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Your skin or mine: Ensuring the viability of a central counterparty

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ABSTRACT

Through their clearing and settlement activity, central counterparties (CCP) ensure the stability of the financial system. They operate a multilevel guarantee system containing the initial margin requirements, the default fund contributions, and their own contribution, referred to as skin-in-the-game (SITG). Using a Monte-Carlo simulation method-based framework, the study examines how the value of SITG changes in different guarantee system settings, specifically through the implementation of a merged, separated, or partially separated guarantee system for interconnected markets. The primary objective is to quantify the minimum amount of SITG necessary for a CCP to protect non-defaulting members or to prevent the execution of the CCP's recovery and resolution plan. The findings indicate that a partially separated guarantee system is the most beneficial option for most stakeholders.

1. Introduction

In response to the Global Financial Crisis (GFC) of 2007–2009 and to the default of Lehman Brothers in 2008, regulators implemented mandatory central clearing for several classes of over-the-counter (OTC) derivative transactions. This was done as a result of the demonstrated effectiveness of central clearing during the GFC (Huang and Takáts, 2020a; Gregory, 2014; Fleming and Sarkar, 2014). At the London Summit in April 2009, the G20 leaders decided to shape the regulatory background to increase the financial system's resilience (G20 London Summit, 2009), later that year in September during the Pittsburgh Summit, the decision was made that all standardized OTC derivatives need to be cleared through central counterparties (G20 Pittsburgh Summit, 2009). As a result of this agreement, the Dodd-Frank Wall Street Reform and Consumer Protection Act (DFA) was enacted in July 2010 in the USA (DFA, 2010), while in July 2012, the European Market Infrastructure Regulation (EMIR) in the European Union (EU) (EMIR, 2012). In consequence, the centrally cleared traded volumes on the derivatives markets have increased (Gregory, 2014). For instance, from 2011 to 2017, the proportion of credit default swaps (CDS) that were cleared through CCPs increased from 17% to 55% according to Tywoniuk (2020). Additionally, Aramonte and Huang (2019) noted that in 2009, only one-third of interest rate derivatives and one-tenth of CDS swaps were cleared centrally. However, by 2019, these figures had risen to four-fifths and one-half, respectively.

CCPs have become the "backbone" of the financial system by mitigating the counterparty risk of market participants through the process called novation. Novation is the term used to describe the procedure where the CCP intervenes between buyers and sellers, effectively "replacing" the original counterparty with itself as the buyer to the seller and the seller to the buyer (BIS, 2004). The novation ensures that if one of the parties defaults, the CCP will fulfill the transaction for the non-defaulting party. Besides managing counterparty risk, CCPs enhance transparency and increase legal and operational efficiency (Gregory, 2014). Despite the benefits of

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CCPs, scholars have emphasized the potential risks (e.g., Lewis and Murphy, 2022) and drawbacks (such as Gregory, 2014, Ferrarini and Saguato, 2013, Saguato, 2020) associated with the centralization process, most importantly emphasizing the CCPs' role in increasing systemic risk. CCPs escalate the systemic risk due to notable (1) concentration (Markose et al., 2017; Duffie, 2015; Huang and Takáts, 2020a, 2020b); (2) increased funding and market liquidity risk; (3) transmission of stress; (4) risk-shifting; (5) wrong-time risk; (6) issues related to information and incentives (Cerezetti et al., 2018; Saguato, 2022). A potential default of the CCP itself has a powerfully negative effect on the whole economy (Duffie, 2015; Duffie and Zhu, 2011). CCPs are becoming not just too-big-to-fail but too-interconnected-to-fail as well (Markose et al., 2012, 2017).

Although there is a stringent regulatory framework in place, CCPs have the flexibility to customize their operation according to their unique risk profile and the specific characteristics of the market(s) they serve. This can affect the interests of stakeholders – clearing members, regulators, owners, and management – and also the cost of clearing, which might influence the trading activities, and the decisions made by the clearing members (McPartland & Lewis, 2017). Demanding excessive collateral requirements may disadvantage the CCP by making members reduce their exposure to the CCP to avoid mandatory clearing obligations, changing market behavior significantly (Baker, 2021). A poor decision of the CCP or the implementation of an inappropriate guarantee system structure, as a modeling risk (Lamanda and Vőneki, 2020) can have severe consequences, such as altering loss allocation between clearing members or transmitting stress in the event of distress. Hence, the clearing activity and the conditions set by the CCP have a significant impact on the balance of positive and negative systemic externalities (Lewis and Murphy, 2022), which ultimately determine the achievement of the primary goal of the regulators, namely to maintain the stability of the financial system (Cerezetti et al., 2018).

The guarantee system operated by the CCPs is comprised of multiple levels, which aims to manage counterparty risk. The default waterfall is the pre-defined order in which these various levels of the guarantee system are utilized. The default waterfall consists of funds provided by clearing members, such as the initial margin requirements (IM), and the default fund contributions (DF); as well as a certain ratio of the CCP's own capital, known as the skin-in-the-game (SITG) (EMIR, 2012, Article 45).

This paper introduces a model based on Monte-Carlo simulation that analyzes the structure of different guarantee system setups and gives special attention to the amount of capital – the skin-in-the-game – a CCP has to risk when providing clearing and settlement services. The more significant stake of the capital should be risked in a certain guarantee system setup, the less optimal it is ceteris paribus since it can decrease the resilience of the CCP. The analysis will be based on four guarantee system operation types, on two different markets, which are interconnected through no-arbitrage pricing, meaning that the financial assets traded on both markets are linked through their pricing. In the four setups the CCP can operate either (1) a merged, (2) a partially separated on the initial margin level, (3) a partially separated on the default fund level, or (4) a fully separated guarantee system on the two interconnected markets. The main goal of this paper is to define the minimum required SITG size that is needed to ensure the viability of the CCP. More precisely, the paper will analyze how the own contribution of the CCP to loss mutualization is affected by considering four different guarantee system operations. The answer to this question is not straightforward because of three reasons. Primarily, the size of the guarantee system might not be a linear function of the risks it is designed to manage, e.g. for example because of the application of procyclicality buffers (RTS, 2013, Chapter VI. Article 28.); or if a CCP applies non-coherent risk measures, like the Value-at-Risk (Acerbi, 2007; Artzner et al., 1999). Secondly, there is a trade-off between the value of the initial margin requirements and the default fund contribution (King et al., 2022). Namely, if ceteris paribus the initial margin decreases, the default fund needs to be increased. The effect of this change on the skin-in-the-game is not obvious, since the decrease in the initial margin level might not be offset – in absolute terms – by the default fund value increase, so this might affect the minimum required amount of SITG as well (Murphy, 2017). Thirdly, by merging markets, clearing members will be able to take advantage of their hedged positions. For instance, consider two financial assets that are traded on two different markets that are interconnected through no-arbitrage pricing – such as a derivative asset and its underlying. If guarantee systems are fully separated, the clearing member will not be able to take advantage of the reduced risk by hedging in terms of lower guarantee payments. In this case, both financial assets will be valued on a stand-alone basis, so the member has to pay guarantees based on the risk associated with each of the assets separately. However, if the guarantee systems are merged, the risk reduction effect of the hedged position will be taken into account, resulting in lower guarantees. Determining how these three phenomena impact the size of the SITG is a complex matter, as several factors come into play, such as the properties of cleared products, clearing members' positions, the risk management models, or the price evolution of financial assets.

This paper will apply the EMIR regulation and its corresponding requirements. Under the EMIR regulation, the main objective of the SITG is to provide the owners of a CCP with an incentive to manage risk prudently, such as by setting appropriate initial margins and default fund contributions. This alignment of incentives is supposed to mitigate the risk of moral hazard (Rec, 2019a, 2019b; Saguato, 2022). The owner's perspective emphasizes the significance of determining the minimum required size of the SITG to avoid implementing the recovery and resolution plan. This implies identifying the SITG value that ensures the guarantee system has enough available collaterals. This question is crucial not only from the viewpoint of the owners but also from the perspective of the regulators, since the more vulnerable a CCP is, the larger the systemic risk is. For managers in public and private CCPs and regulators of CCPs, this model and results help in decision-making when formulating a guarantee system or reviewing an existing one. Besides them, the skin-in-the-game is important from the clearing members' point of view, as they must understand the guarantee system's dynamics, the trade-off between the initial margin, the default fund and the skin-in-the-game, and the cross-guarantee and risk-sharing feature of the default fund (Friesz et al., 2021). The members must assess the guarantee system's vulnerability and determine the threshold at which the SITG is insufficient – besides the defaulting clearing members' collaterals –, and the CCP starts to cover losses from the non-defaulting clearing members' default fund contributions. Based on all of the stakeholders' interests, this paper will analyze the minimum required SITG from two viewpoints: how large the SITG should be at least to (1) to protect the non-defaulting members, and (2) to prevent the recovery and ultimately, the resolution process.

