margin gains/profits due to the non-defaulting members. All claims, either gross or net or only marked to market gains, can be subject to haircutting. The most significant disadvantage is that over time, participants will be unwilling to provide the required initial margin. If the CCP cannot reestablish its clearing activity promptly, further steps should be taken.
Use of initial margin	As discussion over the initial margin usage in the previous sections stated, it is used to cover the obligations of the provider, and it cannot be used for loss-mutualization purposes. Generally, the initial margin is remote from the insolvency of the CCP, and it is not subject to a reduction in either recovery or insolvency. However, in some jurisdictions, this enormous pool of pre-funded resources may, in the event of the CCP's insolvency, be exhausted to fulfill creditors' claims, thus becoming a tool in recovery. If the initial margin of the surviving members is used, they are required to replenish the initial margin, and to decrease their exposure at the CCP to the level that their remaining initial margin provides adequate coverage or a combination of both. This recovery tool being implemented could further undermine confidence in the CCP. It would also generate procyclicality in the

	system. The willingness of the clearing members to meet the margin calls imposed by the CCP will plummet drastically. The regulator draws precautions to the use of this tool!
Other tools that involve collateral and capital	These tools are the use of the CCP's own capital and, if necessary, raising additional capital. The purpose is to cover losses of a default. This tool can be part of the ordinary default waterfall, or it can appear among recovery or both.
Tools to address uncovered liquidity shortfalls	
Obtain liquidity from third-party institutions	A CCP can have arrangements in place with third-party institutions. These tools are useful in case of less stressed market conditions. They are less reliable forms of liquidity, but if included in the recovery plan, additional tools should be used to manage liquidity shortfalls in highly stressed events as well.
Obtain liquidity from participants	Two option play here: Requiring participants who are owed funds by the CCP, to the extent of those obligations to provide a collateralized loan, a repo, or a swap transaction. The second option is the application of ex-ante rules that permit the CCP to obtain liquidity more broadly from all participants. While the first option has the benefit of incentivizing participants to follow up on the CCP's risk management, the second option could lead to performance risk, and participants could "*be exposed to payment obligations that they might not be sufficiently able to control* "(CPMI-IOSCO, 2014, p. 23)
Tools to replenish financial resources	
Cash calls	Ex-ante assessment rights, as discussed above.
Recapitalization	Raise additional equity capital, as discussed above.
Tools for CCPs to re-establish a matched book following participant default	
Forced allocation of contracts	The CCP would first try to reach out to voluntary and mandatory tools to achieve a matched book. A CCP can sell the positions to direct or indirect participants the outstanding obligations of the defaulter; it can also buy-in any assets a defaulter has sold but failed to deliver, or the CCP can sell any assets a defaulter has bought but failed to pay. During a forced allocation process, the CCP fully allocates unmatched positions of the

	defaulter's contracts to participants that have not defaulted. They can also be compensated, as far as resources allow, for acquiring these contracts.
Contract termination: tear-up (complete, partial, and voluntary)	During complete tear-up, all positions - matched or unmatched positions – are terminated. There is a possibility to tear-up just some of the positions, or participants can be invited to nominate contracts to terminate them. By reducing some of the contracts, the CCP will reduce the exposure towards the concerned clearing members and, therefore, it can re-establish a matched book.
Tools to allocate losses not caused by participant default	
Capital and recapitalization	Raise additional equity capital, as discussed above.
Insurance or indemnity agreements	Insurance or indemnity agreements may be an effective way of addressing the impact of specific business losses
Other tools	Cash calls, as discussed above.

Table 1: Recovery tools

Source: CPMI-IOSCO, 2014, own edition

Most demanding and challenging is to define the tools that can be assessed to serve as a recovery tool. The challenge in choosing these tools is to fit the business model, the liability structure of the CCP, but it is vital to notice that some safety tools are already built into CCPs' risk management. Domanski et al. (2015) bring a third important feature in analyzing the clearinghouses: the diversity of CCPs' organizational structures, functions, and designs. Moreover, besides the specific and detailed quantitative stipulations, the CCP's governance and oversight arrangements are introduced with broad international principles. TThe CPMI-IOSCO decided to execute these norms across jurisdictions, such as the compliance and consistency results of existing "*CCP stress testing, margin frameworks, prefunded loss-absorption capacities, and recovery planning*" (Domanski et al.,2015, p. 71).

The regulators endeavor to establish the interaction between CCPs and the whole financial system as stable as possible. The steps taken are vital in every area, and the progress since the financial crisis of 2007–09 is remarkable from the evolution of the central clearing activity point of view. However, the need for recovery and resolution tools must have objective and prudent regulation

as well. The fail of a CCP would imply that procedures, risk management policies, and safeguard tools, were not prudent enough, or at least they have failed to fulfill their loss-absorbing objective.

Binder (2021) concludes regarding the CCP recovery that "*the CCPs' discretion to implement recovery measures at the expense of the soundness of non-defaulting clearing members and, ultimately, systemic stability is thus balanced by corresponding supervisory powers. Still, whether or not the proposed Regulation offers sufficient guidance to CCPs and supervisory authorities in this respect is not free from doubt"* (Binder, 2021, p. 17).

5.2. Resolution planning

The growing network of CCPs and the expansion of transactions guided under these market infrastructures; nevertheless, the horizontal integration in products and geographical levels have substantially changed systemic risk and crisis propagation mechanisms. The implications of a central clearing have also affected the financial system's response and behavior in normal and stressed conditions. In knowing the effect of these responses, authorities have a tool in their hand that may help establish a macroprudential perspective on the regulation and supervision of financial systems that rely on central clearing (Peters and Wollny, 2018).

Improving resilience is the most critical aspect. A primary tool is incorporating liquidity and concentration risk factors in margin calculation methodologies and applying appropriate procyclical buffers. Complying with the Cover 2 standard to calibrate the default fund, using extreme but plausible scenarios, prepares CCPs to withstand market stress. Increasing CCP contributions to the default waterfall to meaningful levels of skin-in-the-game is particularly critical concerning for-profit institutions. Central counterparties must have effective default management processes (ISDA, FIA, IIF, 2019).

Nonetheless, enhancing transparency by publishing valuable, standardized, and audited disclosures on CCP risk methodologies, backtesting, and stress testing. Non-default loss event management is also essential; therefore, its manifestation should be supported by appropriately sized regulatory capital

requirements. Besides the robust setup of the default waterfall, central counterparties also apply mechanisms, they set rigorous membership criteria, and systematic assessment of members, collateral eligibility, and investment restrictions are also tools that help in achieving resilience (JPM, 2020).

The recovery plan is highly dependent on the design of the default waterfall the CCPs uses. A general approach of a recovery plan is to facilitate the process itself, and it is recommended to use the tools listed above. This list includes the pre-defined assessment rights, more capital of pre-funded CCP resources, variation margin gains haircutting, tear-up of contracts (Plata, 2017).

Authorities intervene in case the resolution plan fails to achieve the desired recovery level to assure continuity of the service providence. The resolution can reach out for tools like ex-ante resources of CCPs that authorities require to set aside.

On 4 December 2019, the European Council adopted a position on recovery and resolution. The proposed framework keeps in mind the role of central counterparties and their systemic nature. Hence, the Council sets out a 3-step approach to coordinate national authorities in the framework of **resolution colleges.** The three steps include (European Comission, 2019):

- **Prevention and preparation**. As in the case of recovery, planning is a fundamental element. CCPs and resolution authorities are required to be prepared for extreme conditions. This explains why they must have an arranged recovery and resolution plans on how to handle financial distress at the right time. The preparation process is an excellent opportunity for authorities to identify obstacles to resolvability, and they can take steps by requiring the CCP to respond appropriately.
- **Timing and intervention.** Supervisory authorities can intervene at an early stage, even before the problems become critical, and the financial situation deteriorates irreparably. Moreover, authorities can require the CCP to undertake specific actions in its recovery plan.

They can even mandate to make changes to their business strategy or legal or operational structure.

- **Resolution tools**. Authorities have tools in their hands in the unlikely event of a failure. These tools include the use of ownership instrument write-downs, a cash-call to clearing members, the sale of the CCP or parts of its business, or the creation of a bridge CCP. The goal is to avoid public support, but authorities can apply for it as a last resort but ensure that shareholders take an appropriate part of the losses.

Plata (2017) analyzes the protection the recovery and resolution plans provide for CCPs, and he suggests four principles that an active CCP recovery and resolution regime should take into account.

Principle 1 is named *Extremeness of this potential event*. It is highly unlikely the default of a CCP would eventually happen, leading to systemic disaster. However, as mentioned before, CCPs must be prepared for such events.

The second "Principle 2: *Importance of restoring a matched book*": A clearing member default would lead to an unbalanced book. The CCP's primary objective in default management is to restore the matched book to avoid exacerbating risk or stress on the market it clears.

The third principle is "Principle 3: *Importance of incentives*" Plata (2017), to emphasizes the role and the design of the CCP, namely, that they are risk management and mutualization systems based on incentives.

The last principle is Principle 4: *Balance between certainty and flexibility*: The events for what the plans are dedicated to managing are extreme and rare; however, they should keep a way to ensure the right balance between certainty regarding the tools to be used and the flexibility of its extent.
In a close parallel to the corresponding provisions in Arts. 15-18 BRRD, Arts. 15-17 of CCP RRR require the resolution authorities to analyze the degree to which a CCP is resolvable without assuming any extraordinary public financial support, central bank emergency liquidity assistance, or central bank liquidity assistance provided under non-standard collateralization tenor and interest rate terms.

Art. 16 CCP RRR provides accommodates a slow arrangement of designated managerial forces, which, beginning with simple proposals to the applicable CCP, eventually brings about the ability to require the CCP to make at least one explicit strides to cure the issues, including both organizational measures and changes to the legal structure of the CCP. Binder (2021) highlights that it is uncertain how these powers will be activated in the case of CCPs, and the frameworks shall be designed and appropriately calibrated. Specifically, the arrangements of action for financing goal activities comparable to CCPs are currently under review.

The chapter raises the importance of adequately planned recovery and resolution for CCPs. Even though these market infrastructures are prepared for stressful situations, beyond extreme circumstances should be handled given the tools for such purposes.

VI. Own research

There are two important aims a CCP must keep in mind when designing the default waterfall. One is to protect the non-defaulting parties from being involved in loss-covering of the defaulting ones, and second, to avoid the implementation of resolution and recovery and, therefore, assuring the system's resilience.

