Doctoral School of Business and Management

THESIS COLLECTION

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Central counterparties

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

Ph.D. dissertation

Supervisor:

Dr. Kata Váradi
Associate professor

2021, Budapest

Department of Finance

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Summary

1. Research background and rationale for the topic

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 have been applied in the financial system. Recent regulatory initiatives aim to enforce the system by proposing more substantial prudential requirements and improved protection rules. Attention has turned to the regulation of central clearing.

1.1. Aim of research

My research aims to give an overview of the regulatory framework proposed by the relevant authorities and identify the most suitable default waterfall design that suits the profile of the CCP, but it avoids distorting the competence on the market among clearing members. The study connects with authorities' steps 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 size. The trading incentives concerning the amount of capital a CCP is willing to contribute to the default waterfall, so this is also an essential milestone of 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 or 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 model is improved to answer to the other question of the study: **What should be the size of the CCP's capital 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?**

1.2. Literature review and hypotheses

Before 2007, there were slightly few studies on CCPs, but especially in the past five years, CCPs gained blooming literature that focuses on five main areas (Berndsen, 2020). Among others, Cont (2015), Cont and Kokholm (2014), Duffie and Zhu (2011), Pirrong (2011, 2014), Biais et al. (2016), Cecchetti et al. (2009) analyze the clearing benefits and dangers of clentral clearing. The optimal number of CCPs were analyzed by Duffie and Zhu (2011), Cont and Kokholm (2014). The size of the default waterfall, where my connects to was studied by Cont (2015), Paddrik et al., 2020, Murphy (2017), Lewis and McPartland (2017), Poce et al. (2018), Berlinger et. al (2016 and 2019) The end of the default waterfall is studies by Peters and Wollny (2018), Domanski et al. (2015), Plata (2017), Priem (2018), Bignon and Vuillemey (2020). Regarding the skin-in-the-game (SITG) Huang and Takáts (2020), Faruqui et al. (2018), Lewis and McPartland, (2018), Carter and Garner (2016), Cox and Steigerwald (2016) contrubited to the literature.

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. In this thesis, I aim to 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 differently. 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 meet the two objectives mentioned above.

Based on the research questions I formulated the following hypotheses:

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.

2. Methods used

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

The model and results of the baseline model are the summary extracted from a recently (August 2021) published article in the special issue of *Risks*.

2.1 Baseline model

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. 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 1. 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 1: 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'□'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 2.

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 2: The parameters of the shock simulation

Four clearing members (CM) are present on the market, with different positions. 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.

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 (2017) EWMA-based method, according to Equation 10-11,

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

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

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),

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

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

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

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

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

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

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.

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

$$margin_t^{\pi\ built\ back}; PROmargin_t)$$

$$MAXmargin_t = MINmargin_t \cdot (1 + band)$$ (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.

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

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

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

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.

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.

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 default fund (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,

$$DF_{CM1} = \frac{Margin_{CM1}}{\sum_{i=1}^{4} Margin_{CMi}} \tag{22}$$

2.2. Sensitivity of the SITG

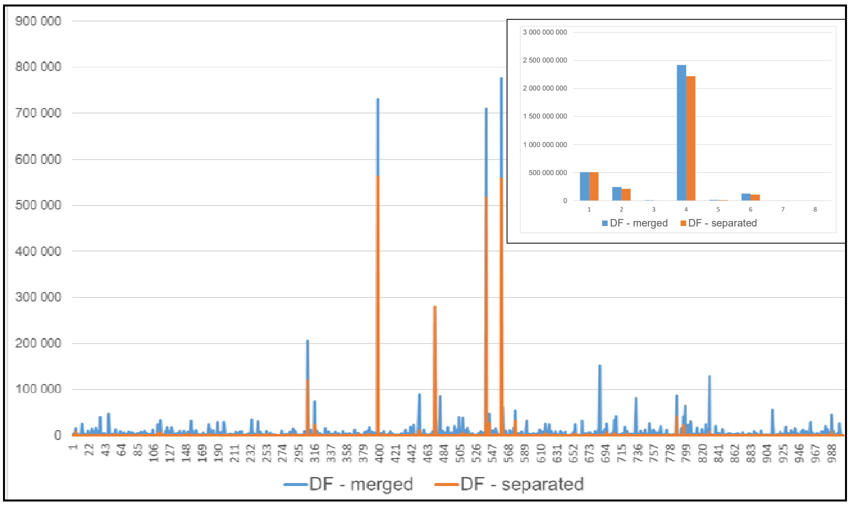
In order to increase efficiency and to analyze and align the incentives of the CCP and its clearing members, I decided to use the model presented above to shows how the CCP's own contribution in the default waterfall is affected in different market structures. The model needed to be simplified to perform 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, while the other members have on both markets. One of them 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).