For scholars, this study contributes to the existing literature by modeling the whole guarantee system and its dynamics in different settings, namely if the CCP operates a separated, a partially separated, or a merged guarantee system. To the author's best knowledge, no one has analyzed this effect before.

The structure of the paper will be the following: Chapter 2 will present the literature review, with a specific focus on the default waterfall elements. In Chapter 3, the applied model will be explained, while Chapter 4 will demonstrate the results. Finally, Chapter 5 will provide a discussion, and Chapter 6 contains the conclusion on which setup is most advantageous or most disadvantageous for each market participant, depending on their risk profile.

2. Literature review

Berndsen (2021) provides an extensive overview of the CCP-related literature up to 2020, categorizing the research questions into five groups. This paper focused on the third group, analyzing the adequacy of the prefunded waterfall size. Under a prefunded default waterfall, we mean those funds that are directly available for a CCP to cover default losses. Berndsen (2021) highlights that the sufficiency of the default waterfall size is very CCP-specific, and it cannot be answered analytically, the research results cannot be generalized. Murphy and Nahai-Williamson (2014) gives a notable contribution to this field, using a simulation approach for analyzing the adequacy of the cover 2 rule – meaning that the prefunded resources should be sufficiently large to cover the possible losses of the two clearing members that have the largest exposure towards the CCP. Based on their research, this paper applies a simulation method for the analysis instead of using empirical data, in order to get a more generalized result in the framework of the EMIR regulation. Further research that focus on the default management procedures and the adequacy of the prefunded resources are e.g., Fenn and Kupiec (1993), Chamorro-Courtland (2010), McLaughlin and Berndsen (2021), Murphy (2017), Capponi et al. (2018) or Poce et al. (2018), McLaughlin (2018). Vicente et al. (2015) influenced the research question formulation of this paper by applying a multi-asset class framework, considering the possible hedging opportunities between the asset classes. In addition, Goldman and Shen (2020) and Raykov (2018) pointed out the importance of considering the effect of the initial margin on the value of the default fund. The model of this paper builds heavily on the of model Friesz et al. (2021), who analyzed the cross-guarantee phenomenon and the risk mutualization. This paper extends that work by taking into account, and focusing on the analysis of the SITG. The research question will be unique compared to the previous work in the sense that it does not examine the sufficiency of the cover 2 rule, instead the size of the SITG in different market structures.

2.1. *The default waterfall – the initial margin and the default fund*

The role of the default waterfall is to define the amount of collaterals that the clearing members and the CCP itself should provide to prepare the CCP to withstand extreme, but plausible market conditions by complying with the cover 2 rule. As a result, every stakeholder expects robustness and safeguard from the CCP because either they have capital included in the system, or because they want to ensure the stability of the CCP and the financial system. A general default waterfall of a CCP follows the exhaustion of resources, as shown in Fig. 1 (EMIR, 2012, Article 45 and Article 9(14) of CCPRRR, 2021).

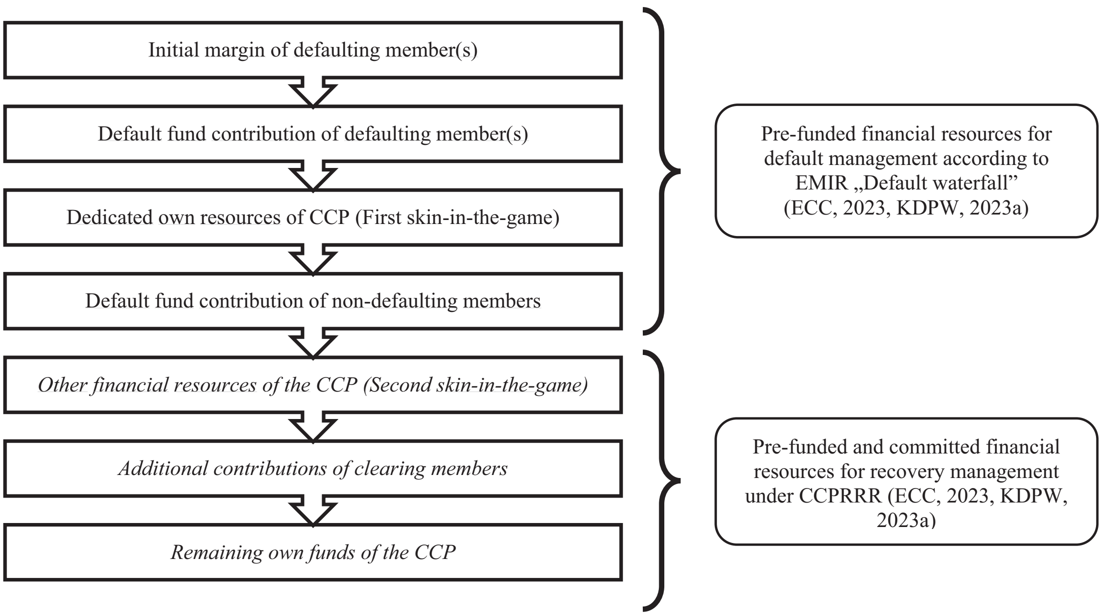


Fig. 1. The total waterfall is split up into two main parts, the first four levels are the default waterfall regulated by the EMIR, while the second three levels are based on the CCPRRR and belongs to the recovery and resolution of the CCP. This paper focuses on the first four layers (ECC, 2023; KDPW, 2023).

Fig. 1 shows the order in which the default waterfall elements are applied when one or more clearing members default. The first one is the initial margin, serving as the primary line of defense. It shall cover losses in normal market conditions. The initial margin value is based on risk measures like the Value-at-Risk (VaR) or the Expected Shortfall (ES) at a given significance level and liquidation period. In the EMIR framework for example, the CCP should apply a 99% significance level and a 2-day liquidation period regarding exchange-traded products (EMIR, 2012, Article 41, RTS, 2013, Chapter VI). The initial margins paid by the non-defaulting members cannot be utilized to cover losses resulting from the defaulting clearing members. In the available literature, the value of the initial margin from several aspects has been investigated, e.g., focusing on liquidity (e.g., Brunnermeier and Pedersen, 2009; Heller and Vause, 2012); procyclicality (e.g., Murphy et al., 2014, 2016; Berlinger et al., 2019a, 2019b; Szabó and Váradi, 2022) or how liquidity risk can transform into systemic risk (e.g., Valderrama, 2015). This paper focuses on losses stemming from default events (e.g., Murphy, 2017, Friesz et al., 2021). However, it is important to note, that in reality, non-default-related losses may also occur. The default waterfall elements do not aim to cover these losses (ISDA, 2020), and therefore, this study excludes non-default-related events or losses.

In case the first layer is deemed insufficient, the CCP should apply the second layer, which involves the default fund – or guarantee fund – contribution of the defaulting member (EMIR, 2012, Article 42, RTS, 2013, Chapter VII). In comparison to the initial margin, the default fund is designed to cover losses in extreme, but plausible market conditions based on the max(1;2 + 3) rule. This implies that the CCP should be able to withstand the default of the clearing member with the highest exposures or the combined exposures of the second and third largest members if their exposures are greater (EMIR, 2012, Article 42(3)). Another significant distinction is the cross-guarantee feature of the default fund, which implies that losses are shared among clearing members since the non-defaulting member's default fund contribution can be used to offset the losses of the defaulting members. The final difference is that the CCP itself can have a stake in the default fund (e.g. in the practice of KELER CCP, 2023a).

The overall size of the default fund is determined through stress tests, while the contribution of each clearing member is typically determined proportionally based on their exposure to the CCP (EMIR, 2012, Article 42, RTS, 2013, Chapter VII). Comparing stress tests to the VaR or ES estimation applied to calculate the initial margin, is that it has the advantage to give information on extreme events. However the shortcoming is, that the stress test cannot associate probability to the events unlike the VaR and ES (ECB, 2009).