Besides setting the risk profile of the CCP, which can depend on the ownership or the market, it is also crucial to construct the default waterfall that is suitable for the main stakeholders, e.g., the owners, the regulators, and the clearing members. The main concern these stakeholders have is to balance between liquidity risk and systematic risk. Namely, minimizing liquidity taken away from the clearing members by decreasing the level of the required collateral while maximizing the loss-absorption effect of the default waterfall by increasing the available collaterals' level to decrease systemic risk. In this thesis, I will present the risk mitigation effects if the CCP can choose the structure of the default waterfall from the viewpoint of mutualizing risk between different markets and market segments by handling the default fund in different ways. The research points out how the handling of the markets can change the requirements of the CCP from its members and how sensitive the value of SITG is if the CCP aims to avoid the exhaustion of non-defaulted members's contributions and, ultimately, the implementation of the recovery plan.

While first I analyze the benefits of cross-guarantee from both the CCP and the market participants' perspectives, another approach will also be part of the research. This latter one shows what benefits and dangers the different operations have from the CCP's own capital viewpoint, highlighting the issue from a managerial perspective.

Introducing a model representing a simplified reality will capture the calibration effects of the stress tests and the, and the results will be analyzed accordingly. The hypothesis I raise are the following:

H1: Cross-financing takes place in the merged setup of spot and derivative markets.

H2: The clearing of several markets by a merged guarantee fund affects the structure and size of the guarantee system.

H3: In the merged clearing of spot and derivative markets, a CCP needs a higher skin-in-the-game amount to remain liquid, avoiding implementing recovery and resolution plans.

6.1. Baseline model

As already mentioned, regulators set out a framework of stress test methodology, called the “EU wide stress test” performed by the European Securities Market Authority at least biannually. The results of the fourth stress test show that CCPs m ust quantify the impact of sudden losses on their guarantee system. The primary purpose of my research is to apply the stress test under different scenarios to see how the guarantee system changes if a CCP clears markets separately, jointly, or partially separated – on the initial margin and default fund level. The stress scenarios will be the basis of the default fund values. This question is essential because risk-sharing and their sizes are always a trade-off between the margin requirements and the default fund. (Capponi et al., 2018). When analyzing this share proportion, I disregard the size of the skin in the game in the analysis. Its size will be examined from a different point of view, detailed above.

A model will be built to show how the stress test parameters affect the default fund and the contribution members are required to meet. At first, the theoretical framework will be established and tested. Sensitivity tests will also be the subject of the research.

The model and results presented in the following were published recently (August 2021) in the special issue of Risks, a Q2 ranked journal.

In this study, our main question is how the default waterfall's size and structure changes regarding the initial margin and default fund size if we clear two markets separately or jointly and how it affects risk mitigation. We choose two markets: the spot market for securities and the derivative market for these securities. It is vital to select two markets that have a connection with each other because we want to show how the risk mitigation of the hedged positions between the spot and derivative assets changes the riskiness of the positions of the clearing members, and through this, the guarantees the clearing members have to pay after their positions. We build up a theoretical model using a Monte Carlo simulation (MCS). During our analysis, we do not simulate or include the value of the SITG. Our model has one CCP, four different clearing members, three different financial assets: a stock, a bond,

and a currency. The stock can be traded on the options, futures, and spot markets, while the bond can be traded only on the futures and spot markets, and the currency can be traded only on the options and futures markets. For the MCS, we had to assume the financial assets' price evolution since we need a time series for initial margin calculation and estimating the default fund. We choose the arithmetic Brownian motion (ABM) to simulate the daily logreturns of the stock and the currency, while we choose the Vasicek model (Vasicek, 1977) to simulate the instantaneous rate in the case of the bond. Based on this, Equation 1 shows the ABM we use for the stock and the currency,

$$dY = \alpha \cdot dt + \sigma \cdot \sqrt{dt} \cdot N(0,1) \tag{1}$$

where 'dY' is the change in the logreturn during 'dt' period, 'α' is the expected value of the logreturn, 'σ' is the standard deviation for the logreturn, and 'N(0,1)' is a standard normal random variable. The price is determined by Equation 2, where 't' stands for time, and 'S' stands for the asset's price,

$$S_t = S_0 \cdot e^{Y_t} \tag{2}$$

In our simulation, the stress test has a central role. We simulate 30 years – since this is the look-back period for defining historical scenarios within the EMIR regulation – for both financial assets. To simulate the stock price and the currency, we set the value of the parameters needed to run the simulation. Moreover, to use "realistic" values in the simulation, which represent the European stock market and currency market, we estimate the expected value of the logreturn (α) and standard deviation (σ) – between 12th January 1991 and 11th January 2021 – of the DAX index, and – between 1st December 2003 and 11th January 2021 – for the EUR/USD (finance.yahoo.com, 2021a, 2021b). Unfortunately, the time series for the EUR/USD was not available for 30 years since the EUR does not exist for 30 years. The first day's price in the simulation is the price of DAX on 12th January 1991 and the price of EUR/USD on 1st December 2003. The applied parameters can be seen in Table 2.

Parameter	Stock	Currency
α	7.71%	0.09%
σ	22.37%	11.85%
S_0	1345.26	1.1965
dt	1 day	1 day

Table 2: The parameters of the price simulation in the case of the stock and the currency

In the case of the bond, we apply the Vasicek model (Vasicek, 1977) determined in Equation 3:

$$dy_t = a \cdot (b - y_t)dt + \sigma * \sqrt{dt} \cdot N(0,1) \tag{3}$$

where 'dy' is the change in the instantaneous interest rate 'y', 'a' is the speed of reversion to 'b', which is the long term mean level, 'σ' is the instantaneous volatility of 'y'. Based on the model, the bond price ('P') is the following according to Equations 4-6, where 'T' is the bond's maturity (Mamon, 2004).

$$A(t,T) = \frac{1-e^{-a(T-t)}}{a} \tag{4}$$

$$D(t,T) = \left(b - \frac{\sigma^2}{2a^2}\right)[A(t,T) - (T-t)] - \frac{\sigma^2 A(t,T)^2}{4a} \tag{5}$$

$$P(t,T,y_t) = exp\left(-A(t,T)y_t + D(t,T)\right) \tag{6}$$

The applied parameters for the bond price simulation can be seen in Table 3. The parameter estimation basis is the monthly time-series data of the term structure of interest rates on listed Federal securities with a residual maturity of 0.5 years between the time period of January 1991 and December 2020, also for 30 years as for the stock and the currency.

Parameters for the price simulation	
Vasicek	Bond
a	5
σ	2.49%
b	12.20%
y0	2.69%
T	5
dt	1 day
Face value	100

Table 3: The parameters of the price simulation in the case of the bonds

Besides the price evolution for the financial assets, we also assume a correlation between the three financial assets' returns. They do not evolve independently from each other. The correlation is considered through the N(0,1) standard normally distributed random number in all three processes. We apply the Cholesky decomposition, which means that the relation between the random variables is the following, based on Equation 7-9 (Medvegyev and Száz, 2010), where 'ϵ' will be a random number used in case of the three assets, and 'ρ' is the correlation coefficient.

$$\epsilon_{stock} = N(0,1)_{Stock} \tag{7}$$

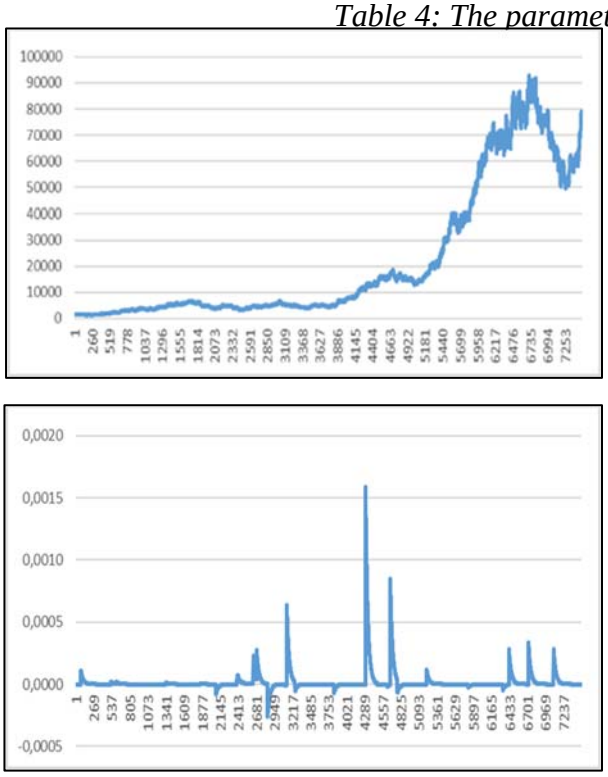
$$\epsilon_{currency} = \rho \cdot N(0,1)_{Stock} + \sqrt{1-\rho^2} \cdot N(0,1)_{Currency} \tag{8}$$

$$\epsilon_{bond} = \rho \cdot N(0,1)_{Stock} + \frac{\rho - \rho^2}{\sqrt{1+\rho^2}} \cdot N(0,1)_{Currency} + \sqrt{1-\rho^2 - \frac{(\rho-\rho^2)^2}{1-\rho^2}} \cdot N(0,1)_{bond} \tag{9}$$

The correlation between the assets is 0.2 in normal market conditions. However, in our price simulation, it is not enough to capture the normal market conditions since we also need stress/shocks in the simulated time series. As we stated before, the initial margin covers possible losses in normal market conditions, while the default fund should cover the losses in extreme but plausible market conditions, which we estimate with stressed market events. As a result, we modify the simulation of the logreturns of the three assets by simulating stresses in the time series of assets' returns as well, so the ABM and Vasicek are not enough for us as we presented before. The stress/shock occurrence is modeled with a Poisson process, while the extent of the shock is modeled with a lognormal distribution. The correlation at the time of the shock – in the case of any of the assets – is increased to 0.95, decreasing by 0.95 every day. The applied parameters for the model are the following according to Table 4, while a realization of the stock price and one realization of the shock can be seen in Figure 14.

Shock parameter affecting the value of the shock			
	Stock	Currency	Bond
μ	-10.00	-10.00	-10.00
σ	2.25	2.25	2.25
decrease of shock	0.97	0.97	0.97
Shock parameters affecting the date of the shock			
λ	0.005	0.0045	0.004

Table 4: The parameters of the shock simulation



(a)

(b)

Figure 13 (a) Realization of the stock price; (b) Realization of the shocks

Four clearing members (CM) are present on the market, with different positions according to Table 5. The positions of the clearing members are built in order to be able to analyze how the merged and separated default funds affect the margin and default fund contributions of the markets. CM4 has positions only on the spot market, while the other clearing members have risky positions, like short straddles, and also positions that handle risk, like a protective put or covered call positions. This is important because if the markets are cleared separately, this risk hedging cannot be used by the clearing members regarding initial margin and default fund payment, while on the merged market, they can hedge the risk. CM3 takes the riskiest position

since it has large unhedged short futures positions and also unhedged short straddles as well.