3. Results

3.1. Baseline model

We run the simulation 1 000 times within the model we have introduced in the previous chapter. The figure below 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 the is the sum of the DF of the spot and the derivative market. I cleaned the database from eight outlier values in order to represent the results.



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, from a risk-taking point of view is note beneficial for every clearing member. 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.

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 highlights 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.

3.2. SITG sensitivity results

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 disadvantage more minor participants from the market because the clearing activity can become too costly. The partially separated on initial margin 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.

Regarding how sensitive the SITG is to the price changes of the traded assets prices, the thesis summarizes figures below summarize the simulation results for the 49 cases (7x7 price change combinations for the stock and currency in the price range of +/-30%). 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.

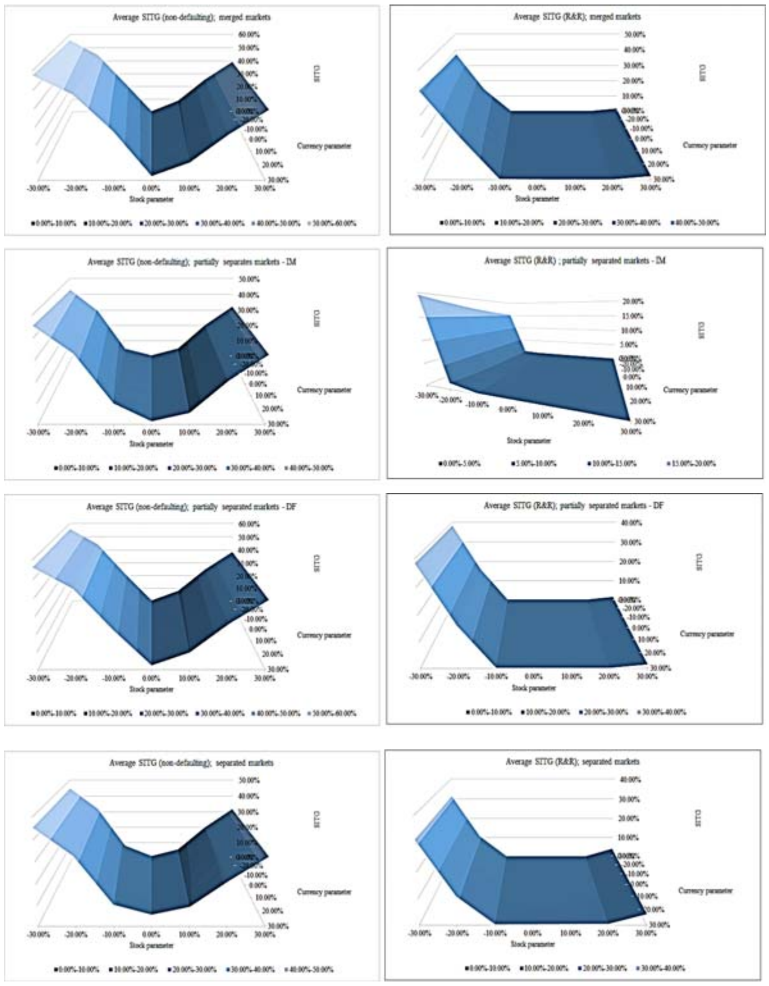


Table 3 compares the four different market settings by ordering them on a 1-4 scale (1 is the worst, 4 is the best). These values are summed up in Table 3, showing which method can be the most optimal to use.

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 3 Order of the four methods

Results show that the most favorable setup 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.

The hypotheses I addressed were 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 second model that 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. 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, a series of defaults will not exhaust the CCP's resources intensely in the long term.

4. Key references

Acharya, V., & Bisin, A. (2014.). Counterparty risk externality: Centralized versus over-the-counter markets. *1*, 53–82.

Baker, C. M. (2016). Clearinghouses for Over-the-Counter Derivatives. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2881090

Banai, Á., Hosszú, Z., Körmendi, G., Sóvágó, S., & Szegedi, R. (2013). Stressztesztek a Magyar Nemzeti Bank gyakorlatában. *Working Paper Central Bank of Hungary*, *109*.

Barker, R., Dickinson, A., Lipton, A., & Virmani, R. (2016). Systemic Risks in CCP Networks. *Working Paper*.

Battiston, S., Caldarelli, G., D'Errico, M., & Gurciullo, S. (2016). Leveraging the network: A stress-test framework based on DebtRank. *Stat. Risk Model*, *33*(3–4), 17–13.

BCBS (2009): Principles for sound stress testing practices and supervision

BCBS (2018): Analysis of Central Clearing Interdependencies

Bella M., Szodorai M., & Váradi K. (2018). *Methodological comparison of central counterparties' and credit institutions' stress tests at European level*. 34.