It is important to emphasize that only the defaulting members' default fund contribution can cover losses in the second layer. Non-defaulting members' default fund contributions may be exhausted, but the third layer will be used before this occurs.

2.2. The default waterfall – the skin-in-the-game

The third layer, the skin-in-the-game, is the main focus of this paper. The SITG is a crucial part of the guarantee system, provided by the CCP itself. Taleb and Sandis (2014) argue that for a complex world to function effectively, it is essential to involve those in the tail risk events through the SITG who would both have the incentive and opportunity to hide risk. The SITG has been applied to ensure that the CCP maintains a robust management and demonstrates alignment between the CCP's and clearing members' interests (EACH, 2021; Cont, 2015), therefore loss-absorption is not its main purpose, compared to the initial margin and the default fund. The fundamental goal is to prevent the application of loose risk management practices of the CCP and to encourage CCPs to apply a calculation methodology that enhances the efficiency of the first two layers. According to the EMIR regulation, the SITG should be 25% of the CCP's capital (RTS, 2013, Chapter IX, Article 35(2)), so it is not linked to the value of the default waterfall, but the size of the CCP. According to McLaughlin (2018), it is arguable if 25% is sufficient, or whether it should be linked to the size of the CCP instead of the default fund. On a different note, Saguato (2022) argues that CCPs should have more skin-in-the-game. In practice, e.g., EU and UK CCPs' SITG accounts for only 0.15% of the average pre-funded waterfall (EACH, 2021). Based on the 2022Q4 Public Quantitative Disclosures (PQD) data for four EU CCPs, the SITG ratio in the default waterfall ranges between 0.04% – 3.3% (LCH, 2023; EUREX, 2023; KDPW, 2023b; KELER CCP, 2023b).[1 and 2] Besides, Clarus (2023) has shown in the case of ten selected CCPs around the world (e.g., CME Base, EUREX Clearing, OCC) that the ratio of the SITG is very small within the default waterfall, with similar values as the previously mentioned ones. These relatively small proportions among the other components indicate that in practice the SITG is not necessarily a „good" loss-absorbing tool for default (ESMA, 2020).

Although in the European legislation the SITG is linked to the size of the CCP, it hasn't been challenged either by a quantitative or qualitative analysis, since neither the European Securities and Market Authority (ESMA) nor the European Commission considered it necessary (EACH, 2021). In addition, ISDA (2021) has suggested that the SITG requirement should be scaled to the CCP's capital, in order to provide a better alignment of incentives and reduce systemic risk. Even though according to the regulators in the EU it is obvious not to apply the SITG as a loss absorption tool, it is not as obvious in other legislations, for example in Singapore, where the SITG is linked to the default fund size. Moreover, there are several places, where there is no minimum requirement set to the value of the SITG (e.g., Canada, USA, Australia, Hong Kong, Japan) (EACH, 2021).

It is being highlighted that in case the CCP decides to contribute a more substantial amount of resources to the default waterfall, it can encourage moral hazard among the clearing members (e.g., Saguato, 2022). On the other hand, a high SITG means an adequately capitalized CCP, which makes the CCP more resilient, giving higher certainty for surviving traders, and increases the probability of not having to exhaust non-defaulting member's collaterals in case of default(s) (CPMI-IOSCO, 2017). While CCPs prefer lower SITG to be introduced, clearing members face the opposite interests from a moral hazard and risk management perspective. If a CCP's capital

[1] The input data were the stock from the following codes: - 4.1.1 - Own funds; 4.3.15 - Total Pre funded resources, excluding IM and 6.1.1 - Total IM. The ratio was calculated as the following: SITG / (IM + DF + SITG). The four values were: 0.04% (LCH); 0.16% (EUREX); 0.68% (KDPW); 3.3% (KELER CCP).

contribution to the waterfall is too small, clearing members would perceive high risk in the clearing activity, so instead of joining the system, they would seek to engage in trades not subject to clearing (Murphy, 2017).

Since skin-in-the-game has an important role in fat tail events (Taleb and Sandis, 2014), it is hard to analyze its adequacy on real market data, especially in the case of CCPs, where the usage of the SITG, or even the default of a CCP (McLaughlin and Berndsen, 2021; Cox, 2015) is a rare event. Whether the SITG should be linked to the size of the CCP or to the size of the guarantee system – especially to the default fund – needs deeper analysis also from a theoretical, and empirical point of view, in order to have a prudent default waterfall. Moreover, even if the main goal is not the loss absorption it might be linked to the size of the CCP and also to the size of the default waterfall.

Finally, it is important to note that the ownership structure has an important role in defining the optimal size of the SITG, and the risk profile of a CCP. Among others, Huang (2019), McPartland & Lewis, 2017, Cerezetti et al. (2018), and Saguato (2017, 2022) analyze the effect of the ownership structure, and explain how each type – for-profit CCPs, government-owned CCPs, and user-owned CCPs – affects the risk profile of the CCP, the incentives of its clearing members, and also how their interests can be misaligned.

If the first four layers of the default waterfall is insufficient to cover the losses, additional layers can also be implemented. CCPs can include a second SITG introduced by the CCPRRR (2021) in the default waterfall after exhausting the non-defaulting members' contributions but before entering the recovery phase (McPartland & Lewis, 2017, FSB, 2017). This paper will only focus on the default waterfall that is regulated by the EMIR, analyzing the CCPRRR is beyond the main scope.

3. Method

It is crucial to set up a default waterfall that is suitable for the main stakeholders. The major concern these stakeholders have is the balancing between liquidity risk and systemic 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. The research points out how the handling of the default waterfalls can change the collateral requirements and shows the sensitity of the value of the SITG.

The article contains a Monte-Carlo simulation of the whole default waterfall with 1000 trajectories, including the size of the initial margin, the default fund and the SITG. Assumptions were implemented regarding the initial margin and default fund calculation methodology. The initial margin on the asset level was defined by the margin calculation methodology of Béli-Váradi (Béli and Váradi, 2017). On a portfolio level, the margining was based on the SPAN methodology (SPAN, 2019), taking into account only the risk array and the short option minimum (set to 10%) component of the SPAN model. According to the EMIR regulation, the default fund calculation was based on a stress test, which had historical and hypothetical scenarios (EMIR, 2012, Article 42). To carry out the simulation, the following assumptions and methods were applied: the economy has two hypothetical markets cleared by one CCP, one of the markets is a spot market with one single stock, and the other market is a derivative market, on which the market participants can trade with options and futures contracts, where the underlying asset is either the stock – traded on the spot market –, or a currency.[2] The clearing members can mitigate their risk by benefitting from the hedged positions between the spot and derivative markets. On the markets, there are four clearing members in order to have a non-defaulting member when calculating the default fund under the max (1;2 + 3) rule.

The price evolution of the stock and the currency was simulated for 7500 trading days in every trajectory since the stress testing methodology should cover a lookback period of thirty years, which is assumed to be 7500 trading days (RTS, 2013, Article 30). In the simulation, the daily logreturns of the stock and the currency follow arithmetic Brownian motion (ABM) (Merton, 1973) based on Eq. 1 where dY is the change in the logreturn during dt period, α is the expected value of the logreturn and σ is its standard deviation, while $N(0,1)$ is a standard normal random variable:

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

The yearly mean and standard deviation value of the stock were 7.71% and 22.37%, while 0.09% and 11.85% respectively for the currency from real historical daily logreturns. The values are based on the time series of the DAX index (30 years, between 1991–2021, finance.yahoo, 2021a) and the EUR/USD currency rates (all available historical data until 2021, finance.yahoo, 2021b). In order to be able to analyze how the default waterfall behaves in extreme market conditions, the simulated time series have been extended with shocks. The occurrence of the shock follows a Poisson process, while the magnitude of the shock followed lognormal distribution in the model, applying the parameters based on Table 1.

The long-term correlation between the DAX index and the EUR/USD currency was 0.098, so this value will represent the "normal" market condition in our simulation, when there are no shocks. However, when a shock occurs in either the stock or the currency time series, the correlation increases to 0.95, and then gradually decreases by 5% until it returns to 0.098 or until another shock occurs.

In order to be able to calculate the prices of the derivatives, the assumption was that the time to maturity is one year – the current day (t_0) is the 7500th day of the simulation –, the options are ATM, and the prices of the options were calculated based on the Black-Scholes model (Black and Scholes, 1973). For the pricing, the risk-free rate is needed as well, which is simulated with the Vasicek model (Vasicek, 1977) according to Eq. 2. The value of the applied parameters can be seen in Table 2.