Position of clearing members	Clearing member 1			Clearing member 2			Clearing member 3			Clearing member 4		
	Stock	Bond	Currency	Stock	Bond	Currency	Stock	Bond	Currency	Stock	Bond	Currency
Long Put	3		5	2								
Short Put							5		5			
Long Call	3		5									
Short Call							3		5			
Long Futures		5			5	5						
Short Futures			5					10				
Long Underlying				2			3			6	5	
Short Underlying	8				5					3		
Name of position	Long straddle + spot	Futures	Long straddle + futures	Protective put	Futures + spot	Futures	Covered call + short straddle + spot	Futures	Short straddle	Spot	Spot	---

Table 5: Number of positions of clearing members

The following shows how we estimate the initial margin and the default funds from the simulated times series data and the clearing members' positions. The margin of the underlying assets (stock, bond, currency) is calculated by Béli and Váradi's (2016) method. This model uses different standard deviations to quantify the VaR value based on delta-normal Value-at-Risk (VaR) calculation. Namely, we have to calculate the equally weighted standard deviation (σ^{equal}) and the exponentially weighted moving average (EWMA) standard deviation (σ^{EWMA}) of the time series of the simulated logreturns (from Equation 1) in the case of the stock and the currency, while in case of the bond the standard deviations should be calculated for the change of the simulated returns from the Vasicek model. Always that type of standard deviation is applied, which has a lower value, according to Equation 10-11,

$$VaR_t^y = min\left(\sigma^{equal} \cdot N^{-1}(99\%); \sigma^{EWMA} \cdot N^{-1}(99\%)\right) \tag{10}$$

$$VaR_{t,bond}^y = D^* \cdot min\left(\sigma^{equal}(\Delta y_t) \cdot N^{-1}(99\%); \sigma^{EWMA}(\Delta y_t) \cdot N^{-1}(99\%)\right) \tag{11}$$

where N-1(99%) is the inverse of the normal distribution's cumulative distribution function at the 99% probability, D* is the modified duration of the bond, while VaR_t^y is the Value-at-Risk at day t for the logreturn (y) in case of the stock and the currency, while $VaR_{t,bond}^y$ is the Value-at-Risk for the bond's logreturn. The Value-at-Risk expressed for the price instead of the logreturn is based on Equation 12-13, where S is coming from the ABM (Equation 1-2), while P is coming from the Vasicek model (Equation 3-6), and T is the liquidaton period, that is being set to 2 days, based on the regulation (EMIR 2012, RTS 2013),

$$VaR_t^{price} = -S_t + S_t \cdot e^{\sqrt{T} \cdot VaR_t^{yield}} \tag{12}$$

$$VaR_{t,bond}^{price} = abs(P_t \cdot VaR_{t,bond}^{y}) \tag{13}$$

Also, a 25% procyclicality buffer is used as well. It is exhausted and built back based on the two standard deviations, and it works the same way for all of the three products, so we will not highlight the bond separately as in Equations 10-13. If the EWMA standard deviation is greater, then the buffer is exhausted gradually. If the equally weighted standard deviation is greater, it is gradually built back, according to Equation 14-16, where π stands for the procyclicality buffer

$$PROmargin_t = VaR_t^{price} \cdot (1 + \pi) \tag{14}$$

$$margin_t^{\pi\ exhaustion} = \max\left(margin_{t-1}; VaR_t^{price}\right) \tag{15}$$

$$margin_t^{\pi\ built\ back} = \min\left(margin_t^{\pi\ exhaustion}; PROmargin_t\right) \tag{16}$$

Finally, the margin at time t is defined by Equation 17-21 for all the three products by calculating a so-called margin band with a minimum and maximum margin value in Equation 17-18.

$$MINmargin_t = if\left(\sigma^{EWMA} \cdot \max\left(\frac{margin_{t-1}}{VaR_t^{price}}; 1\right) > \sigma^{equal}\right); \tag{17}$$
$$margin_t^{\pi\ built\ back}; PROmargin_t)$$

$$MAXmargin_t = MINmargin_t \cdot (1 + band) \quad (18)$$

Till the calculated margin in Equation 10-16 does not reach this minimum and maximum value, the margin requirement will not change, according to Equation 19-21. The main goal of this calculation is to stabilize the value of the margin, not to have to change it on a daily basis, which is essential in practice from the clearing members' liquidity management point of view.

$$margin_t = if(margin_{t-1} > MAXmargin_t; MAXmargin_t) \quad (19)$$

$$margin_t = if(margin_{t-1} < MINmargin_t; MINmargin_t) \quad (20)$$

$$margin_t = if(MAXmargin_t > margin_{t-1} > MINmargin_t; margin_{t-1}) \quad (21)$$

After defining the margin on the individual asset level, we have to quantify the portfolio level margin. We carry it out using the SPAN (Standard Portfolio Analysis of Risk) method by applying simplification. The SPAN is a complex method, according to Figure 15 (CME Group, 2019).

Figure 14: SPAN methodology

For simplicity, we assume that there is only a risk array and Short Option Minimum (SOM), which will be 10% of the underlying asset's margin, except in the case of the bond, since there are no options, so SOM is not needed either. The risk array contains scenarios for the portfolio, according to Table 6. This means that the positions are revalued with the new underlying asset prices and new standard deviations. The scenario that gives the most significant loss is considered the margin (will be the MarginCMt in Equation

22) of a particular CM portfolio. One unit of change in the spot price will be the value of the asset's actual margin calculated in Equation 10-21, while one unit of change in the standard deviation will be 90% of the actual daily standard deviation.

Scenario	The change in spot price will be multiplied by this amount	The change in the standard deviation will be multiplied by this amount
1	0.00	1
2	0.00	-1
3	0.33	1
4	0.33	-1
5	-0.33	1
6	-0.33	-1
7	0.67	1
8	0.67	-1
9	-0.67	1
10	-0.67	-1
11	1.00	1
12	1.00	-1
13	-1.00	1
14	-1.00	-1
15	2.00	0
16	-2.00	0

Table 6: SPAN scenario parameters

During portfolio-based margining, we determine the price of the options with the Black-Sholes model (Black and Scholes, 1973). We assume the following: the options are ATM options, with a maturity of one year, the standard deviation is the actual daily standard deviation that is used in the margin model, the one-year risk-free return is calculated with the Vasicek model, in the case of the currency option, the counter currency's risk-free return is 0%. The futures positions have the same parameters as the options.

We simulate the margins on a portfolio level in two different ways, once when the margin and default fund are calculated for the spot and derivative markets as merged markets and once when they are separated. This is important because during the portfolio margining with the SPAN method in the merged case to spot position could be hedged with the derivative position, hence the risk is lower, so the margin should be lower for the portfolio, while in the separated case, one portfolio is for the spot positions, and another portfolio is for the derivative positions, hence the risk should be higher, and the margin should be higher as well. In our analysis, we aim to show this

phenomenon, and also we want to show how it affects the value of the default fund, and as a final effect, how the size of the guarantees will change.

We need to run the stress test based on the EMIR regulation (2012) and Hull (2018) to calculate the default fund. We estimate historical and hypothetical scenarios, as well. Altogether, we have eight stress scenarios: six historical and two hypothetical in our stress test. In every scenario, we have a stress parameter for all three financial assets, one for the stock, one for the currency, and one for the bond. We use the same stress scenarios on the spot and derivative markets. The focus of our stress test is to see that if we stress the current market price – which is the last simulated price in our price simulation with ABM and Vasicek, so the 7500th day – with every stress scenarios' stress parameters, would the margin be enough to cover the potential losses in case the CM would default. According to EMIR, the value of the default fund will be the scenario that has the highest loss of the max(1;2+3) exposures. We apply the following rule to define the historical scenarios: we take the simulated 30 years time series and search for the day where the stock had the lowest return. On this same day, we take the return of the bond and the currency as well. This is one scenario, and we name this as "min stock." The other five historical scenarios are based on the same method, summarized in the following the six historical scenarios can be seen:

- Historical 1 – Min stock: lowest stock return during the 7500 days, and taking the currency returns and the bond yield change on the same day.
- Historical 2 – Max stock: highest stock return during the 7500 days, and taking the currency returns and the bond yield change on the same day.
- Historical 3 – Min bond: lowest yield change during the 7500 days, and taking the stock and currency returns the same day.
- Historical 4 – Max bond: highest yield change during the 7500 days, and taking the stock and currency returns the same day.
- Historical 5 – Min currency: lowest currency return during the 7500 days, and taking the stock returns and bond yield change the same day.
- Historical 6 – Max currency: highest currency return during the 7500 days, and taking the stock returns and bond yield change the same day.

In hypothetical scenarios, we must consider the correlation between the different risk factors and risk parameters. To fulfill the regulator's requirements, we choose the stress parameters the European Systemic Risk Board (ESRB) put together during the EU-wide stress test for the central counterparties in 2019. The test's time horizon is five days, but we run our test only on a daily time horizon, so we convert the given parameters to daily ones. For the DAX index, -14% is given by the ESRB, so on a daily basis, it becomes -2.80%, the shortest government bond stress parameter belonged to the 1-year maturity bond, which was -36 basis points, so we apply -7.2 basis points. For the EUR/USD, the USD/EUR parameter is set at -5.8%, which means that the EUR/USD parameter would be 6,16%, and on a daily basis it is 1.23% (ESRB, 2019). We have two hypothetical scenarios, one with the parameters explained and another with the opposite of these numbers. An example of the eight stress scenarios based on our price simulation can be seen in Table 7.

	Historical scenarios						**Hypothetical scenarios**	
Parameters	Min stock	Max stock	Min currency	Max currency	Min bond	Max bond	First	Second
Stock	-5.28%	4.71%	-0.48%	-1.59%	-1.59%	0.08%	-2.80%	2.80%
Bond	0.00%	0.00%	0.00%	0.00%	0.03%	-0.02%	-0.07%	0.07%
Currency	-1.26%	0.13%	-2.69%	2.90%	0.92%	-0.29%	1.23%	-1.23%
Number of day in the simulation	6 839	179	3 380	915	5 897	5 576		

Table 7: An example of the stress scenarios

Overall, we define the largest and the sum of the second and third largest exposure (loss not covered by the initial margin) in every historical and hypothetical scenario. That scenario will "win" that has the largest exposure, so the one that had the largest max(1;2+3) value. Moreover, this value will be the value of the default fund (DF).

