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Risk Management Practices of Central Counterparties: European vs. Third-Country CCPs

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ABSTRACT

As central counterparties can act as shock absorbers but may also lead to financial stability problems themselves, this paper explores the financial risk management practices of central counterparties around the world. Furthermore, we compare European with third-country CCPs to see whether different risk management practices are being applied. Our results indicate that CCPs in the EU require more money to be deposited at a central bank of issue as initial margins compared to non-EU CCPs. The former also demand a higher fraction of prefunded clearing member contributions. In addition, asset segregation is more common at EU CCPs. In terms of investment risk management, EU CCPs prefer to deposit cash at central banks, while non-EU CCPs tend to have cash deposits at commercial banks. European CCPs have almost three times as many liquid resources as non-EU CCPs.

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1. Introduction

At the 26 September 2009 summit in Pittsburg, the G20 expressed its desire for central counterparties (CCPs) to centrally clear standardized over-the-counter derivatives. During the great financial crisis, CCPs indeed functioned as 'shock absorbers' and managed to terminate all financial relations with defaulted clearing members, such as Lehman Brothers, in a quick and orderly manner. From a non-defaulting client perspective, CCPs guaranteed the performance of their trades and assisted in transferring their positions to other clearing members that were still solvent (Gregory, 2014).

Although CCPs are considered as a firewall to prevent the spreading of financial losses across the financial system in case a clearing member defaults and sufficient collateral of the defaulter is available (see Wendt, 2015; Arregui et al., 2015), the opposite situation could also occur where CCPs act as catalysts and cause severe systemic risks. In case one or more clearing members can no longer meet their payment obligations and default, the CCP will have unbalanced exposures because of its outstanding obligations to non-defaulting clearing members. In times of market stress, the CCP might recover only an insufficient amount to cover the costs of liquidation. In this case, additional financial resources beyond the initial margin posted by the non-defaulting clearing member may be necessary, such as contributions to the default fund (Duffie, 2014). Against this background, this paper aims to provide a holistic view of financial risk management practices of central counterparties. This article thus contributes to the finance and market microstructure literature on post-trade risk management (e.g. Milne, 2017) and complements the analyses of Boissel et al. (2015) on the capacity of CCPs to cope with financial crises. Our paper builds further on the emerging literature on the role of CCPs, where CCPs can provide efficient protection against idiosyncratic counterparty risk, while they need be closely monitored for their lack of intrinsic protection against aggregate risk and the spillover effects they may generate (e.g. Biais et al., 2012).

This article is the first to rely on the recent CPMI-IOSCO Public Quantitative Disclosure ("PQD") data that CCPs have been publishing on their websites only since 2016. This data makes it possible to empirically examining counterparty risk management, asset segregation practices, and liquidity risk management of CCPs. The specificities and the granularity of this dataset can provide new insights into the risk management of CCPs compared to what was observed early by scholars. While a limited number of scholars have indeed studied CCPs'

risk management practices, most of them[1] focused only on counterparty credit risk and examined the collateral management of CCPs at the product-level (e.g. CDS, interest rate swaps, and repurchase agreements). This paper departs from this view and offers a much broader picture that allows gathering insights on how CCPs generally manage their counterparty risks, regardless of the type of financial product that they clear.

Furthermore, while Duffie et al. (2015) and Heller & Vause (2012) concentrated on the margins - which they first had to estimate in their studies - our dataset includes both the actual size and composition of default waterfalls (i.e. the initial margins and the default contributions of their clearing members) not suffering from a potential estimation bias. This article also examines haircut decisions that CCPs apply to the received collateral received to cover their counterparty credit risk exposure. This granularity allows us to measure the actual protection of CCPs against both the default of a clearing member and the default risk of the CCPs. In addition, we further analyze the level of asset segregation that CCPs offer, thereby investigating whether the assets (i.e. collateral) of the clearing members are sufficiently protected against the default of another clearing member or the CCP itself.

Another issue of financial risk management is liquidity risk. Since CCPs are required to invest the financial resources they receive from their clearing members in high-quality assets and must be able to promptly use the pre-funded default resources, we analyze whether CCPs invest in high-quality liquid assets that can be readily available. In that sense, the investment risk and liquidity risk of CCPs are closely intertwined. As CCPs are systematically important institutions, it is of utmost importance that they also manage their liquidity requirements adequately and have sufficient liquidity reserve capacity in case of an emergency (see Van Cauwenberghe, 2015). If a clearing member defaults or certain members do not provide their margins on time, the CCP has an obligation to continue making payments to non-clearing members and must therefore have sufficient financial resources to do so (Parkinson, 2014). Accordingly, we empirically analyze the amount of liquid resources directly available to CCPs.