[2] In practice (e.g. KELER CCP, 2023c) the spot market can be cleared as well, since the settlement of the transacion happen on a T + 2 days procedure.

Table 1
The parameters of the shocks. The parameters were calibrated to generate simulated time-series data that closely approximates real-world time-series data. The magnitude of shocks is influenced by the 'μ' parameter, with lower values resulting in smaller shocks. The 'σ' parameter impacts the frequency of the shocks, with a higher value indicating less frequent shocks. The 'ν' parameter determines the speed at which the shock decays, while the 'λ' parameter determines the timing of the shock. Given the higher standard deviation observed in the real historical time-series of the DAX index, we adjusted the calibration of the data to generate a simulated time-series that features larger shocks with greater magnitude for the stock.

Parameters of the shocks		
	Stock	Currency
μ	−11.00	−14.00
σ	2.25	3.25
ν	0.97	0.95
λ	0.005	0.0045

$$dy_t = a \bullet (b - y_t)dt + \sigma^* \sqrt{dt} \bullet N(0,1) \tag{2}$$

In the model, the initial margin and the default fund contributions were defined for each clearing member on their position on the 7500th day. The parameters of the initial margin calculation according to Béli and Váradi (2017) are summarized in Table 3.

For conducting the stress test to estimate the default fund, both historical and hypothetical scenarios were utilized. The historical scenarios involved the price changes on four days when the stock or the currency achieved the maximum or the minimum returns over the 7500-day simulation period. On the other hand, the hypothetical scenarios were based on the statistical data of the real historical time series of those financial assets, providing the foundation for the simulation. In Table 4 the scenarios can be seen in one of the trajectories.

The positions of the four members on the 7500th day – the positions on the previous days were not simulated, as those do not affect the default waterfall in this model setting on the 7500th day – are pre-defined. The positions were designed to examine the behavior of contributions when one member (clearing member 4) has positions only on the spot market while the other members have positions on both markets. One member (clearing member 3) faces high risk, due to unhedged positions such as short straddle positions. The remaining two members have both unhedged risks and positions that manage risk, like a protective put or a covered call. The positions were structured to result in an overall zero-net position on the market. The positions are as follows:

1. Clearing member 1:
   a. Stock: long straddle + short spot
   b. Currency: long straddle + short forward
2. Clearing member 2:
   a. Stock: protective put +2 long call +2 short spot
   b. Currency: long forward
3. Clearing member 3:
   a. Stock: covered call +2 short straddle
   b. Currency: short straddle + long forward
4. Clearing member 4:
   a. Stock: long stock

To sum up, by the end of the 7500th day the initial margin, the default fund, the prices of the assets and the positions of the clearing members are known. Since the primary objective of the model was to demonstrate the required skin-in-the-game size under the cover 2 rule, to protect non-defaulting members or prevent recovery and resolution in the event of a market shock, a shock hits the system on

Table 2
Parameters of the Vasicek model, 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.

Parameters of the Vasicek model	
a	5
b	3%
y0	5%
σ	8%

Table 3
The initial margin was calculated with a Value-at-Risk (VaR) model, based on the EMIR regulation, on a 99% significance level, and 2-day liquidation period. The lookback period for the VaR calculation was 250 days, namely 1 year, while the procyclicality buffer was 25%, also based on the EMIR. The application of the liquidity buffer, the expert buffer and the band is based on the method of Béli and Váradi (2017), and is set to 15%, 15%, and 25% respectively for both of the financial assets. The method is based on applying equally weighted standard deviation, and also EWMA weighted standard deviation, for which a tolerance level is given as 1%, based on the method. The initial price for the two assets has been set to 1000. The initial prices are not based on the real market price of the DAX index and the EUR/USD prices.

	Stock	Currency
Significance level	99%	99%
Liquidation period	2 days	2 days
Lookback period	250 days	250 days
Liquidity buffer	15%	15%
Expert buffer	15%	15%
Procyclicality buffer	25%	25%
EWMA parameter – tolerance level	1%	1%
band	25%	25%
Initial price	1000	1000

Table 4
The columns show the six scenarios, four of them are historical scenarios, and two of them are hypothetical. The historical scenarios based on the simulated data, namely the scenarios were defined based on the worst and best daily logreturn of the 7500-day. For example, in the case of the stock the worst day was the 108th simulated day, when the daily logreturn was −5.11%. On this same day the logreturn of the currency was 0.68%. In the case of the hypothetical scenarios the real stock and currency time series were the basis, namely the expected daily logreturn was modified with +/−3 standard deviations of the daily logreturn.

	Historical				Hypothetical	
Parameters	Min stock	Max stock	Min currency	Max currency	First	Second
Stock	−5.11%	5.95%	0.21%	−2.46%	4.28%	−4.21%
Currency	0.68%	−0.11%	−2.71%	2.66%	−2.25%	2.25%
Day	108	3702	4174	4930		

the 7501st day. According to Taleb and Sandis (2014), SITG plays a significant role in extreme tail events. Table 5 specifies that market shocks are characterized by extreme tail events. As per the table, the daily expected logreturns were adjusted by incorporating the standard deviation estimates obtained from the real-time series, using values of +/− 15, +/− 10, and +/− 5 standard deviations.

In total, the analysis takes into account 49 different scenarios based on a 7x7 combination of price changes. These scenarios include a 0 standard deviation change for the sake of comparison. The article will show the adequacy of the default waterfall in these 49 cases.

Four types of operations were simulated: if the CCP manages the default waterfall of the two markets (1) separately, (2) partially separated on the initial margin level, (3) partially separated on the default fund level, or (4) merged. Separated markets mean defining the value of the initial margins and the default fund separately for the spot and derivative markets. Suppose there is a loss, e.g., on the derivative market, with a magnitude which cannot be fully covered by the default waterfall of the derivative market. In that case, the remaining losses cannot be covered by the spot market's default fund, and the recovery and resolution phase will commence. 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

Table 5
Magnitudes of shocks on day 7501. The daily log-return estimates were derived from the annual log-return estimates of the DAX and EUR/USD time series, by dividing them by 250 trading days. Additionally, the daily standard deviations were determined by dividing the annual standard deviation by the square root of 250 trading days. To gauge the impact of extreme price movements, the shocks were quantified based on the calculated extreme values, obtained by adding or subtracting 15, 10, or 5 times the standard deviation from the expected values.

	Stock	Currency
daily expected logreturn	0.03%	0.0004%
daily standard deviation	1.41%	0.75%
+15 standard deviation	21.25%	11.24%
+10 standard deviation	14.18%	7.49%
+5 standard deviation	7.10%	3.75%
−5 standard deviation	−7.04%	−3.75%
−10 standard deviation	−14.12%	−7.49%
−15 standard deviation	−21.19%	−11.24%

contribution of the market participant may have to be used, who is not even active on the derivative market. Partially separated on the default fund level is the case, when a clearing member benefits from netting on the initial margin level, but the default fund contributions are handled separately. In case of a shock, only the default fund contribution associated with the market where the default occurred is utilized. In the case of a merged market, the initial margins and the default funds will be defined as the two markets are cleared together. In this case, the hedged positions decrease market risk faced by the clearing member, so through the applied risk management models – e.g., VaR, SPAN and the stress test – both the initial margin and the default fund size will be affected.

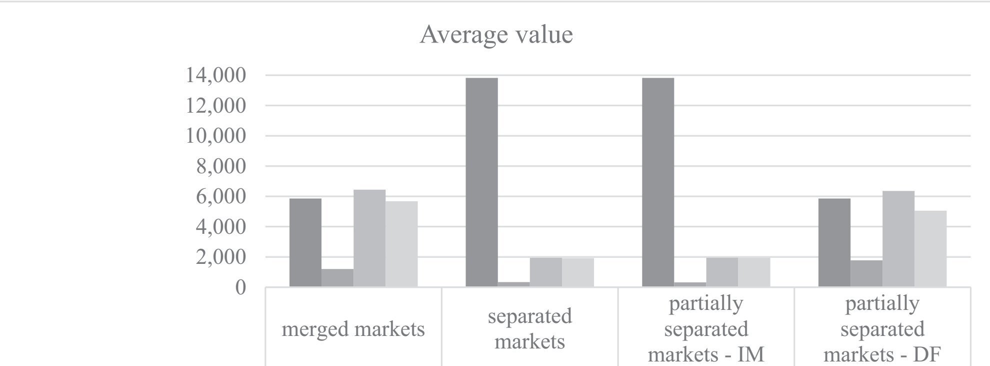
4. Results

Based on the +/−15, +/−10, and +/−5 standard deviation price changes on day 7501; the clearing members' positions; initial margin accounts; and default fund contributions; it was analyzed whether the clearing members' pre-funded elements (IM and DF contribution) would have been enough to cover losses if they defaulted on day 7501. The assumption is that the default happens under the cover 2 rule.