As a final step, this DF is split up between the clearing members according to their ratio of margin payment within the total margin value on the market, according to Equation 22,

$$DF_{CM1} = \frac{Margin_{CM1}}{\sum_{t=1}^{4} Margin_{CMt}} \tag{22}$$

6.2. **Results**

We run the simulation 1 000 times within the model we have introduced in the previous chapter. Figure 4 shows the default funds' values in the cases of merged and separated markets for 1000 realizations. In the separated DF-s, the value shown in Figure 4 is the sum of the DF of the spot and the derivative market. We cleaned our database from eight outlier values in order to represent the results since, in these outlier cases, the size of the default fund is so high that one graph could not contain all of them at once. The outliers can be seen in the right upper corner of Figure 16.

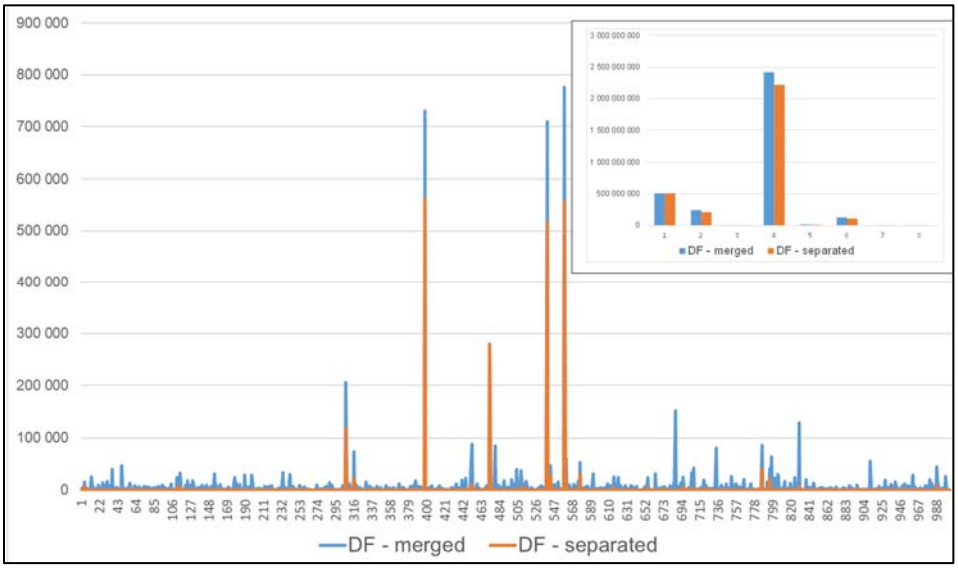


Figure 15: Size of the default funds in the two different cases

A striking difference can be seen between the markets regarding the value of the default fund (DF), namely that the DF's value is always higher in the merged market, which means that in the merged case, the cross-guarantee taking between the CMs became larger. Moreover, in the separated market, the DF value is 0 in 649 times of the cases, while in the merged case, only once out of 1000. This is a vast difference, which is essential from a loss absorption point of view since zero DF value means that the value of the

initial margin is enough to cover the losses both on the derivative and on the spot market as well in the separated structure, while in the case of the merged market this could nearly never happen.

In the cleared dataset, the minimum DF value is zero in both market structures. While the separated DF has its maximum at 561 914, the merged DF is much higher: 776 197. The difference between the average DF value is more significant since the merged DF values' average is more than three times as large, 7 618, while in the separated, it is only 2 419.

One of our goals was to examine how the contribution to the default fund changes per each clearing member in the two different structures since we wanted to analyze how risk mutualization changes. To show this, we looked at how the default fund contribution – not in absolute terms, but the percentage of the total value of the DF – changed for each clearing member in the two cases. The result can be seen in Figure 17 for those cases when the DF was not 0 in the separated case. Figure 17 shows the difference between each CMs' DF contribution within the merged and separated market. If the value is positive, the CM has a larger share in the DF in the merged case than in the separated, while if it is negative, the CM's share became smaller.

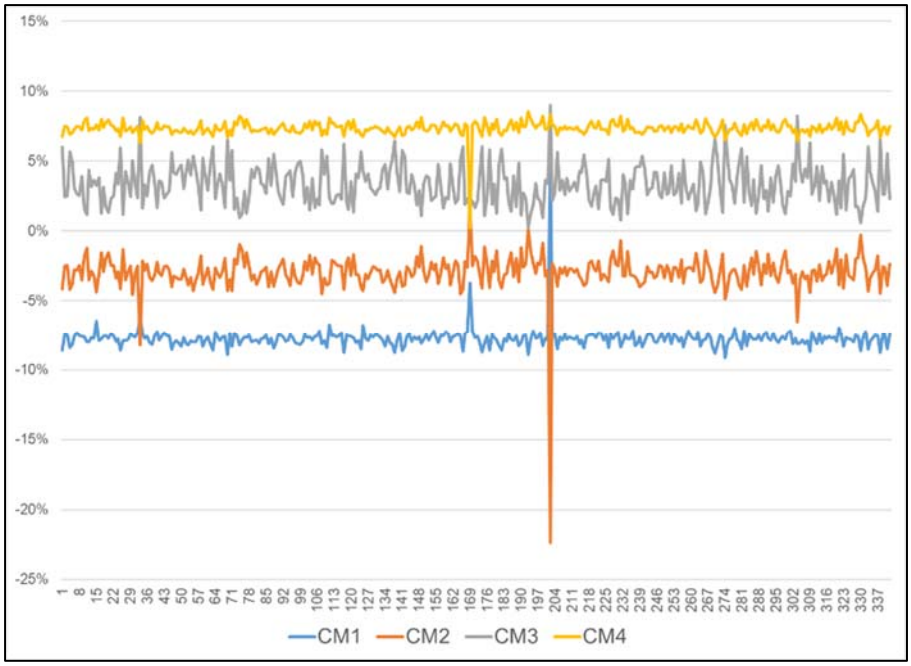


Figure 16: Difference between the DF contributions of each CMs

The results show the DF contribution for CM3 and CM4 has constantly increased, while CM1 and CM2 consistently decreased, except one occasion out of the 1 000 for CM1. CM3 only has net long positions in the stock and the bond, so it did not have any derivative positions. Merging the markets increases its share in the mutualized risk, so it has to face larger cross-guarantee commitments because of the high risk those traders take, who also trade on the derivative markets. However, on the other hand, CM4, which had taken the most considerable risk since it has several unhedged short options and huge unhedged short futures positions, also has to increase its share in the default fund. So its positions' risk is mutualized, but at the same time, its guarantee payments had to be increased as well in relative terms compared to the other CMs. Interestingly, those two CMs – CM1 and CM2 –, who have several hedged positions and could use the derivative products' risk hedging effect, could decrease their DF payment contribution share.

The DF structure is impressive, and the whole guarantee system, namely how the initial margin payment has changed and how the total value of the guarantees (IM + DF) changed. By analyzing the whole guarantee system, we can conclude that the total amount of guarantees is always higher in the separated markets, according to Figure 18. Figure 19 shows the difference between the two guarantee systems, showing that the guarantees' total value always decreases in the merged case.

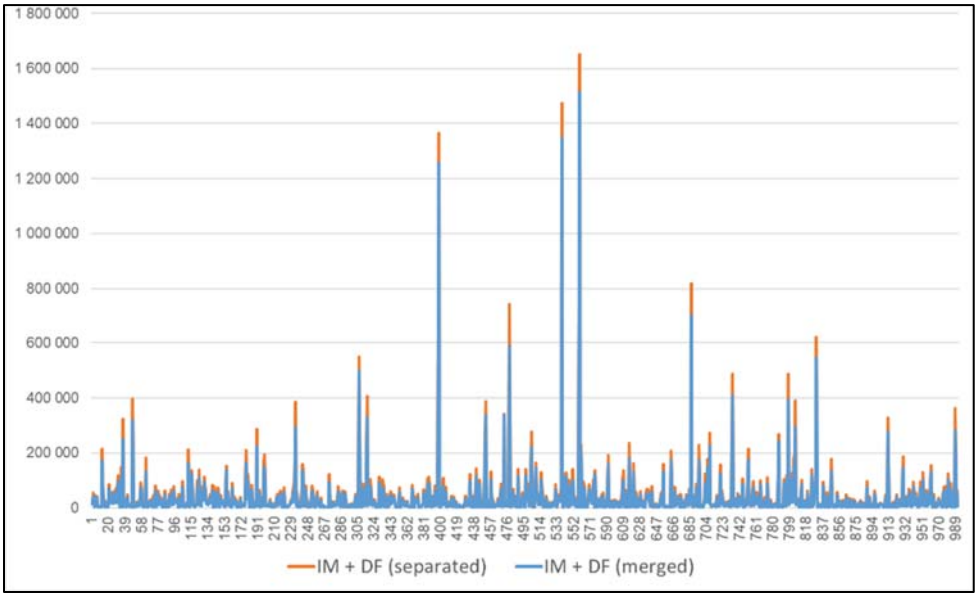


Figure 17: Total value of the guarantees in the merged and the separated case

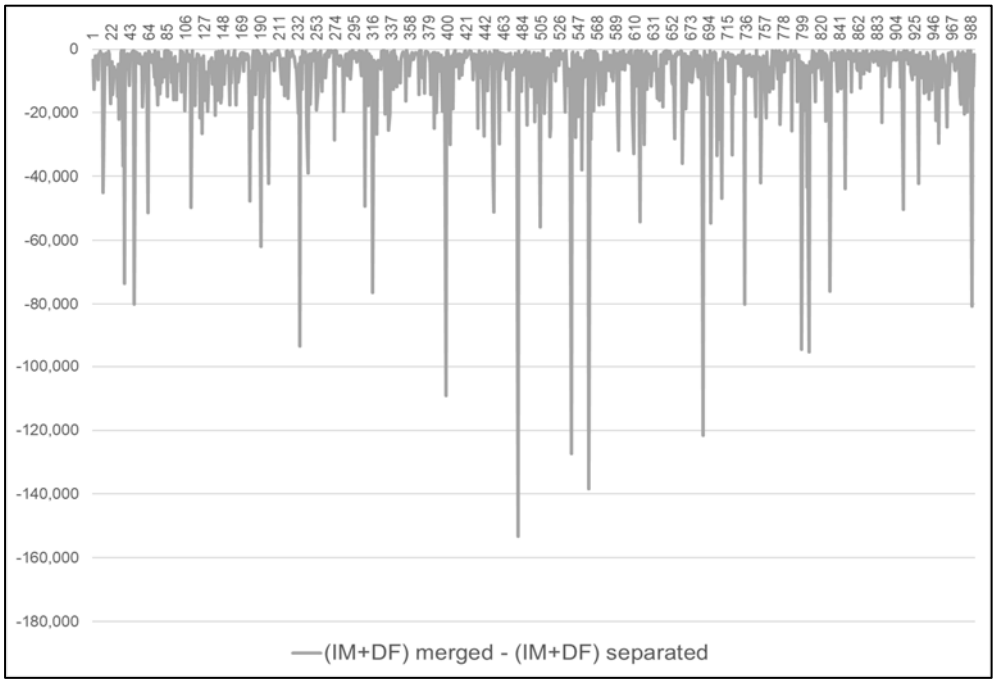


Figure 18: Difference between the guarantee values of the separated and merged markets

This difference can be the consequence of the portfolio margining on the merged markets since the risk of the spot and derivative markets' positions cancel out, reflected in the margin values. In every case, the margin is higher on the separated markets than on the merged ones. The difference is presented in Figure 20.