Ben Naceur, S., & Roulet, C. (2017). Basel III and Bank-Lending: Evidence from the United States and Europe. *IMF Working Papers*, *17*, 1. https://doi.org/10.5089/9781484328309.001

Béres, D. (2018). Securities Post-trading Infrastructure – Past, Present and Future. *Public Finance Quarterly*, 4, 564–580.

Berlinger, E., Dömötör, B., & Illés, F. (2019). *Anti-cyclical versus risk-sensitive margin strategies in central clearing*. *Journal of International Financial Markets, Institutions&Money* (62), 117–131.

Berlinger, E., Dömötör, B., Illés, F., & Váradi, K. (2016a). Stress indicator for clearing houses. *Central European Business Review*, *4*.

Berlinger E., Dömötör B., Illés F., & Váradi K. (2016b). A tőzsdei elszámolóházak vesztesége. *Közgazdasági Szemle*, *63*(9), 993–1010. https://doi.org/10.18414/KSZ.2016.9.993

Bernstein, A., Hughson, E., & Weidenmier, M. (2019). Counterparty Risk and the Establishment of the New York Stock Exchange Clearinghouse. *Journal of Political Economy*, *127*(2), 689–729. https://doi.org/10.1086/701033

Berndsen, R. (2020). Five Fundamental Questions on Central Counterparties. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3709691

Biais, B., Heider, F., & Hoerova, M. (2012). Clearing, Counterparty Risk, and Aggregate Risk. *IMF Economic Review*, *60*(2), 193–222.

Biais, B., Heider, F., & Horeova, M. (2016). Risk-Sharing or Risk-Taking? Counterparty Risk, Incentives, and Margins. 71(4), 1669–1698.

Biedermann, Z., & Orosz, Á. (2015). Eltérő irányú pénzügyi szabályozások a válság után? Az EU és az Egyesült Államok válaszainak összevetése. *Financial and Economic Review*, *14*(1), 30–56.

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

Basel Committee on Banking Supervision (BIS), (2017) *Supervisory and bank stress testing: range of practices,* December, Available: https://www.bis.org/bcbs/publ/d427.htm

Black, F. and Scholes, M. 1973: The pricing of Options and Corporate Liabilities. *Journal of Political Economy*, 81(3) pp. 637-654.

Basel Committee on Banking Supervision (BIS), (2020) *OTC derivatives statistics at end-June 2020* https://www.bis.org/publ/otc_hy2011.htm

Brown, W. O., Mulherin, J. H., & Weidenmier, M. D. (2008). *Competing with the New York Stock Exchange∗*. Available: https://www3.nd.edu/~finance/020601/news/Harold%20Mulherin%20Paper%20-%202008%20Spring%20Seminar%20-%20Revised.doc

Brunnermeier, M., & Pedersen, L. H. (2009). Market Liquidity and Funding Liquidity. *Review of Financial Studies*, *22*(6), 2201–2238.

Buch, C., Dages, B. G., (2018) Bank for International Settlements, & Committee on the Global Financial System. *Structural changes in banking after the crisis: The nature of regulatory capital requirements*. https://www.bis.org/publ/cgfs60.pdf

Campbell, S. D., & Ivanov, I. (2016). *Empirically evaluating systemic risks in CCPs: The case of two CDS CCPs.*

Capponi, A., Jiaxu Wang, J., & Zhang, H. (2018). Central Clearing and the Sizing of Default Funds. *Working Paper*.

Carter, L., & Garner, M. (2016). Skin in the game: Central counterparty risk controls and incentives. *The Journal of Financial Market Infrastructures*, *4*(3), 39–54. https://doi.org/10.21314/JFMI.2016.056

Cecchetti, S. G., Gyntelberg, J., & Hollanders, M. (2009). *Central counterparties for over-the-counter derivatives*. https://www.bis.org/publ/qtrpdf/r_qt0909f.htm

Cihák, M. (2007). *Introduction to applied stress testing. IMF working papers, WP/07/59.*