Fig. 2 contains the result of the 1000 trajectories. The average total value of the initial margins can be seen, the average total size of the default fund, (total value of the initial margins and default funds on the spot and derivative market for all the four clearing members together). The average size of the SITG is based on the −15 standard deviation price change on the 7501st day 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 Fig. 2) 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 Fig. 2) when the CCP applies all four levels of the default waterfall totally and would start the recovery and resolution process.

Based on the results, the key findings is that the *separated market* outperforms the other three markets in terms of skin-in-the-game requirement. This is because in a stressed market environment, it requires the lowest level of SITG to withstand the default of the two clearing members with the highest exposure. From the perspective of the CCP, a lower value of the required SITG in the event of defaults is desirable, as it means less of the CCP's own capital is at risk. Similarly, from the regulator's standpoint, a smaller SITG requirement need is better, as it implies that the CCP's losses can be more readily covered by the defaulting member's resources in the event of a default. The use of taxpayers' money for an expected bailout is less probable. This doesn't mean that the actual size of the SITG should be lower, this result just shows, that a lower portion of the SITG is being risked in this market setting. So from a systemic risk point of view, the separated IM and DF structure is the best.

Comparing the results with real market data is challenging since this model only considers four clearing members and two financial assets, and the applied shock was immense. As a result, the SITG plays a significant role in the default waterfall, although based on



	merged markets	separated markets	partially separated markets - IM	partially separated markets - DF
Margin	5,858	13,827	13,827	5,858
Default fund	1,200	335	324	1,772
SITG (non-defaulting)	6,443	1,939	1,945	6,357
SITG (R&R)	5,675	1,923	1,941	5,049

Fig. 2. Average value of the initial margin, default fund, and SITG in the 1000 trajectories. The SITG calculation is based on the −15 standard deviation price movement of the stock and the currency on the 7501st day. This means a − 21.19% and − 11.24% return in one day. It should be noted that the SITG value depicted in the figure is not the actual SITG, that should be quantified based on the EMIR regulation, which mandates a SITG of 25% of the capital. Instead, the simulation defines only the minimum required value in order to fulfill the cover 2 rule. How this value relates to real data, or to simulated data that is in line with the EMIR regulation would need a more complex model that takes into account the size of the CCP's capital.

The standard error of the SITG estimates are the following:

Standard errors	merged markets	separated markets	partially separated markets - IM	partially separated markets – DF
SITG (non-defaulting)	6.31	22.00	22.53	6.62
SITG (R&R)	6.95	21.43	22.52	6.848

previous research or PQD data, the SITG ratio is usually insignificant. However, if we consider a more realistic and less extreme scenario, such as a price change of −5 times the standard deviations in both financial assets, the results in Fig. 3 indicate that the minimum required SITG becomes quite low.

It is noteworthy, that when the default waterfalls are completely separated or separated only on the initial margin level, the guarantee system's structure follows the same pattern as that observed in actual market data. However, in the other two setups, where the default waterfalls are entirely merged or separated only at the default fund level, a greater amount of SITG is necessary to withstand an extreme shock, since the default waterfall structure differs significantly across the various configurations. This is due to the fact that when implementing separate default waterfalls for the two markets on the initial margin level (either with a separated default fund or not), the initial margin is higher than in the merged scenario, as the clearing members are unable to take advantage of the derivative positions' risk-mitigation benefits from a margining perspective.

Fig. 4 provides further evidence to support this, 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. For CM1 and CM2, who had both uncovered risky positions as well as positions where the risk was mitigated (e.g., protective put) or limited (e.g., long straddle), it is clear that they have to pay less margin if the markets are merged compared to the case when it was separated. For 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 increased when the markets were merged.

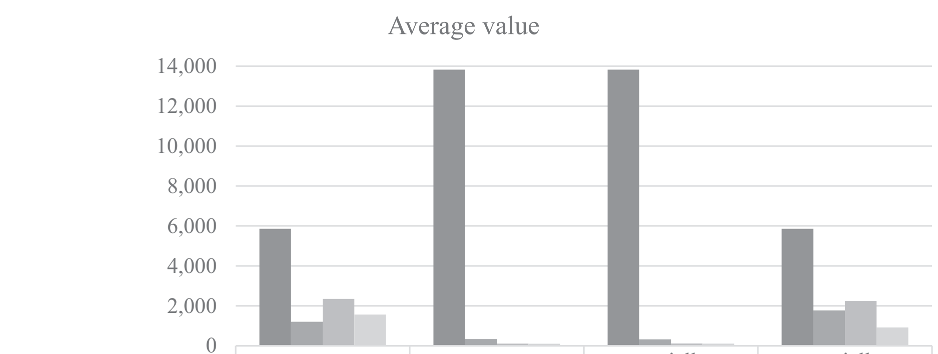
In the case of the default fund contributions on the clearing member level, the same patterns can be seen for the initial margins based on Fig. 5. It is also important to note that the total value of the default fund was the highest in the case of the separated market on the default fund level, while the lowest in the case of the partially separated on the initial margin level, based on Fig. 2. 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.

Overall, from a liquidity point of view, the merged setup is the best for the clearing members, since the IM + DF is the lowest in that case, but for the CCP, the separated solution would be the best, because that would provide the most of the pre-funded resources. Table 6 contains the average, minimum and maximum value of the total default waterfall (initial margin, default fund, and minimum necessary SITG). In all cases, the fully separated market offers the highest default waterfall value, the partially separated on the IM level is the second, while the partially separated on the DF level and the merged market offer significantly lower values. It depends on the goal of the CCP, which suits better for it, whether security is the most important, or the issue of liquidity of market participants.

Regarding how sensitive the SITG is to the price changes of the traded asset prices, the article summarizes the simulation results for the 49 cases in the Appendix (7x7 price change combinations for the stock and currency in the price range of the expeceted logreturn +/−15, +/−10, +/−5, +0 standard deviation). Fig. 6 shows only the merged market, in the case when the minimum amount of necessary SITG is defined aiming to avoid using the non-defaulting members' default fund contribution.

5. Discussion

The risk profile is an important aspect of the operations of a CCP. The models presented in this paper are a simplified reality of a general CCP and its activity with the potential types of clearing members. Handling markets separately gives the CCP additional



	merged markets	separated markets	partially separated markets - IM	partially separated markets - DF
Margin	5,858	13,827	13,827	5,858
Default fund	1,200	335	324	1,772
SITG (non-defaulting)	2,346	110	115	2,241
SITG (R&R)	1,565	99	111	921

Fig. 3. Average value of the initial margin, default fund, and SITG in the 1000 trajectories. The SITG calculation is based on the −5 standard deviation price movement of the stock and the currency on the 7501st day. This means a − 7.04% and − 3.75% return in one day.

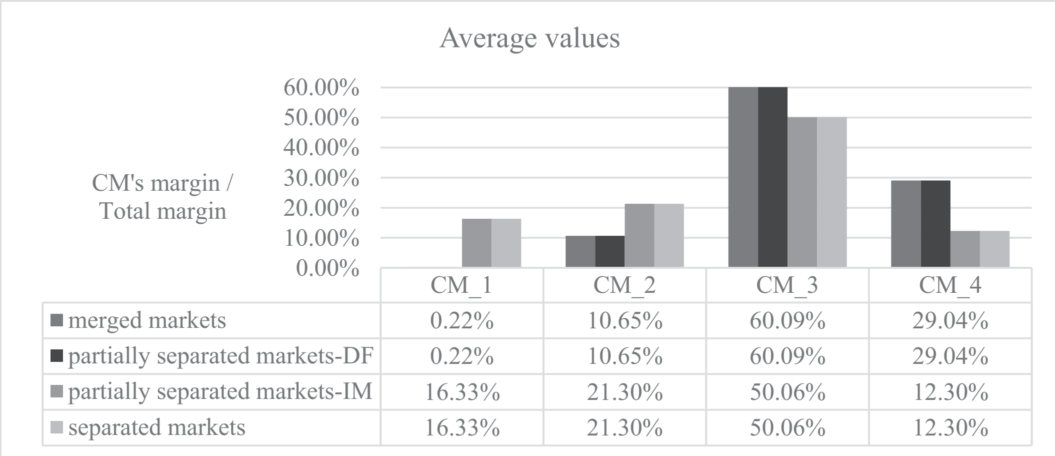


Fig. 4. Average value of the initial margin of the clearing members compared to the total size of the first layer of the default waterall.