Besides investigating the financial risk management of CCPs, our paper further contributes to the literature by taking a global perspective, thereby comparing European CCPs with CCPs from outside the EU. A comparison of CCPs across the globe could provide insights on which CCPs are more prudent or which CCPs are obliged to impose stricter requirements on

[1] Heller & Vausse (2012), Sidanius &Zikes (2012), Duffie et al. (2015), and Boissel et al. (2017).

clearing members because of e.g. market risk being more prevalent in their countries.[2] These insights could also help legislators and regulators to assess whether a one-size-fits-all approach is useful or whether a targeted supervisory approach is more effective. ESMA (2013) has published detailed legal analyses comparing EU and third-country legislation in the context of the recognition decisions of third-country CCPs. These legal analyses indicate that, although some non-EU CCPs appear to have equivalent risk management practices, there may be differences between CCPs established in a country of the European Union and those that are not. To the best of our knowledge, their legal analyses have never been confronted with empirical data as most studies are country-specific[3] and have not compared CCPs established in different countries. Our null hypothesis is thus that CCPs in the EU have different risk-management practices than their non-European counterparts. To carry out this test, we compare CCPs with regard to their credit, market, and liquidity risk management together with their level of asset segregation.

Our findings are consistent with the null hypothesis, as the PQD data shows that the risk management of EU CCPs differs significantly from that of CCPs outside the EU. While our empirical results find no significant difference for the size and composition (i.e. the percentage of initial margin) of the default waterfall between the two groups of CCPs, EU CCPs require significantly more cash deposits at a central bank of issue and secured cash deposited at commercial banks relative to non-EU CCPs, which accept more unsecured cash deposits at commercial banks. As a result, EU CCPs face a smaller need to impose stringent haircuts. Regarding the level of segregation, omnibus and individual client segregation are significantly more common among CCPs in the EU.

The remainder of this article is organized as follows. Section 2 provides a literature review and explains the benefits and risks of central clearing for the reader to detail why CCPs' risk management is of utmost importance to reach these benefits. Section 3 explains the risk

[2] Our main goal is to examine whether EU CCPs are significantly different compared to non-EU CCPs without attempting to proof that certain CCPs, like the European ones, are more prudent. The main reason is that many dependent variables, such as the default fund contribution and initial margins (see infra) could both be the result of a- more prudent and severe risk management, c) the level of accuracy of the margin and/or default fund methodology, c) the consequence of e.g. the clients of the CCPs being more risky thereby inducing CCPs to ask for more collateral, and/ or both. Indeed, CCPs that succeed in estimating future potential losses more accurately might afford to request lower initial margins and default fund contributions not making them necessary less prudent. In addition, we do not have information on e.g. the client base of the CCPs and thus the underlying drivers of the observed variables in our database. To answer the question on whether EU CCPs are more prudent than non-EU CCPs, we have to get more insights into the drivers of the independent variables, which data is currently not available.

[3] Duffie et al. (2015) and Loon & Zhong (2014) focus on the US while Boissel et al. (2017) investigate the European case.

management processes of CCPs required by the European EMIR regulation. Section 4 discusses the arguments relating to the difference in risk management practices between European and third-country CCPs, while Section 5 introduces our empirical strategy to analyze this difference. Section 6 describes the CPMI-IOSCO PQD data and Section 7 presents our empirical results. In that section, we explore the size and composition of the default waterfall, the level of asset segregation that CCPs offer to their clearing members, the investments of CCPs, and the size and composition of their liquidity resources. Section 8 presents our multivariate logistic regression results. Finally, Section 9 concludes.

2. Literature review and benefits of CCPs

The benefits of CCPs for clearing members in terms of reducing counterparty risk have been extensively documented by e.g. Bernanke (1990), Biais et al. 2012, Koeppl et al. 2012, and Loon & Zhong (2014). Bilateral contracts are novated to the CCP, facilitating multilateral netting of exposures (Ripatti, 2004). This multilateral netting between multiple counterparties reduces the total credit exposure in the market, as the number and values of outstanding settlements (deliveries of assets and corresponding payments) between various parties decreases. By concentrating credit risk, CCPs isolate the effects of a potential bankruptcy of a market participant.

The concentration of credit risk is beneficial for market participants, but leads to an exposure for the CCP until the transaction is finally settled. In case a clearing member is no longer able to meet its margin obligations, the CCP will have unbalanced exposures due to its outstanding obligation to the non-defaulting clearing member on the other end of the contract. In that situation, the CCP has to take an identical position to that of the clearing member that defaulted to eliminate this risk of suffering replacement costs and to return to a matched book (e.g. Russo et al., 2002; Plata, 2017). The CCP eliminates its outstanding positions via an auction amongst the non-defaulting clearing members and/or through hedging (Wendt, 2015). These actions reduce the CCP's risk exposure to changes in the market value of its outstanding positions with the defaulted clearing member.