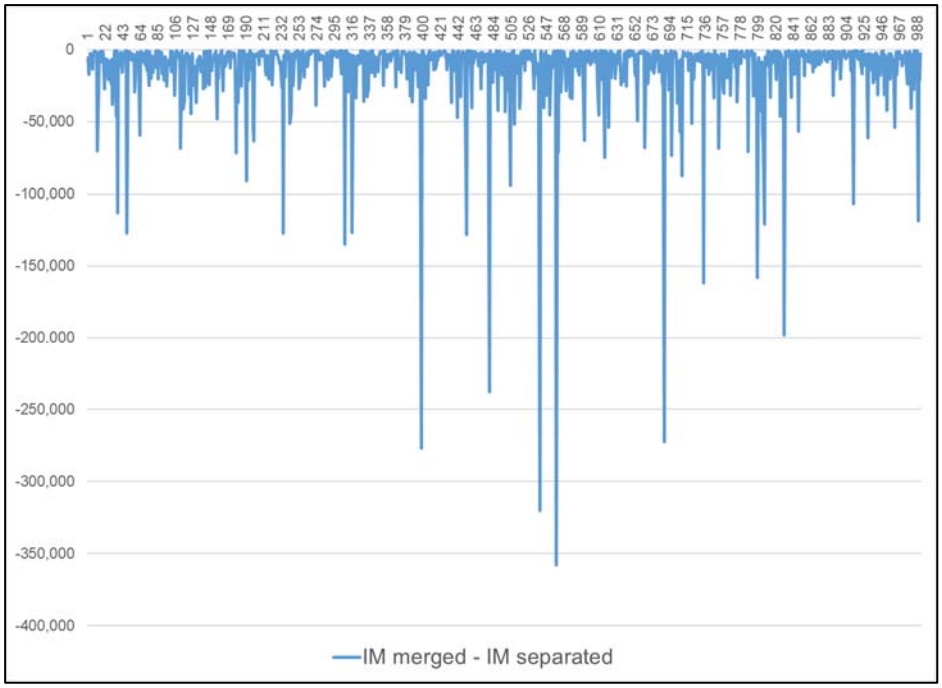


Figure 19: Difference between the margin values of the separated and the merged markets

As a robustness check, we ran this 1 000 simulation a few times more, and the results always had the same patterns as the simulation we have shown.

The open positions were built up to show how the cross-guarantee undertaking changes between them if the CCP merges or separates the guarantee system – the default waterfall – for the spot and derivative markets. One of the members had mainly open short derivative positions, so this clearing member's portfolio represented a perilous portfolio. Another one had only positions on the spot market, with this, **we represented how the cross-guarantee changes between markets**. The remaining two had hedged open spot positions with derivative products, so they were active on both of the markets, so we could show how the hedged positions' advantage from a risk reduction point of view is reflected in the amount of guarantees the clearing members have to pay. We also showed in our paper how the total size and the structure of the guarantee system changes.

The paper has pointed out why it is essential to carefully build a guarantee system and applying it jointly or separately for different markets. Besides complying with the regulatory background, it is also crucial to carefully set up the risk management framework for a CCP. The amount of the margin can

affect the amount of the default fund, which has different effects on the CCP and the CMs as well, not necessarily positively for both at the same time. Our model is a simplified reality, but the results show how much impact the merged and separated market has regarding cross-guarantee. Our primary goal was to examine how the contribution to the default fund and initial margin changes per each clearing member if we calculate on separated or merged markets and show how the total size of the guarantee system changes. The DF is higher on the merged market in all of the simulated cases. Although analyzing the whole guarantee system, we can conclude precisely the opposite. Namely, the total amounts of guarantees are higher in the case of the separated markets. The difference can result from the portfolio margining on the merged markets since the risk of the spot and derivative markets' positions cancel out, reflected in the margin values. We also found that the default fund contributions have increased on merged markets – compared to the separated markets – for the clearing members who trade only on the spot markets, so they have to take over some of the other clearing members' risks. Finally, from a financial stability viewpoint, we would recommend clearing the markets separately since the total value of the guarantees are larger in this case, so the loss-absorbing capacity of the CCP is larger.

6.3. Conclusion of model I.

This model showed how the guarantee system's size and structure change if a central counterparty applies it merged or separately for different markets. As a general conclusion, it can be stated that in the separated case, the overall guarantees that are available in the guarantee system is higher; however, the value of the default fund is always larger in the merged case, so the **cross-guarantee between the clearing members and markets are more notable**. From the clearing members' perspective, this result makes the merged markets more favorable, since in this case, the trading is cheaper for them because less collateral is required to be posted. However, because the ratio of the cross-guarantee commitments changes, it is questionable if it is better from a risk-taking point of view for all of the clearing members or not. From the CCPs point of view, if it wants to increase its competitiveness by lowering the guarantees' value, the merged version should be chosen, but if it wants to

have a more prudent guarantee system, the markets should be separated. Finally, from a financial stability point of view, since in the separated case, in more than 60% of the cases, the initial margin was enough to cover potential future losses, the default fund value was 0, it can be stated that the separated markets are more stable, more stress-resistant, so it should be chosen if the financial stability of the CCP is in focus.

From a regulatory perspective, our recommendation to policymakers, on the one hand, is to follow the more prudent path and specify the operation of the default funds to be handled separately. On the other hand, if the regulator's most important goal is to handle systemic risk, it must keep a balance between increasing the size of the initial margin and default fund and the liquidity risk it causes with it for the clearing members. So it is not evident that the higher initial margin and default fund value is adequate from a systemic risk point of view.

The proposed model’s limitation is that we had one CCP with four clearing members with small open positions, and we did not consider the third layer of the default waterfall, the SITG. Researches focusing on the SITG highlight that incentives of the CCP and its clearing members should be aligned to increase efficiency. During this research, the goal was to build a model that offers a solid basis to address future improving policies regarding CCPs. However, the model is built in Microsoft Excel, and the program can handle a limited set and complexity of data.

6.4. Model for sensitivity testing of the SITG

In order to increase efficiency and to analyze and align the incentives of the CCP and its clearing members, I decided to use the model presented above to shows how the CCP's own contribution in the default waterfall is affected in different market structures. The model needed to be simplified to perform a sensitivity test on the SITG. Overall, the model is improved, and all three layers are part of the stress testing so results are based on the whole default waterfall rather than just a part of it and therefore reached more sophisticated conclusions.

Using the same model and pricing principles, the following assumptions and methods were applied: the economy still has two hypothetical markets cleared by one CCP, one of the markets is a spot market with one single stock, the other market is a derivative market, on which the market participants can trade with options and futures contracts. In this scenario, **the number of assets was reduced to stock and currency.** The underlying asset can be the stock traded on the spot market, and it can be a currency as well, not traded on the spot market. The clearing members can still mitigate their risk and benefit from the hedged positions between the spot and derivative markets. The number of clearing members remains four. The positions of the four members are pre-defined to see how the contributions behave if one of the members has positions only on the spot market (clearing member 4), while the other members have on both markets. One of them (clearing member 3) has highly risky positions built up mainly from short straddle positions, and the remaining two clearing members have risky positions, but also positions that handle risk (protective put or covered call) according to the following:

1. Clearing member 1:
    a. Stock: long straddle + short spot
    b. Currency: long straddle + short forward
2. Clearing member 2:
    a. Stock: protective put
    b. Currency: long forward
3. Clearing member 3:
    a. Stock: covered call + short straddle

b. Currency: short straddle

4. Clearing member 4:
    a. Stock: long stock

7500 trading days were simulated in every trajectory since the stress testing methodology should cover a lookback period of thirty years, which is assumed to be 7500 trading days. Based on this 7500 days' simulated price evolution, the initial margin and the default fund contributions were defined for each clearing member on their position on the 7500th day. The following day, the stock price changes and the currency were not simulated but ranged from +30% to -30%, with steps of 7%. So altogether, a 7x7 combination of price changes is considered in the analysis, resulting in 49 different cases. The additional one day was needed because the primary goal is to show how large the skin-in-the-game should be to cover losses caused by these price change combinations, so authors have analyzed the adequacy of the default waterfall in these 49 cases. In comparison, the simulation's mean and standard deviation value of the stock was 7% and 22%, while 1% and 12% for the currency. The values are based on the time series of the DAX index (30 years) and the EUR/USD currency rates (all available historical data).

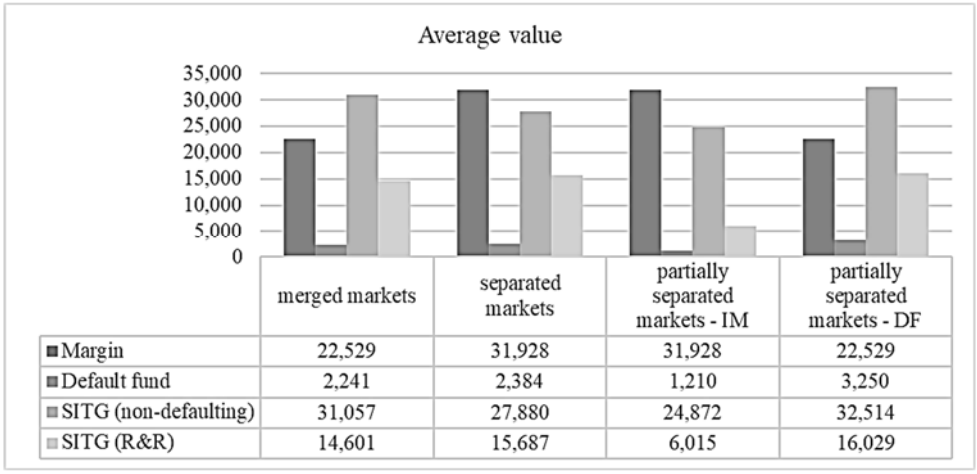
In this model, **four types of operations** were simulated: besides the merged and separated setup, I introduced two more: partially separated on margin and partially separated on the default fund contribution level. In the scenario where the separation is on margin level, the default fund contribution remains merged, while in the other setup, the margin is merged, but the default fund contribution is separated. Separated markets mean defining the value of the initial margins and the default fund separately for the spot and derivative markets. If there is a loss, e.g., on the derivative market, which cannot be covered totally by the default waterfall of the derivative market, the remaining losses cannot be covered from the spot market default fund, and the recovery and resolution will start. Partially separated on margin level means that the initial margin is being defined separately for the two markets. However, there is only one default fund for the two markets, so if losses occur on the derivative market, the merged default fund can be applied, so the default fund contribution of a market participant may have to be used, who is

not even active on the derivative market. Based on the simulation, the expectation is that a larger default fund will be available to cover losses compared to the fully separated case. Partially separated on the default fund level is the case, when a clearing members benefits of netting on the initial margin level, but the default fund contribution is handled separately, so if stress hits the market, the only default fund contribution that is used is the one where the default happened. From a CCP's point of view, a smaller amount of initial margin bears more risks, so the threat of reaching the SITG level is heightened. In the case of a merged market, the initial margins and the default funds will be defined as the two markets are cleared together, meaning that the risk-mitigating effect of having spot and derivative contracts as well would decrease the risk associated with the positions, causing smaller initial margins, all else being equal. This can happen since traders benefit from spot positions' hedging with the derivative ones by applying the SPAN methodology. From their perspective, the risk is lower, so the margin requirements will be lower on the portfolio, too. The benefit from hedging disappears in the separated market model, resulting in higher potential risks, so traders must include more collateral in the system.