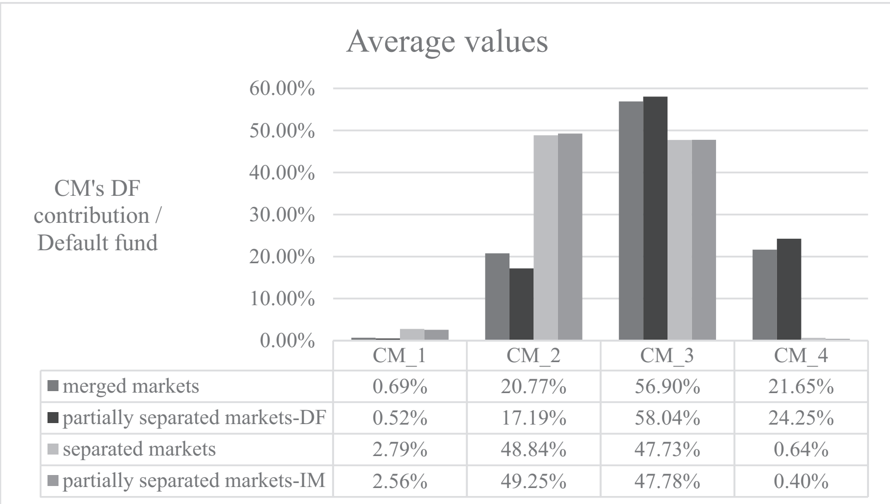


Fig. 5. Average value of the default fund contribution of the clearing members compared to the total size of the default fund.

Table 6
The total size of the default waterfall. In the upper part the total size of the IM + defaulting member's DF + SITG can be found, while the lower part contains the non-defaulting member's DF contribution as well.

Exhaust three layers of the default waterfall	merged markets	separated markets	partially separated markets - IM	partially separated markets - DF
Average	9404	14,272	14,265	9871
Minimum	138	226	226	148
Maximum	509,294	695,394	694,881	509,397
Exhaust the total waterfall	merged markets	separated markets	partially separated markets - IM	partially separated markets - DF
Average	8623	14,261	14,262	8551
Minimum	138	226	226	148
Maximum	509,294	695,394	694,881	509,397

security by asking for more collateral, which is optimal from a pure risk management perspective of the CCP. Moreover, the minimum own contribution, as SITG to withstand notable losses in case of shocks, could be also 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 liquidity shortage in the market. Second, in practice, brokers ask for a margin with a multiplier of the CCP's requirement, thus burdening the participants. In addition, in the separated setup, the cross-mutualization is reduced, which means that members who are only active in one market will not be impacted by defaults in the other market. On the other hand, risk-taking members must have the proper collateral to sustain their risky trading habits. Overall, the separated setup requires more collateral compared to the merged

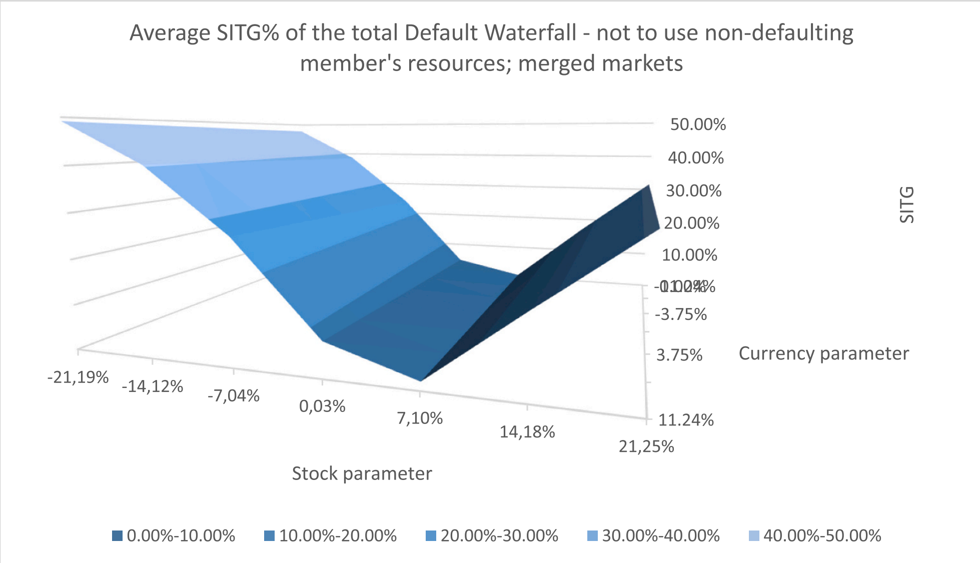


Fig. 6. Summary of the minimum needed SITG amount in case of 49 different combinations of price shocks of the stock and the currency. It can be seen how the SITG ratio within the total value of the default waterfall changes if the CCP exhausts the first three levels of the default waterfall.

setup on the clearing member level. In terms of SITG, the partially separated setup on the IM level performed slightly worse than the fully separated setup, but both of them were the best performers. The other two methods were significantly worse. Table 7 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 7, showing which method can be the most optimal to use.

According to Table 7, when analyzing the guarantee system from the perspective of clearing members and considering various properties of the default waterfall, the totally separated setting may not necessarily be the best option, but the partially separated on the IM level, since that method got the highest score. However, it is still evident that the totally separated and partially separated on the IM level outperform the other two settings.

In cases where the owners of the clearinghouse are the clearing members, the risk-taking member benefits from the cross-guarantee phenomenon but burdens the other traders. Such a massive difference in the risk-taking willingness among members would shift the incentives: the more minor risk-taking parties' membership will become too costly, and the whole default fund 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 in this model, even about on average 45%, according to Figs. 2-5. 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, motivating the risk-averse ones to leave the clearing system, as ultimately, the responsibility for

Table 7
The order of the four methods. The ranking of the four methods is based on the perspectives of both the CCP and clearing members. For the CCP, a higher amount of initial margin available in the guarantee system is more optimal, and the notable difference between initial margin values when defined separately or jointly is reflected in the points. A lower minimum needed SITG amount is also better, as less actual SITG is required in case of a default. The protection aspect is based on the total size of the guarantee system, with a higher value being more favorable. From the clearing members' perspective, lower initial margin and default fund payments are better from funding liquidity point of view. Vulnerability is based on the size of the guarantee system, with a low value being unfavorable for clearing members as they may lose their funds. Risk mutualization is based on the size of the default fund, with a higher value being positive. In this research it is taken as a positive characteristic, however it might be highly affected by the position of the CM. Finally, the hedging benefits reflected in the value of the initial margin are also considered.

Characteristics	Merged markets	Separated markets	Partially separated markets - IM	Partially separated markets - DF
CCP's perspective				
High amount of initial margin	1	4	4	1
Minimum needed SITG amount	2	4	3	1
Protection	1	4	3	2
Clearing members' perspective				
Lower level of guarantees	4	1	2	3
Vulnerability of the CCP	1	4	3	2
Risk-mutualization	3	1	3	4
Hedging benefits	4	1	2	3
Total score	**16**	**19**	**20**	**16**

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, suppose one or more members are causing increased concentration in real life. In that case, it is recommended to be handled, especially if the CCP is owned by its clearing members. Under the EMIR framework, concentration add-ons are aimed at addressing concentration related issues (EMIR, 2012, Articles 36–40).

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. A for-profit CCP will seek profit maximizing ways, since it is its most important goal. However, it is also essential to consider the effects of scale in the clearing business. To attract as many market participants as possible and offer clearing in as many instruments as possible, a CCP should prioritize low-cost clearing services that accept greater risk. Therefore, while a robust margining methodology and default fund calculation methodology are necessary for risk management, a profit-oriented CCP should balance these measures to attract market participants and achieve multilateral netting and portfolio margining benefits through low-cost clearing services. 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.