CCP BEST PRACTICES. (2019). *A CCP12 POSITION PAPER*. https://ccp12.org/wp-content/uploads/2019/05/CCP-Best-Practices__CCP12_Position_Paper.pdf
CME Group (2019): CME SPAN ® Standard Portfolio Analysis of Risk ®, available at https://www.cmegroup.com/clearing/files/span-methodology.pdf downloaded: 11th March 2019.
CME Group (2020). Default waterfall, shorturl.at/ftTZ8
Coeuré, B. (2017). Central clearing: Reaping the benefits, controlling the risks. *Banque de France Financial Stability Review*, *21*, 97–110.
Coeuré, B., 2015, Ensuring an adequate loss-absorbing capacity of central counterparties," Remarks at the Federal Reserve Bank of Chicago 2015 Symposium on Central Clearing, Chicago (10th April), available at: https://www.ecb.europa.eu/press/key/date/2015/html/sp150411.en.html
Committee on Payments and Market Infrastructures, (CPMI) – International Organization of Securities, & Commissions (IOSCO). (2012). *Principles for financial market infrastructures*.
Commission, "Impact Assessment Proposal for a Regulation of the European Parliament and of the Council on a Framework for the Recovery and Resolution of Central Counterparties and Amending Regulations (Eu) No 1095/2010, (Eu) No 648/2012, and (Eu) 2015/2365
Cont, R. (2010). Network structure and systemic risk in banking systems. *Working Paper*. https://ssrn.com/abstract=1733528 or http://dx.doi.org/10.2139/ssrn.1733528
Cont, R. (2017). Central Clearing and Risk Transformation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2955647
Cont, R. (2015). The end of the waterfall: Default resources of central counterparties. *Journal of Risk Management in Financial Institutions*, *8*(4), 365–389.
Cont, R., & Kokholm, T. (2015). Central Clearing of OTC Derivatives: Bilateral vs multilateral netting. *Statistics and Risk Modeling*, *31*(1), 3–22. DOI 10.1515/strm-2013-1161
Cox, R. T., & Steigerwald, R. S. (2017). *A CCP is a CCP is a CCP*.
Cox, R. T. (2015). Central counterparties in crisis: The Hong Kong Futures Exchange in the crash of 1987. *Journal of Financial Market Infrastructures*. https://www.risk.net/node/2437961
CPSS-IOSCO (2004). Recommendations for Central Counterparties. 55.
CPMI-IOSCO (2012) Principles for financial market infrastructures, April
CPMI-IOSCO (2014) Recovery of financial market infrastructures, October.
CPMI-IOSCO (2015) Implementation monitoring of PFMI: Assessment and review of application of Responsibilities for authorities, November.
CPMI-IOSCO (2017) Resilience of central counterparties (CCPs), April.
CPMI-IOSCO (2019) A discussion paper on central counterparty default management auctions, June
CPMI-IOSCO. (2020). Central counterparty default management auctions issues for consideration. https://www.bis.org/cpmi/publ/d192.pdf
Daly, R. (2015). Do CCPs Need More Skin in the Game? *Tradersmagazine.Com*, 1.
De Nederlandsche Bank. (2013) *All the Ins and Outs of CCPs,* Accessed: 11.21.2020. https://www.dnb.nl/en/binaries/711869_All_Ins_Outs_CCPs_EN_web_v3_tcm47-288116.pdf
De Nederlandsche Bank. (2017). *A top-down stress testing framework for the Dutch banking sector*.
Domanski, D, Gambacorta, L., Picillo, C., (2015) *Central clearing: Trends and current issues*.. 18., www.bis.org/publ/qtrpdf/r_q1512g.pdf
Duffie, D. (2011). Resolution of Failing Central Counterparties, in Kenneth E. Scott, Thomas H. Jackson & John B. Taylor, Making Failure Feasible, How Bankruptcy Reform Can End "Too Big to Fail. *Stanford, CA: Hoover Institution Press)*, *Working paper*. http://www.darrellduffie.com/uploads/working/DuffieCCP-ResolutionJan2015.pdf
Duffie, D and H Zhu (2011): "Does a central clearing counterparty reduce counterparty risk?", Review of Asset Pricing Studies, vol 1, no 1.
EACH. (2021). *EACH Paper – Carrots and sticks: How the skin in the game incentivises CCPs to perform robust risk management*. https://www.eachccp.eu/wp-content/uploads/2021/01/EACH-Paper-Carrots-and-sticks_How-the-skin-in-the-game-incentivises-CCPs-to-perform-robust-risk-management-January-2021.pdf
EMIR – European Market Infrastructure Regulation: Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4th July 2012 on the OTC derivatives, central counterparties and trade repositories (EMIR - European Market Infrastructure Regulation) Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0648&from=EN downloaded: 8th February 2019.
ESMA (2012). European Securities and Markets Authority, Consultation Paper on Anti-Procyclicality Margin Measures. Available: https://www.esma.europa.eu/press-news/esma-news/esma-consults-ccp-anti-procyclicality-margin-measures downloaded: 8th January 2019
ESMA (2018): EU-wide stress test report. http://firds.esma.europa.eu/webst/ESMA70-151-1154%20EU-wide%20CCP%20Stress%20Test%202017%20Report.pdf
ESMA (2019a). EU-wide CCP stress test. ESMA, February 2019.
ESMA. (2019b). *Capital markets union: Council adopts updated rules for financial derivative products and clearing*. https://www.consilium.europa.eu/en/press/press-

releases/2019/05/14/capital-markets-union-council-adopts-updated-rules-for-financial-derivative-products-and-clearing/