Based on the +/-30% price changes on day 7501, the clearing members' positions, initial margin accounts, and default fund contributions, I analyzed whether the clearing members' guarantees would have been enough to cover losses if they defaulted on day 7501. The assumption is that the default happens on a max(1;2+3) basis, so there is at least one non-defaulting member.

Figure 21 contains the result of the 1000 trajectories. The average total value of the initial margins can be seen (total value of the initial margins on the spot and derivative market for all the four clearing members together), the average total size of the default fund, and the average size of the SITG if the price change on the 7501st day is -30% for both the stock and the currency. The value of the SITG was analyzed in two cases; once when the value of the SITG (signed as „*SITG (non-defaulting)*" in Figure 18 was defined to avoid exhaustion of the non-defaulting clearing members' default fund

contributions, namely the CCP applies the first three levels of the default waterfall totally to cover the losses. The other case contains the value of the SITG (signed as „*SITG (R&R)*" in Figure 21 when the CCP applies all four levels of the default waterfall totally and would start the recovery and resolution process if other defaults would occur.



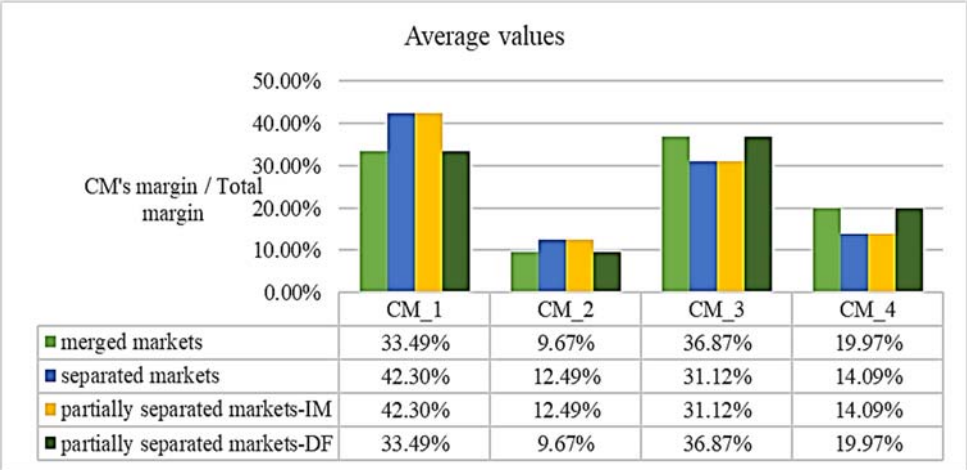
	merged markets	separated markets	partially separated markets - IM	partially separated markets - DF
Margin	22,529	31,928	31,928	22,529
Default fund	2,241	2,384	1,210	3,250
SITG (non-defaulting)	31,057	27,880	24,872	32,514
SITG (R&R)	14,601	15,687	6,015	16,029

Figure 20: Average value of the initial margin, default fund, and SITG in the 1000 trajectories

The most important conclusion drawn from the results is that a partially separated market - IM is superior to the other three markets from the skin-in-the-game perspective. Based on Figure 21, it can be seen that the least SITG is needed when a CCP applies a partially separated structure on initial marging level, and most in the case of the partially separated on default fund level structure in both cases: if focusing on the non-defaulting clearing member's protection, and also if "only" the recovery and resolution prevention is the main goal. Analyzing this from the CCP's point of view, the smaller the value of the needed SITG is, the better since less own capital is being risked and motivation for a robust risk management method on the first layer is also strong. Also, from the regulator's point of view, the smaller SITG is needed better since it means that in case of an immense default, the CCP's losses can be more easily covered from the defaulting member's resources, and the probability of contagion of losses between clearing members would be more negligible. The use of taxpayers' money for an expected bailout is less probable. So from a systemic risk point of view, the partially separated on IM level structure is the best. A robustness check has been run as well,

other price change combinations were analyzed in the range of +/-30%, and overall, the same pattern could have been seen.

It is also important to note, based on Figure 21, that the structure of the default waterfall changes notably between the structures. When applying the default waterfall separately for the two markets (fully or partially), the initial margin results in a higher value than in the merged case since the clearing member cannot take advantage of the derivative positions' risk mitigation effect from the margining point of view. This is supported by Figure 22, where the ratio can be seen of the total initial margins a certain clearing member has to pay and the total value of all of the initial margins provided to the CCP. In the case of CM1 and CM2 - who had uncovered risky positions but also had positions where the risk was mitigated (e.g., protective put) or it was limited (e.g., long straddle) – it can be seen that they have to pay less margin if the markets are merged compared to the case when it was separated. Compared to CM3, who had notable uncovered losses through short straddles, and CM4, who had an open, uncovered risky position on the spot market, the ratio of the total initial margins has increased for them.

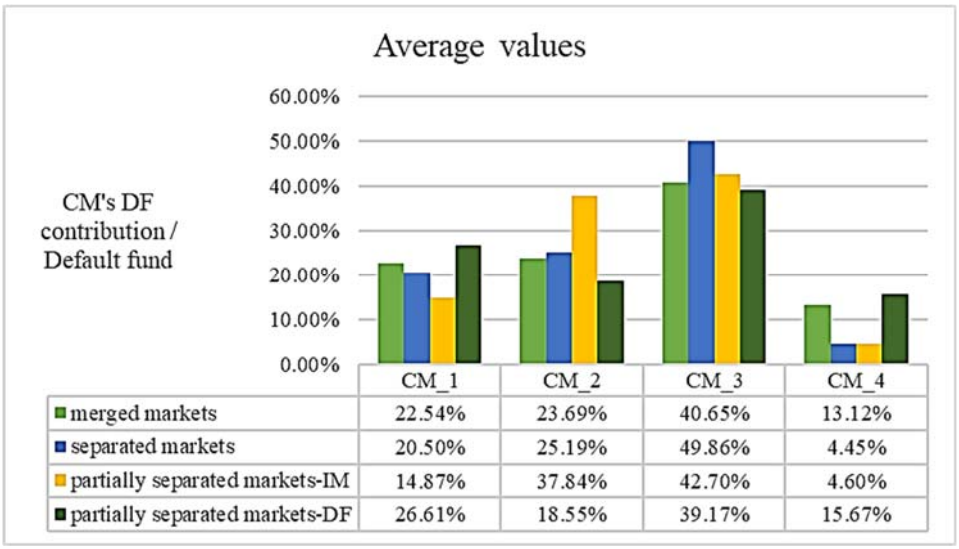


	CM_1	CM_2	CM_3	CM_4
merged markets	33.49%	9.67%	36.87%	19.97%
separated markets	42.30%	12.49%	31.12%	14.09%
partially separated markets-IM	42.30%	12.49%	31.12%	14.09%
partially separated markets-DF	33.49%	9.67%	36.87%	19.97%

Figure 21:Average value of the initial margin of the clearing members

In the case of the default fund contributions on the clearing member level, the same patterns can be seen for the initial margins based on Figure 22. It is also important to note that the total value of the default fund was the highest in the case of the fully separated market, while the lowest in the case of the partially separated, based on Figure 21. The reason can be the relatively high

margin requirement resulting from the separation of markets and the loss mitigation effect of calculating the default fund jointly.



	CM_1	CM_2	CM_3	CM_4
merged markets	22.54%	23.69%	40.65%	13.12%
separated markets	20.50%	25.19%	49.86%	4.45%
partially separated markets-IM	14.87%	37.84%	42.70%	4.60%
partially separated markets-DF	26.61%	18.55%	39.17%	15.67%

Figure 22:Average value of the default fund contributions of the clearing members

So from a liquidity point of view, the merged setup is the best for the clearing members, but for the CCP, the separated solution would be the best. Since from the viewpoint of the CCP, the absolute total value of the whole guarantee system is important, the higher it is, the more liquidity it will take away from the market, but it provides a more secure operation of the CCP and liquidity for it in case of default(s). Table 8 contains the average, minimum and maximum value of the total default waterfall (initial margin, default fund, and SITG). In all cases, the fully separated market offers the highest default waterfall value, the partially separated is the second, and the merged market offers the lowest value. It depends on the goal of the CCP, which suits better for it, whether the security is the most important, or the issue of liquidity of market participants.

Exhaust three layers of the default waterfall*	**merged markets**	**separated markets**	**partially separated markets - IM**	**partially separated markets - DF**
Average	55,827	62,192	58,010	58,293
Minimum	123	168	168	123
Maximum	1,308,494	1,574,901	1,564,149	1,309,106
Exhaust the total waterfall*	**merged markets**	**separated markets**	**partially separated markets - IM**	**partially separated markets - DF**
Average	39,371	50,000	39,153	41,808
Minimum	123	168	168	123
Maximum	1,308,494	1,574,901	1,564,149	1,309,106

Table 8: Total size of the default waterfall

**The initial securities values were $ 1,000 and $ 1,000 for stock and currency before the 7,500 days, while the price change on the 7501st day is -30% for both of the underlying assets*

Regarding how sensitive the SITG is to the price changes of the traded assets prices, I summarize the simulation results for the 49 cases (7x7 price change combinations for the stock and currency in the price range of +/-30%) in Figure 24. It can be seen how the SITG ratio within the total value of the default waterfall changes if the CCP exhausts the first three levels of the default waterfall or if it exhausts all of its levels.