6. Conclusion

The regulatory background for central clearing has developed immensely since the Global Financial Crisis. Nowadays, the most prominent thing is the smooth operation of these market infrastructures, as they are becoming more and more concentrated, and also too-interconnected-to-fail. To enhance efficiency, it is crucial to ensure that the incentives of the CCP and its clearing members are aligned. Therefore, an efficiently managed guarantee system is critical for both parties. The model proposed in this paper shows how four different default waterfall structures affect not only the certain layers of the default waterfall, but also give special attention to the CCP's own contribution, namely to the skin-in-the-game. It is important, since this contribution is financed from the CCP's own capital. The larger this contribution is, the larger the stake of the CCPs' capital is risked. The four settings were the following: totally *separated*; *partially separated on the initial margin level*; *partially separated on the default fund level*; and totally *merged* default waterfalls on two interconnected markets. Despite the fact that the *merged* and *partially separated on the default fund* level scenarios offer greater diversification and hedging benefits between the traded assets, the decrease in the initial margin amount was so significant that it required a substantial increase in the default fund. In addition, the minimum amount of SITG was considerably higher than in the *separated* and the *partially separated on the initial margin* level setups, meaning that a higher ratio of the SITG was needed to cover the losses in case of a shock. These setups – *merged* and *partially separated on the DF level* – are favorable for some members engaging in risky trading, and also, this also affects clearing members' funding 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. Due to the heightened level of loss-mutualization, these setups are disadvantageous for members active only on one of the cleared markets. The *separated* design gives an advantage to the CCP and would be the best option for minimizing risk but ultimately can phase out more minor participants from the market because the clearing activity can become too costly. The *partially separated on the initial margin level* one was proven to be the most suitable for both parties. It brings the benefits of a higher margin requirement and the second smallest minimum needed SITG for the CCP after the *separated* setup, but the difference between the two SITG was not notable. The main advantage of the *partially separated on initial margin level* is that members can profit from hedging and risk-mutualization on a default fund level, which can be an advantage from the CCP's point of view as well. Although the default funds on the two separate markets are larger together in size, than in the case if we merge only the default funds, but in the event of a default, a larger pool of funds is available for the CCP, since the total default fund can be used to cover losses. In the *separated* case, only that default fund can be used, which is operated on the market where the default happened. In sum, the disadvantage – a slightly lower default fund and a somewhat higher minimum needed SITG level compared to the totally *separated* setup – is balanced by the notable advantage of the mutualized risk on the joint default fund level.

Overall, the recommendation is, that the **best compromise** between parties is the *partially separated default waterfall on the initial margin level*. 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.

It is important to note that the presented model has its limitations. 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 on one hand 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. The regulator could also consider changing the purpose of the SITG and to a defined extent use it as a loss-absorbing tool. On the other hand a more complex model could be built, that takes into account more financial assets and more clearing members, with heterogenous risk profiles who might have rational or irrational (Berlinger et al., 2021) behavior.

Author statement

Váradi Kata: Conceptualization, Methodology, Simulation, Writing- Original draft preparation.

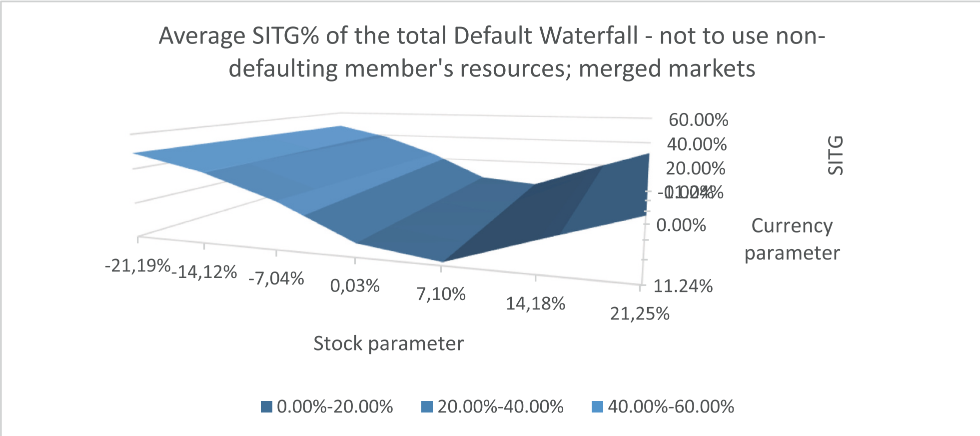
Friesz Melinda: Writing- Reviewing and Editing, Visualization, Validation

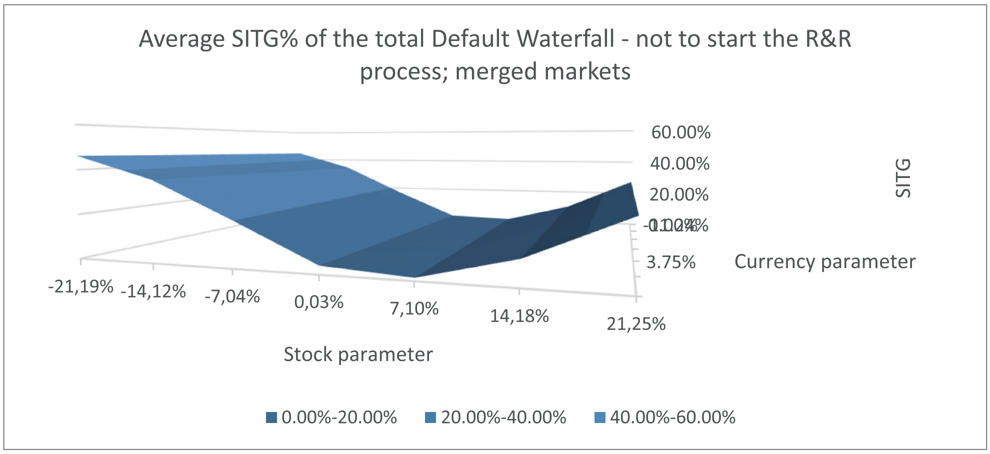
Data availability

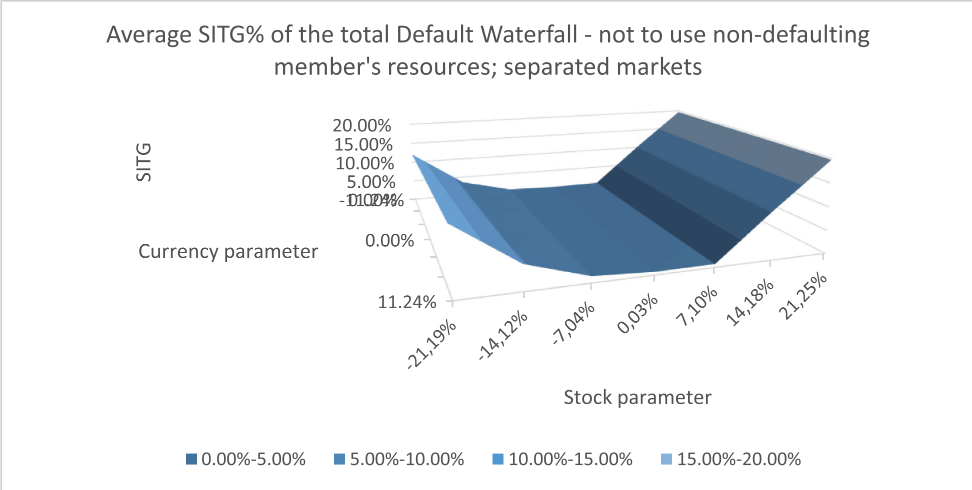
Váradi, K. (2023): "Data and margin calculation", Mendeley Data, V1, doi: 10.17632/cjw9bx9ygm.1