ESMA (2020) ESMA's third EU-wide CCP stress test finds system resilient to shocks. Retrieved 19th June, 2021, from https://www.esma.europa.eu/press-news/esma-news/esma%E2%80%99s-third-eu-wide-ccp-stress-test-finds-system-resilient-shocks

ESMA (2021a) ESMA launches 2021 Central Counterparties Stress Test. Retrieved 23rd August, 2021, from https://www.esma.europa.eu/press-news/esma-news/esma-launches-2021-central-counterparties-stress-test

ESMA (2021b) Consultation Paper: Draft Guidelines on CCP recovery plan scenarios (Article 9(12) CCPRRR); Retrieved 11th September, 2021, from https://www.esma.europa.eu/sites/default/files/library/esma70-151-3404_guidelines_ccprrr_recovery_plan_scenarios_0.pdf

European Council Council of the European Union (2019) Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on a framework for the recovery and resolution of central counterparties and amending Regulations (EU) No 1095/2010, (EU) No 648/2012, and (EU) 2015/2365 and Directives 2002/47/EC, 2004/25/EC, 2005/56/EC, 2007/36/EC, 2011/35/EU and (EU) 2017/1132. https://www.consilium.europa.eu/media/41614/st14540-ad01-en19.pdf

European Council Council of the European Union (2020) *Clearing houses: Presidency and Parliament reach political agreement on recovery and resolution*. Retrieved 12th September, 2020, from http://www.consilium.europa.eu/en/press/press-releases/2020/06/23/clearing-houses-presidency-and-parliament-reach-political-agreement-on-recovery-and-resolution/

Eurostat (2021) *Selected euro area statistics and national breakdowns*. European Central Bank. Available: https://www.ecb.europa.eu/stats/ecb_statistics/escb/html/table.en.html?id=JDF_MFI_MFI_LIST

Faruqui, U., Huang, W., & Takáts, E. (2018). Clearing risks in OTC derivatives markets: The CCP-bank nexus. *BIS Quarterly Review*, 73–90.

Finance.yahoo.com. 2021a. Time series of the DAX index prices for the period of 12th January 1991 – 11th January 2021. https://finance.yahoo.com/quote/%5EGDAXI/history?p=%5EGDAXI

Finance.yahoo.com. 2021b: Time series of the EUR/USD currency rate for the period of 1st December 2003 – 11th January 2021.

Friesz, M., Muratov-Szabó, K., Prepuk, A. and Váradi, K., 2021. Risk Mutualization in Central Clearing: An Answer to the Cross-Guarantee Phenomenon from the Financial Stability Viewpoint. *Risks*, *9*(8), p.148.

Frey, H. C., & Patil, S. R. (2002). Identification and Review of Sensitivity Analysis Methods. *Risk Analysis*, *22*(3), 553–578. https://doi.org/10.1111/0272-4332.00039

FSB (2010) Implementing OTC Derivatives Market Reforms, October

FSB (2014) Key attributes of effective resolution regimes for financial institutions, October.

FSB (2017) Guidance on central counterparty resolution and resolution planning – consultative document, February.

FSB (2020) *2020 list of global systemically important banks (G-SIBs)* Available: https://www.fsb.org/wp-content/uploads/P111120.pdf

G20, 2009. A Framework for Strong, Sustainable, and Balanced Growth. Leaders Statement: The Pittsburgh Summit. September 24–25, 2009, Pittsburgh, Accessed: http://www.g20.utoronto.ca/2009/2009communique0925.html

Ghamami, S., & Glasserman, P. (2017). Does OTC derivatives reform incentivize central clearing? *Journal of Financial Intermediation*, *32*, 76–87.

Goodhart, C. A. E. (1995). The Costs of Regulation (1988). In C. A. E. Goodhart (Ed.), *The Central Bank and the Financial System* (pp. 440–452). Palgrave Macmillan UK. https://doi.org/10.1057/9780230379152_19

Gurrola Perez, Pedro, Procyclicality of CCP Margin Models: Systemic Problems Need Systemic Approaches (December 2020). World Federation of Exchanges Research Working Paper, 2020, Available at SSRN: https://ssrn.com/abstract=3779896 or http://dx.doi.org/10.2139/ssrn.3779896

Heller, D., & Vause, N. (2012). Collateral requirements for mandatory central clearing of over-the-counter derivatives. *BIS Working Paper*, *373*.