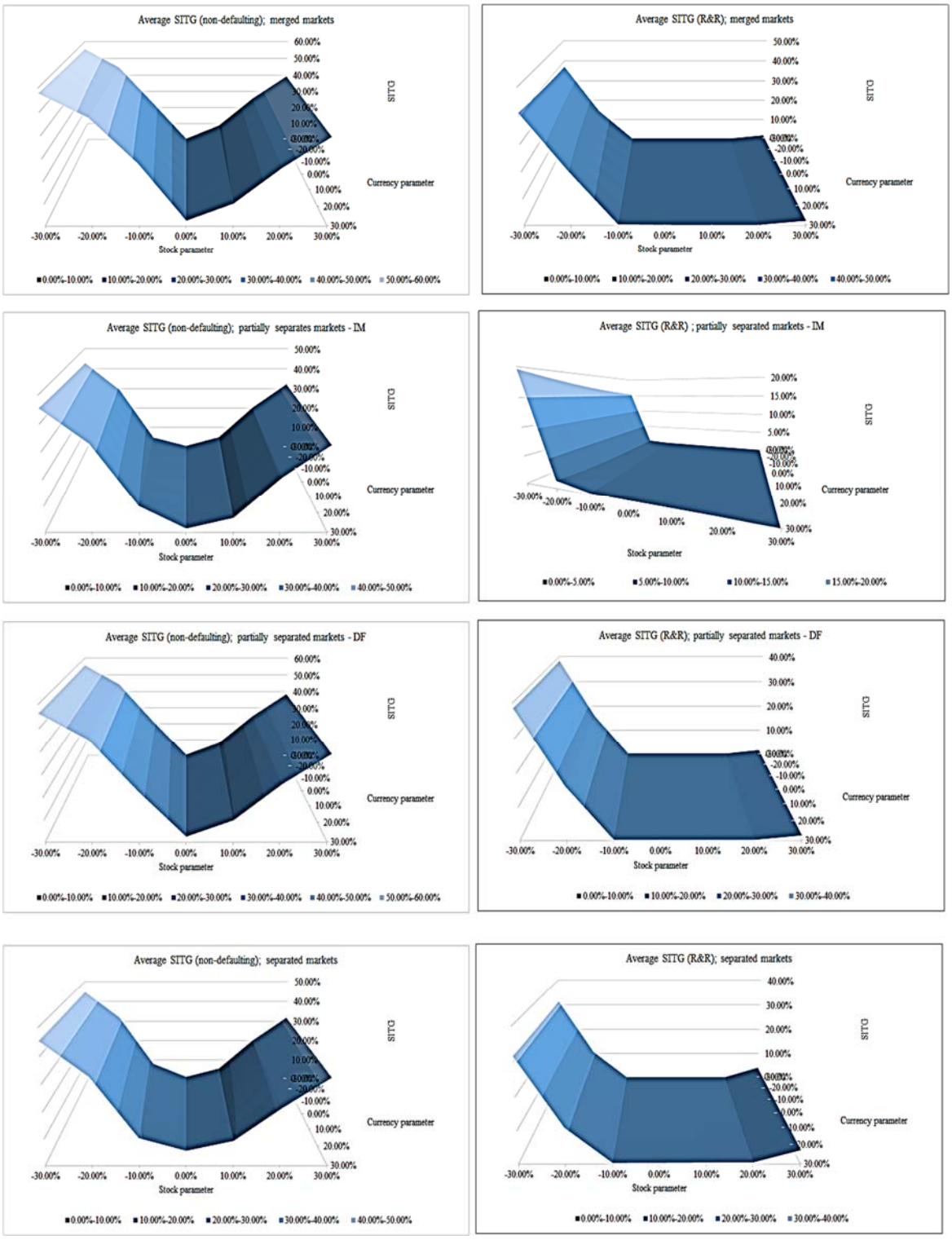


Figure 23:Summary of SITG amount, including the stress of the assets

H2: The clearing of several markets by a merged guarantee fund affects the structure and size of the guarantee system.

The difference between the operations is remarkable. It can be stated that merging the default waterfalls has its effects and the structure and the size depend on it.

6.5. Defining the risk profile of the CCP

As seen in the literature, it is an important aspect of what shareholders expect from the CCP. The models presented are a simplified reality of a general CCP and its activity with the potential types of clearing members. Apart from the ownership structure, the operation can, too, send a message to the market. The handling of markets separately gives the CCP additional security by asking for more substantial collateral, which is optimal from a pure risk management perspective of the CCP. Moreover, the own contribution, as SITG, could be lower than in the merged case.

Nevertheless, it has its shortcomings as well. First, the risk of liquidity „pile-up" at the CCP can affect traders negatively, and it can cause a shortage in the market. Second, in practice, brokers can ask for a security margin with a multiplier of the CCP's requirement, and thus burdening the participants. Finally, from the trader's point of view, this operation is favorable if it is active only on one of the cleared markets, therefore not missing the benefit of hedging.

However, cross-mutualization is lower, so members active in one market will not be affected by the default from the other market. On the other hand, risk-taking members must have the proper collateral to sustain their trading behavior. Overall, the separated setup requires more collateral compared to the merged setup on the clearing member level. From a SITG perspective, the partially separated setup is the best, benefiting the other two. The margin requirement is the same as in the case of the separated, covering the arising losses. The contribution will be lower than merged markets with a common default fund, resulting in lower SITG needs. So the margin requirements are higher, the risk-mutualization appears at the default fund level, where members can enjoy the advantages of hedging.

Table 9 compares the four different market settings by ordering them on a 1-4 scale (1 is the worst, 4 is the best). These values are summed up in Table 9, showing which method can be the most optimal to use.

Characteristics	Merged markets	Separated markets	Partially separated markets - IM	Partially separated markets - DF
CCP's perspective				
High amount of initial margin	1	2	2	1
SITG amount	2	3	4	1
Protection	1	4	3	2
Clearing members' perspective				
Lower level of guarantees	4	1	3	2
Risk-mutualization	4	1	3	2
Hedging benefits	4	1	3	2
Total score	**16**	**12**	**18**	**10**

Table 9: Order of the four methods

Results show that the most favorable set up for both parties is the partially separated markets – IM, meaning that while the CCP has higher IMs, so from a safety perspective is advantageous. Clearing members can enjoy the benefits of hedging on a DF level.

Suppose the ownership structure follows the historical setup, where clearing members are also the owners of the clearinghouse. The risk-taking member benefits from the cross-guarantee phenomenon but burdens the other traders. Such a massive difference between the risk-taking willingness among members would shift the incentives: the more minor risk-taking parties' membership will become too costly, and funding would originate from its own members, so the dependence between them would increase. The model of this analysis shows that the concentration is a potential threat because the defaulting clearing member's contribution to the fund can be enormous, even about on average 45% in this model setting, according to Figures 19 and 20. This means that this particular member may have opposed purposes with the other members regarding the contribution and may encourage sloppy risk management practices or even enforce its will on the other members. This

could result in a power imbalance among members, the risk-averse ones can be burdened with higher financial requirements, although their trading activity is significantly less risky, as ultimately, the responsibility of losses resulting from default is split between them. It is important to note that the heightened concentration is on one side due to the small number of clearing members. However, if one or more members are causing increased concentration in real life, it is recommended to be handled, especially if the CCP is user-owned.

A for-profit CCP profile in this model should address the issue of concentration. A wide-ranged type of clearing member immersion must be managed, especially the ones taking excessive risks. Because maximizing profit is the main goal in this risk profile, a robust margining methodology and default fund calculation methodology is a must. In the for-profit CCP world, the profit originated from trading; therefore, the goal is to increase the market's turnover and have as many clearing members as possible. This requires the market to be liquid and fast-flowing, avoiding the liquidity being tied up in collaterals. Respectively, they would prefer to push down the margin and default fund because they can be cheaper than other CCPs, and thus, they are in a better competitive position. If the default funds are managed separately, the CCP will have more collateral to use in default events, but it will be a burden for members, primarily if they trade on both markets. The merged market design, in this case, gives expanded risk for the CCP, so the incentives of the CCP will be to set an even more stringent margin methodology compared to the separated calibration in order to avoid the exhaustion of the SITG. This will also increase participants' burden, motivating them to trade outside the cleared market. An extreme risk-taker can create the illusion of hedged positions with cleared and non-cleared trades.

H3: In the merged clearing of spot and derivative markets, a CCP needs a higher skin-in-the-game amount to remain liquid, avoiding implementing recovery and resolution plans.

The merged market is the most unfavorable from a CCP's perspective, and more SITG is needed to cover the losses. However, as Murphy (2020), EACH (2021), Linsey (2020) mentioned, the SITG's primary purpose is not loss-absorption.

6.6. Conclusion of model II.

The proposed model shows how the CCP's own contribution in the default waterfall is affected in different market structures. It is an important question since this own contribution is being financed from the capital of the CCP. So the larger this contribution is, the larger the stake of the CCPs' capital is risked. The merged market scenario is risky for the CCP since it offers the lowest value for the overall default waterfall, and also, the CCP has to provide the largest SITG value compared to the fully or partially separated structures. This setup is favorable for some members engaging in risky trading and also affects clearing members' liquidity the least. In the long run, the CCP would need a tremendous amount of capital to support the system, mainly if it aims to protect non-defaulting members. Overall, this setup would not increase the resilience of the CCP. However, to avoid resolution, the CCP relies on the fund provided by the non-defaulting members. Due to the heightened level of loss-mutualization, this setup is disadvantageous for members active only on one of the cleared markets.

In contrast, the separated design gives an advantage to the CCP from this perspective, it can be stated that it is more resilient, but ultimately it can phase out more minor participants from the market because the clearing activity can become too costly. The partially separated on IM level was proven to be the most suitable for all stakeholders. It brings the benefits of a higher margin requirement and smaller SITG for the CCP, but members can profit from hedging and risk-mutualization on a default fund level, ultimately, this being the best compromise between parties.

Although the model is a simplified reality, this has its limitations, too. First of all, on an actual market, the positions are not predefined. In this model, there are preset for every clearing member, so the reality is slightly different.

The connection between the parties can also be much more complicated and based on their positions, and the interconnectedness can increase. The model cannot handle this. It is important to note that the presented model has the limitation that the resulting SITG value is compared only to the total value of the default waterfall and not to the own capital of the CCP; however, e.g., the EMIR regulation defines its value in the ratio of the own capital. Further research could analyze actual data of a specific market to compare how the ratio of the SITG within the default waterfall and the ratio of the SITG to the own capital relate to each other. It could answer if the 25% of the EMIR regulation is enough or a smaller/larger proportion would be adequate. Meanwhile, it could confirm the current SITG's level is satisfactory or encourage the system to heighten the ratio where currently represents a more humble proportion of the system, i.e., in the US.