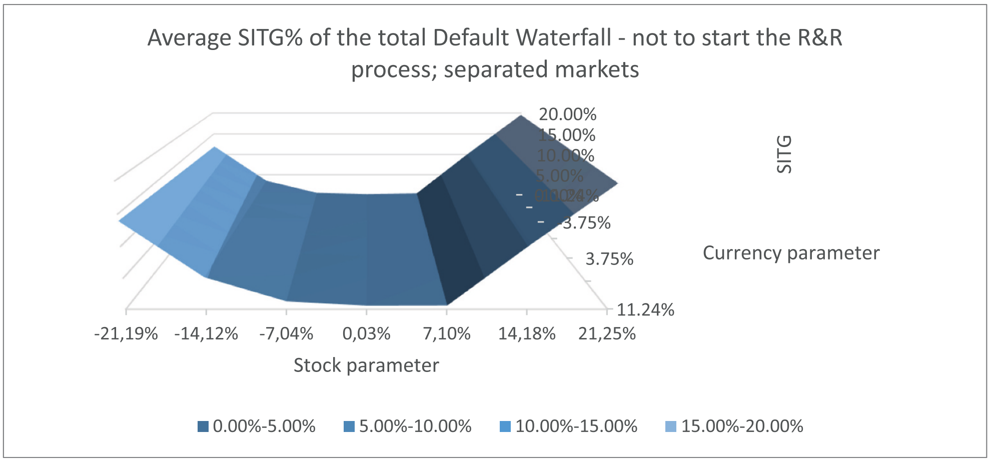
Appendix A. Appendix

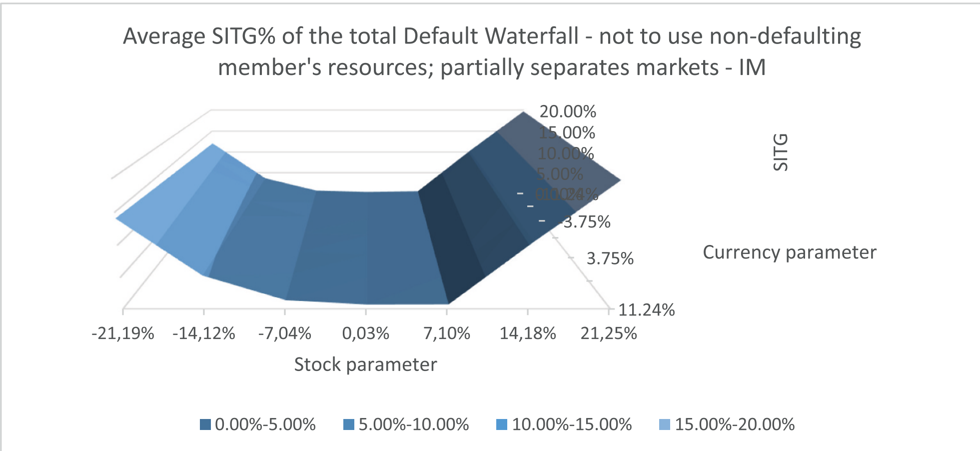
The sensitivity of the SITG to the price changes of the traded asset prices in the 49 analyzed cases: 7x7 price change combinations for the stock and currency in the price range of the expeceted logreturn +/−15, +/−10, +/−5, +0 standard deviation).

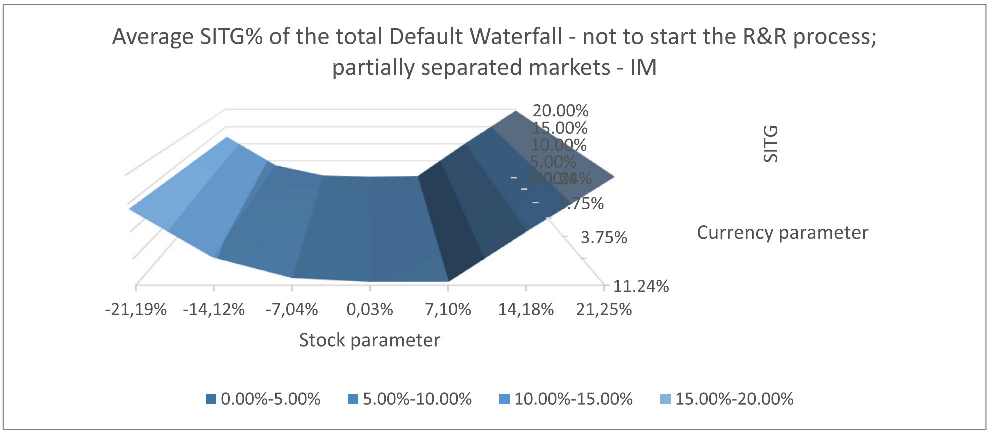


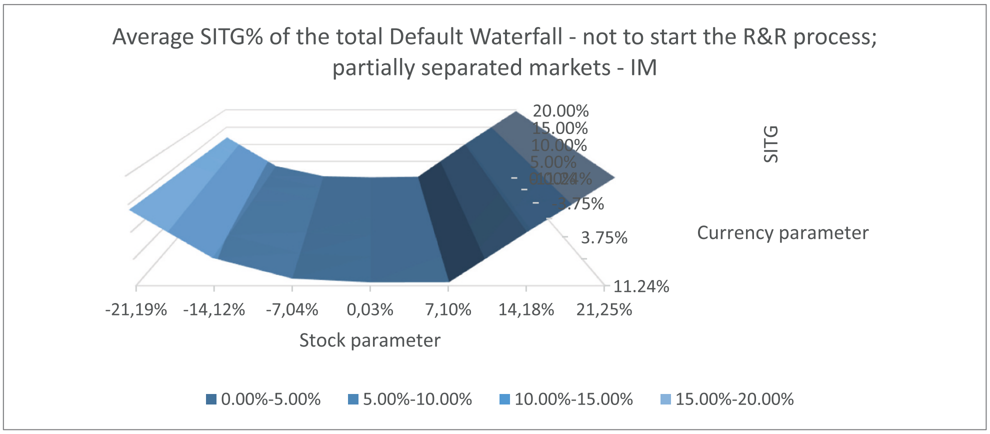


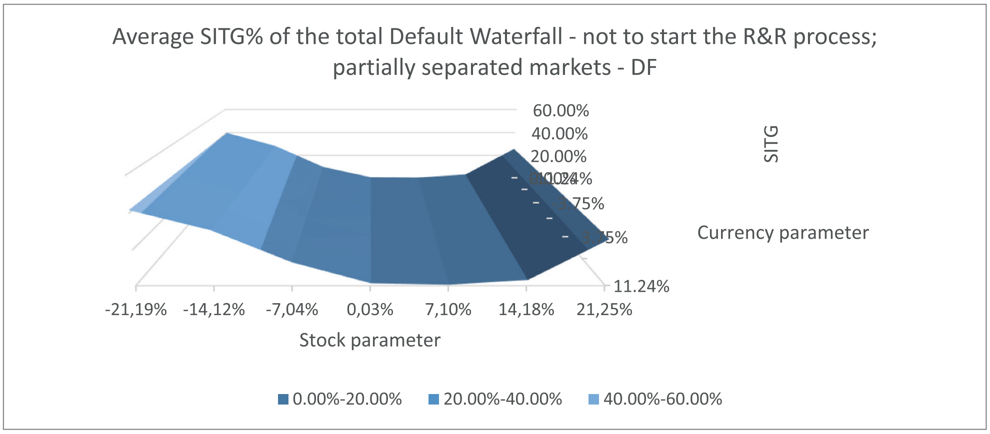

Average SITG% of the total Default Waterfall - not to use non-defaulting member's resources; separated markets
SITG
20.00%
15.00%
10.00%
5.00%
0.00%
11.24%
Currency parameter
-21,19%
-14,12%
-7,04%
0,03%
7,10%
14,18%
21,25%
Stock parameter
0.00%-5.00%
5.00%-10.00%
10.00%-15.00%
15.00%-20.00%


Average SITG% of the total Default Waterfall - not to start the R&R process; separated markets
20.00%
15.00%
10.00%
5.00%
3.75%
11.24%
SITG
Currency parameter
-21,19%
-14,12%
-7,04%
0,03%
7,10%
14,18%
21,25%
Stock parameter
0.00%-5.00%
5.00%-10.00%
10.00%-15.00%
15.00%-20.00%


Average SITG% of the total Default Waterfall - not to use non-defaulting member's resources; partially separates markets - IM
20.00%
15.00%
10.00%
5.00%
3.75%
11.24%
SITG
Currency parameter
-21,19%
-14,12%
-7,04%
0,03%
7,10%
14,18%
21,25%
Stock parameter
0.00%-5.00%
5.00%-10.00%
10.00%-15.00%
15.00%-20.00%







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