Huang, W. (2019). *Central counterparty capitalization and misaligned incentives*. https://www.bis.org/publ/work767.htm

Huang, W., & Takáts, E. (2020a). *Model risk at central counterparties: Is skin-in-the-game a game changer?* BIS Working Papers, 866. https://ssrn.com/abstract=3613194

Huang, W., & Takats, E. (2020b). *The CCP-bank nexus in the time of Covid-19*. 9., BIS Bulletin (11 May), Available: https://www.bis.org/publ/bisbull13.pdf

Hughes, D., & Manning, M. (2015). CCPs and Banks: Different Risks, Different Regulations. *December Bulletin*.

https://brs.website.rba.gov.au/publications/bulletin/2015/dec/8.html
Hull, J. C. (2018). *Risk management and financial institutions* (5th ed.).
Illes, F., Muratov-Szabo, K., Prepuk, A., Szodorai, M., & Varadi, K. (2019). Together Forever Or Separated For Life: Stress Tests Of Central Counterparties In Case Of Merged And Separated Default Funds. *ECMS 2019*, 78–84. https://doi.org/10.7148/2019-0078
King, T., Nesmith, T. D., Paulson, A., & Prono, T. (2020). Central Clearing and Systemic Liquidity Risk. *Finance and Economics Discussion Series*, *2020*(009). https://doi.org/10.17016/FEDS.2020.009
Kiff, J. (2019). History of Central Counterparty Failures and Near-Failures. *The OTC Space*. https://www.theotcspace.com/content/history-central-counterparty-failures-and-near-failures-derivative-primer-7
Koeppl, T., Monnet, C., Temzelides, T., 2012. Optimal clearing arrangements for financial trades. J. Financ. Econ. 103 (1), 189–203
Kubitza, C., Pelizzon, L., & Sherman, M. G. (2021). *Loss Sharing in Central Clearinghouses: Winners and Losers*. 58. Available: ttps://www.econtribute.de/RePEc/ajk/ajkdps/ECONtribute_066_2021.pdf
Lam, K., Sin, C.Y., Leung, R., 2004. A theoretical framework to evaluate different margin-setting methodologies. *J. Futures Markets* 24 (2), 117–145
Lin, L., & Surti, J. (2013). *Capital Requirements for Over-the-Counter Derivatives Central Counterparties*. 47.
Lisney, W. (2021) *Skin-in-the-game more costly for small clearers - panelist*, Global Investor, p. N.PAG. Available at: https://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=150209495&site=eds-live (Accessed: 26th August 2021).
Labuszewski, J.W., Nyhoff, J.E., Co R., and Peterson, P.E. (2010) *The CME Group Risk Management Handbook*, Hoboken, New Jersey: John Wiley & Sons, p. 80
LCH (2020) Default waterfall, https://www.lch.com/services/listed-rates/risk-management
Lloyd, H.D. (1899), "*Clearing, and clearing houses*", Cyclopædia of Political Science, Political Economy, and the Political History of the United States, 1, New York: Maynard, Merrill, and Co, p.223*)*
Loon, Y. C., & Zhong, Z. K. (2014). The impact of central clearing on counterparty risk, liquidity, and trading: Evidence from the credit default swap market. *Journal of Financial Economics*, *112*(1), 91–115. https://doi.org/10.1016/j.jfineco.2013.12.001
Lopez, C., & Saeidinezhad, E. (2017). Central Counterparties Help, But Do Not Assure Financial Stability. *Munich Personal RePEc Archive*, *80358*. https://mpra.ub.uni-muenchen.de/80358/
Lui Hu-chung, O (1992.) Hong Kong Futures Exchange & The Development Of Options On The Hang Seng Index, Available at https://core.ac.uk/download/pdf/48541870.pdf (Accessed 29.01.2019)
Madar, L. (2010). Stressztesztek használata anticiklikus tőkeszügséglet meghatározására. *Financial and Economic Review*, *9*(5).
Mamon, R. (2004) Three ways to solve for bond prices in the Vasicek model, *JOURNAL OF APPLIED MATHEMATICS AND DECISION SCIENCES*, 8(1), 1–14
Markose, S., Giansante, S., & Shaghaghi, A. (2012). Too interconnected to fail", Financial network of US CDS Market: Topological fragility and systemic risk. *Journal of Economic Behavior and Organization*, *83*(3), 627–646.
Matthews, P. (1921), *The bankers' clearing house*, London.
McPartland, J., & Lewis, R. (2017). The Goldilocks problem: How to get incentives and default waterfalls "just right." *Economic Perspectives, Federal Reserve Bank of Chicago*, *1*.
Menkveld, A. (2016). Systemic risk in central clearing: Should crowded trades be avoided? *Working Paper*.
Medvegyev, P. and Száz, J. (2010): Meglepetések jellege a Pénzügyi piacokon (Properties of surprises on the financial markets), Nemzetközi Bankárképző központ.
Muratov-Szabo, K., Prepuk, A., Szodorai, M., & Varadi, K. (2020). The Necessary Size Of The Skin-In-The-Game To Stay In The Game. *ECMS 2020 Proceedings* https://doi.org/10.7148/2020-122
Murphy, D., Vasios, M., and Vause, N (2016), A Comparative Analysis of Tools to Limit the Procyclicality of Initial Margin Requirements,. *Bank of England Working Paper* No. 597, Available at SSRN: https://ssrn.com/abstract=2772569
Murphy, D. (2017). I've got you under my skin: Large central counterparty financial resources and the incentives they create. *Journal of Financial Market Infrastructures*, *5*(3), 54–74. https://doi.org/DOI: 10.21314/JFMI.2017.073
Murphy, D., & Nahai-Williamson, P. (2014). Dear Prudence, won't you come out to play? Approaches to the analysis of CCP default fund adequacy. *Ank of England Financial Stability Papers*, *30*.
Murphy, D. (2020). *Too Much, Too Young: Improving the Client Clearing Mandate* (SSRN Scholarly