6.7. Possible policy recommendations

The operations presented in the models prove that the management of the default waterfall is indispensable. The actual resistance of the CCP will show in stressed conditions, so when defining the setup, the proper scenarios to be defined are a must. From a policy perspective, I recommend that policy-makers consider a framework that regulates the handling of guarantee systems, allowing the different setups according to the local market types. If one of the markets cleared by the CCP is more pronounced, this should be considered, as clearing members that trade on only one market will benefit from a segregated guarantee fund, as cross-guarantee may be to their disadvantage. The CCP will also have a higher level of collateral. Clearing members active on more markets can take advantage of the hedging benefits, as results show partially separated on margin level setup being the best for every market participant. In my opinion, a fully merged setup, although it may be charming for clearing members, it is the riskiest among all: it can take liquidity away if the contributions are too high, or the CCP will not fulfill its role and fail due to intense market movements. Therefore, the regulatory framework shall be strict and limit the merging of markets. Under limitations, I understand that not all products can be hedged. For instance, commodity and exchange markets shall not be merged since there is no hedging possibility on a product level, commodity markets can be more volatile, and the risk levels may differ.

Nonetheless, a CCP's long-term viability can be assured if the risk profile is defined and the incentives of the CCP and clearing members can be aligned. In the long term, it is advised for policy-makers to set up rules for the possibility of handling the guarantee systems as presented in the current thesis. The framework for the proposed operation can differ between markets, so not every environment is compatible with it. The hedging principles must be fine-tuned accordingly. (i.e., limited to product lines).

VII. Conclusions

In my thesis, I highlighted the importance of central clearing and the path this field has reached since the global financial crisis of 2007-2009. This research area is a young one. As shown, there were only a few articles and studies regarding central clearing and the importance of the CCP on the market before 2007. As a first step, I explained the difference between CCPS and clearinghouses, namely that they have the same goal, while a significant difference appears on an operational level. To understand the importance of the topic, I dedicated a large space to analyze the history of central clearing and the regulatory framework that shapes the daily operation for CCPs.

In Chapter I. I presented the evolution of central clearing, beginning from the manual check clearing processes to the automated systems. This is followed by the presentation of how CCPs reduce exposure and manage counterparty risks. CCP clearing concentrates on trade management, position management, collateral and risk management, and delivery management. There are two forms of CCP inclusions: first, the CCP becomes the original buyer and seller's counterparty. Second, the CCP is a facilitator, in which case the original buyer and seller remain legal counterparties to each other. The CCP will validate and match the delivery instructions, the result of which is forwarded to settlement. The clearing is performed first by the CCP, then the CSD's turn is to perform the settlement. The process when the CCP imposes itself a "central" party between traders and, therefore, "becoming a buyer to the seller, and a seller to the buyer" is called novation. The CCP will provide insurance against the bilateral default risk for the two parties. They are no longer exposed to each other but only to the CCP. First, the CCP takes market participants' trading exposures onto its balance sheet, relieving multilateral risk exposures' counterparties. This action reduces counterparty risks among market participants, and multilateral netting gives further benefits to the members.

The most important message of this chapter is the lessons learned from the past events, where CCPs failed or almost failed to perform their activity,

given the heightened volatility on the markets, lax risk management, and the lack of transparency and cooperation from clearing members.

The second chapter emphasized how banks and CCPs differ since it is a common mistake to view CCPs as banks. Their risk profiles, operation, and function differ, so it was important to show that CCPs act *as risk managers* – therefore subject to credit and liquidity risk of clearing members default - *while banks are risk-takers*.

Regulators have implemented several frameworks since CCPs became the center of attention, so in the third chapter, I summarize the regulatory framework for the EU and the USA, capturing the milestones both had on an international level. In sum, no matter which markets a trader chooses, CCPs and clearinghouses are designed to ensure that they will break contagion among their members and mitigate systemic risk across markets and economies. The two frameworks mutually accept non-local CCPs under their supervision with the condition to have an as prudent and robust applied operation as the local one. The EU had more challenges to take during the stabilization of the regulatory background. Since the United States system is more or less homogeneous and uniform, the EU had to deal with the very different interests of the 28 Member States. Researchers point out that due to this diversity, the EU experienced a slowing down in the legislative processes, and it also made the outcome more fragmented. Since in this thesis I use the conditions set by EMIR, I analyze it thoroughly.

The fourth chapter contains the presentation of the default waterfall by showing how the implementation of the regulations for CCPs works. I present the main findings by researchers and professionals related to the default waterfall resources by focusing on the general elements: the different margin requirements, procyclicality issues, the CCP's capital - the skin-in-the-game, and the default fund related contributions. Since the resilience of the CCP is tested during extreme stress, I analyzed the literature from this perspective as well: researchers have defined stress and systemic stress in several ways. Systemic stress is a set of circumstances that leads to the failure of a significant part of the financial sector, resulting in a reduction of credit

availability that can affect the real economy adversely. The subchapters contain the most important finding by researchers, who point out the potential weaknesses of the regulation or draw attention and endorse the CCP's advantages. Moving forward, I presented the EU-wide CCP and DFA latest stress test, both showing the systems' resilience. They even cover the effects of Covid19, so overall, according to the results. The chapter also contains the opinions of researchers and experts regarding the SITG. CCP experts show their dissenting opinion to the regulator regarding the amount of the SITG. CME highlights that "*Skin in the game doesn't protect end client*." The high skin-in-the-game can encourage moral hazard among clearing members if the CCPs contribute more substantial financial resources. The overall conclusion is that by defining the risk profile of a CCP, incentives of stakeholders and the market participants shall be aligned to avoid tension between the CCP and its clearing members.

The fifth chapter aimed to show what possibilities does a CCP has if the default waterfall is proven to be inadequate to cover the losses of one or multiple members. The fail of a CCP would imply that procedures, risk management policies, and safeguard tools, were not prudent enough, or at least they have failed to fulfill their loss-absorbing objective. The regulators endeavor to establish the interaction between CCPs and the whole financial system as stable as possible. The steps taken are vital in every area, and the progress since the financial crisis of 2007–09 is remarkable from the evolution of the central clearing activity point of view.

In my research, I focused on how the CCP survives extreme market distress if it operates its default waterfall in different ways and how sensitive the SITG is if the default waterfall is managed differently. The main concern of stakeholders is to balance between liquidity risk and systematic risk. Namely, minimizing liquidity taken away from the clearing members by decreasing the level of the required collateral while maximizing the loss-absorption effect of the default waterfall by increasing the available collaterals' level to decrease systemic risk. In this thesis, I present the risk mitigation effects if the CCP can choose the structure of the default waterfall from the viewpoint

of mutualizing risk between different markets and market segments by handling the default fund in four different ways. The research points out how the handling of the markets can change the requirements of the CCP from its members and how sensitive the value of SITG is if the CCP aims to avoid the exhaustion of non-defaulted members and, ultimately, the implementation of the recovery plan.

To analyze the cross-guarantee phenomenon, we choose two markets with my co-authors: the spot market for securities and the derivative market for these securities. It is vital to select two markets that have a connection with each other because we want to show how the risk mitigation of the hedged positions between the spot and derivative assets changes the riskiness of the positions of the clearing members, and through this, the guarantees the clearing members have to pay after their positions. Our model has one CCP, four different clearing members, three different financial assets: a stock, a bond, and a currency. The stock can be traded on the options, futures, and spot markets, while the bond can be traded only on the futures and spot markets, and the currency can be traded only on the options and futures markets. We had to assume the financial assets' price evolution since we need a time series for initial margin calculation and estimating the default fund.

Introducing the model representing a simplified reality captures the calibration effects of the stress tests, and the results are analyzed accordingly. The hypothesis I raised are the following:

H1: Cross-financing takes place in the merged setup of spot and derivative markets.

As a general conclusion based on the results is that in the separated case, the overall guarantees that are available in the guarantee system are higher; however, the value of the default fund is always larger in the merged case, so the cross-guarantee between the clearing members and markets are more notable.

H2: The clearing of several markets by a merged guarantee fund affects the structure and size of the guarantee system.

In order to increase efficiency and to analyze and align the incentives of the CCP and its clearing members, I decided to use the model presented above to shows how the CCP's own contribution in the default waterfall is affected in different market structures. The model needed to be simplified to perform a sensitivity test on the SITG. Using the same model and pricing principles, the following assumptions and methods were applied: the economy still has two hypothetical markets cleared by one CCP, one of the markets is a spot market with one single stock, the other market is a derivative market, on which the market participants can trade with options and futures contracts. In this scenario, the number of assets was reduced to stock and currency. The underlying asset can be the stock traded on the spot market, and it can be a currency as well, not traded on the spot market. The clearing members can still mitigate their risk and benefit from the hedged positions between the spot and derivative markets. The number of clearing members remains four. The positions of the members are pre-defined to see how the contributions behave.

Both models showed how the guarantee system's size and structure change if a CCP applies it merged or separately for different markets. From the clearing members' perspective, this result makes the merged markets more favorable, since in this case, the trading is cheaper for them because less collateral is required to be posted. A CCP's resilience, in this case, may decline since less collateral is available for loss-absorption.

H3: In the merged clearing of spot and derivative markets, a CCP needs a higher skin-in-the-game amount to remain liquid, avoiding implementing recovery and resolution plans.

The merged market operation requires higher SITG from the CCP, so in the long term, a series of defaults can shake the system's stability since the resources of the CCP are finite. The separated setup can shake the stability from a CM side since if there is a high level of liquidity tied up at the CCP, members will run out of resources, and the stress will be triggered from this side. The initial margin being the first layer of defense, it is strongly recommended not to merge the contributions on this level. This explains why partially separated – DF setup is a disadvantageous setup: it requires more

SITG since the margins run out faster and the DF contributions are lower. The default fund level merged setup, where the margins are calculated separately, benefits both parties: while it motivates the CCP for solid risk management, it does not burden parties from a total contribution perspective. The CCP can include less SITG, therefore in the long term, a series of defaults will not exhaust the CCP's resources at a high pace.

Although the models are a simplified reality, they have their disadvantages. First of all, on an actual market, the positions are not predefined. In this model, there are preset for every clearing member, so the reality is slightly different. The connection between the parties can also be much more complicated and based on their positions, and the interconnectedness can increase. The model cannot handle this. It is important to note that the presented model has the limitation that the resulting SITG value is compared only to the total value of the default waterfall and not to the own capital of the CCP; however, e.g., the EMIR regulation defines its value in the ratio of the own capital. Further research could analyze actual data of a specific market to compare how the ratio of the SITG within the default waterfall and the ratio of the SITG to the own capital relate to each other. It could answer if the 25% of the EMIR regulation is enough or a smaller/larger proportion would be adequate. Meanwhile, it could confirm the current SITG's level as satisfactory or encourage the system to heighten the ratio where currently represents a more humble proportion of the system, i.e., in the US.

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