Paper ID 3768398). Social Science Research Network. https://papers.ssrn.com/abstract=3768398
Nabilou, H., & Asimakopoulos, I. G. (2020). In CCP we trust … or do we? Assessing the regulation of central clearing counterparties in Europe. *Capital Markets Law Journal*, *15*(1), 70–97. https://doi.org/10.1093/cmlj/kmz026
Naceur, B., Marton, K., Roulet, C., 2018. Basel III and bank-lending: Evidence from the United States and Europe, Journal of Financial Stability 39 (2018) 1–27
Nagy, Á., Dézsi-Benyovszki, A., & Székely, I. (2016). *Measuring financial systemic stress in Romania: a composite indicator approach*. Financial Studies – 3/2016
Nasdaq Business (2018.) Nasdaq Statement Regarding Member Default, Available at (https://business.nasdaq.com/mediacenter/pressreleases/1808225/nasdaq-statement-regarding-member-default, (Accessed: 29.01.2019)
Nevin, E., & Davis, E. W. (1970). *The London Clearing Banks*. Elek.
Nosal, E. (2012). Clearing Over-The-Counter Derivatives. *Economic Perpectives*, *4*, 137–145.
Nwogugu, M. (2015). Failure of the Dodd-Frank Act. *Journal of Financial Crime*, *22*(4), 520–572. http://dx.doi.org/10.1108/JFC-11-2014-0053
OCC's Clearing Member Default Rules and Procedures. (2020). https://www.theocc.com/components/docs/risk-management/default-rules-and-procedures.pdf
Online Business Dictionary—*BusinessDictionary.com*. (2021). Retrieved 23rd August, 2021, from http://www.businessdictionary.com/
Paddrik, M., & Young, H. P. (2017). How safe are central couterparties in derivative markets? *Discussion Paper, University of Oxford.*
Paddrik, M. E., & Zhang, S. (2020). Central Counterparty Default Waterfalls and Systemic Loss. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3634656
Paisley, J. (2017). Stress testing: Where next? *Journal of Risk Management in Financial Institutions*, *10*(3), 224–237.
Parkinson, P. M. (2014). CCP Liquidity Risk Management and Related Failure Management Issues. *Federal Reserve Bank of Chicago Annual Over the Counter Derivatives Symposium*.
Parkinson, P. M., Committee on Payment and Settlement Systems, Euro-currency Standing Committee, & Bank for International Settlements. (1998). *OTC derivatives: Settlement procedures and counterparty risk management*. Bank for International Settlements.
Paulsson, L., & Hotler, M. (2018). *Phantom Trader Who Blew Hole in World's Oldest Power Market—Bloomberg*. https://www.bloomberg.com/news/articles/2018-09-15/phantom-trader-who-blew-a-hole-in-world-s-oldest-power-market
Peer, N. O., & Lewis, R. (2018). The CCP Recovery Game: The Default Auction as a Stag Hunt. *Working Paper*. https://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID3228436_code3069345.pdf?abstractid=3228436&mirid=1
Peters, M., & Wollny, H. (2018). Central clearing counterparties' recovery and resolution: Where do we stand in the European Union? *Journal of Securities Operations & Custody*, *11*(12), 98–111.
Guarino (2015) Philadelphia Stock Exchange | *Encyclopedia of Greater Philadelphia*. Retrieved 13th October, 2019, from https://philadelphiaencyclopedia.org/archive/philadelphia-stock-exchange/
Pirrong, C. (2014). A Bill of Goods: CCPs and Systemic Risk. *Journal of Financial Market Infrastructures*, *2*(4), 55–85.
Plata, R. (2017). Recovery and resolution regimes for CCPs: Making financial markets resilient to the most extreme events. *Journal of Securities Operations & Custody*, *9*(2), 98–105.
Poce, G., Cimini, G., Gabrielli, A., Zaccaria, A., Baldacci, G., Polito, M., Rizzo, M., & Sabatini, S. (2018). What do central counterparties default funds really cover? A network-based stress test answer. *Journal of Network Theory in Finance*, *4*(4), 43–57.
Robinson, S., (1984.) Traders shunning Kuala Lumpur Commodity Exchange pressuring government to re-establish credibility, United Press International. Available at https://www.upi.com/Archives/1984/09/09/Traders-shunning-Kuala-Lumpur-Commodity-Exchange-pressuring-government-to-re-establish-credibility/5435463550400/ (Accessed 2019.01.29)
Rendleman, R. and B. Bartter (1980). "The Pricing of Options on Debt Securities". *Journal of Financial and Quantitative Analysis*. **15**: 11–24. doi:10.2307/2979016
RTS – Technical Standard: Commission delegated regulation (EU) 153/2013 of 19th December 2012 supplementing Regulation (EU) No 648/2012 of the European Parliament and of the Council with regard to regulatory technical standards on requirements for central counterparties. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:052:0041:0074:EN:PDF downloaded: 8th January 2019.
Surprise, G. (2015). Skin in the game doesn't protect end client, CME says. *GlobalCapital*, *3/9/2015*, 106–106.
Szanyi, C., Szodorai, M., & Váradi, K. (2017). A Supplement to the Regulation of Anti-Cyclical

Margin Measures of Clearing Activities. *Working Paper*, *SSRN 3242078*.
Sykes, W., & Karsten, E. (2019). *EMIR Refit—What you need to know—Macfarlanes*. Retrieved 24th August, 2021, from https://www.macfarlanes.com/what-we-think/in-depth/2019/emir-refit-what-you-need-to-know/
The Financial Services and Markets Act 2000 (Over the Counter Derivatives, Central Counterparties and Trade Repositories) (No. 2) Regulations 2013
Thursfield, J. (2019, 9th February). *SITG not significant loss absorbing resource – CCP12 | News | Global Investor Group*. www.globalinvestor.com
Váradi, K. (2018). A critique of the regulation of guarantee systems operated by central counterparties. *Economy and Fincance*, *2*(5).
Váradi, K., & Béli, M. (2017). Alapletét meghatározásának lehetséges módszertana. *Financial and Economic Review*, *16*(2).
Vasicek, O. (1977): An equilibrium characterization of the term structure. Journal of Financial Economics, Vol 5. No. 5. pp. 177-188.

5. Own publications related to the topic

Bella, M., Szodorai, M., Váradi, K (2018) Központi szerződő felek és hitelintézetek európai szintű stressztesztjeinek módszertani összehasonlítása, *Közgazdász fórum 21*. évf. 3. (136.) sz. (2018.) 33-65 pp http://epa.oszk.hu/00300/00315/00126/pdf/
Friesz M., (2020) The Financial System's Resilience is Everything, But at what Cost? *PÉNZÜGYI SZEMLE/PUBLIC FINANCE QUARTERLY* (1963-) (0031-496X 2064-8278): 65 4 pp 472-484 (2020) DOI: https://doi.org/10.35551/PFQ_2020_4_2
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
Friesz M., Váradi, K. (2021) How is it done? Comparison between the margin calculation methodology of central counterparties and clearinghouses *PÉNZÜGYI SZEMLE/PUBLIC FINANCE QUARTERLY* (1963-) (0031-496X 2064-8278):
Friesz, M., Muratov-Szabó, K., Prepuk, A. and Váradi, K. (2020) The Necessary Size Of The Skin-In-The-Game To Stay In The Game *Proceedings of the 34th International ECMS Conference on Modelling and Simulation, ECMS 2020* :, pp 122-128
Friesz, M., Muratov-Szabó, K., Prepuk, A. and Váradi, K., (2021). Risk Mutualization in Central Clearing: An Answer to the Cross-Guarantee Phenomenon from the Financial Stability Viewpoint. *Risks*, 9(8), p.148.
Friesz, M., Muratov-Szabó, K., Prepuk, A. and Váradi, K., Központi szerződő felek stressztesztjei elkülönített garanciaalapok esetében A garanciaalap tervezése és méretének számítása *Gazdaság és Pénzügy* , 7. évf. 2. sz. 2020. jún., DOI: 10.33926/GP.2020.2.5
Illes F.; Friesz, M., Muratov-Szabó, K., Prepuk, A. and Váradi, K. (2019) Together forever or separated for life: stress tests of central counterparties in case of merged and separated default funds, *Proceedings of the 33rd International ECMS Conference on Modelling and Simulation : ECMS 2019,* Nottingham: European Council for Modelling and Simulation (ECMS), pp 78-84
Szanyi, Cs.; Szodorai, M.,Váradi, K. (2018) Supplementation Of The Regulation Of Anti-Cyclical Margin Measures, *ECMS 2018 Proceedings : 32nd European Conference on Modelling and Simulation,* pp 46-47
Szodorai, M. (2019) Managing risks and getting under the central counterparty's skin, *Selected chapters of corporate finance and risk management,* Budapesti Corvinus Egyetem, pp 109-114