Especially in times of market stress[4], the recoverable amount could be insufficient to cover the liquidation costs. In that case, additional financial resources over the initial margin - such

[4] When selling long positions to (or buying short positions from) surviving clearing members in an auction process, it could happen that asset prices have moved adversely, especially in case of severe market volatility. In case the CCP needs to sell assets, the prices provided to them in the auction by the non-defaulting clearing

as contributions to the default fund - may be required (Duffie, 2014). When the defaulted clearing member's default fund contributions are also exhausted, the CCP may need to use its assessment rights, after using its skin-in-the-game, to guarantee its survival (see infra). In that case, non-defaulting clearing members would be required to commit additional financial resources, which might have negative effects on their own solvency. If these clearing members in turn default because of the increased amount of collateral they have to post, the actions of the CCP have resulted in a spreading of a financial disease, called procyclicality[5].

Considering this financial stability risk, various national and international legislations, such as the US Dodd-Frank Act and the European Market Infrastructure Regulation (EMIR) entered into force. These regulations impose various conduct and prudential requirements on CCPs to keep them financially sound and protect their clearing members. In this respect, legislators put a special focus on CCPs' default management processes in case one or several clearing members defaults. One of the main objectives is to avoid the spreading of financial losses and alleviate market contagion.

3. CCP's financial risk management: EMIR requirements

The main objective of this part is to describe CCPs' financial risk management according to the requirements of the European Market Infrastructure Regulation (EMIR).[6] These requirements, applicable to EU CCPs, can then serve as a benchmark when comparing EU CCPs with non-EU ones in line with the practice of the European Commission when deciding whether to recognize a third-country CCP. This part is divided into four subsections dealing with credit risk, investment risk, asset segregation, and liquidity risk.

3.1. Counterparty (credit) risk management

EMIR considers margins[7] as one of the primary lines of defense for CCPs to manage their credit exposures vis-à-vis their clearing members. CCPs have to impose, call, and collect

members could have dropped to almost zero. In case of a buy transaction, clearing members could ask prices exceeding the CCP's available resources.

[5] Over the last five years, two CCPs (i.e. Nasdaq Clearing in Europe and KRX in Korea) experienced clearing member defaults that exceeded the defaulted clearing members' contributions. The CCPs launched cash calls to their non-defaulting clearing members, thereby spreading financial losses.

[6] Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4 July 2012 on OTC derivatives, central counterparties and trade repositories.

[7] In case of initial margins, a clearing member transfers or pledges cash or securities with the CCP. In case the clearing member defaults, the CCP is able to keep the posted margins to offset losses that the clearing member caused. In this article, we focus on initial margin requirements rather than on variation margin requirements because initial margins are designed to protect a CCP against losses resulting from a clearing member's default and to cover the future exposures that would arise if the CCP fails to fully liquidate or replace the defaulted clearing member's trading positions (Gregory, 2014). Variation margins, however, are calculated on e.g. a daily

sufficient initial margins to cover, at least daily, potential exposures that CCPs estimate to occur until the liquidation of the relevant positions.

EMIR does not prescribe any methodology to compute initial margins, but their evaluations should comply with specific requirements in their base components. Specifically, initial margins must be large enough to cover a) losses resulting from at least 99% of the exposure movements of financial instruments other than OTC derivatives, and b) losses resulting from at least 99.5% of the exposure movements of OTC derivatives. The methodology to calculate the initial margins should used data over a historical period of at least 12 months to capture a full range of market conditions including stressed periods. The liquidation period (i.e. the period during which CCPs sell the outstanding positions via e.g. auctions) that the methodology should incorporate has to be at least five business days for OTC derivatives and two business days for other financial instruments. In case of OTC derivatives where transactions are more illiquid, the legislators took into consideration that the CCP will need a longer period to close out its positions. Initial margins are not allowed to be compromised by the existence of a highly competitive environment. In practice, most CCPs use Value-at-Risk, Expected Shortfall, or Standard Portfolio Analysis (SPAN) calculations to comply with the EMIR requirements (Hull, 2012).

The collateral that CCPs can accept from their clearing members has to be highly liquid with minimal credit and market risk. Examples are cash, government bonds, and guarantees callable on first demand granted by a central bank. Covered bonds, gold, or commercial bank guarantees are also acceptable, but under strict conditions. Commercial bank guarantees can be eligible after a thorough assessment of the issuer and the legal, contractual, and operational framework of the guarantee. CCPs may accept the underlying asset of the derivative contract or the financial instrument that originates the exposure as collateral, when appropriate and sufficiently prudent.

When the CCP needs to liquidate collateral in stressed market conditions, its recoverable amount can be lower than its initial value. Hence, CCPs need to apply adequate haircuts[8] to asset values that may potentially decline over the interval between their last revaluation and

basis in response to changes in the market value of the respective positions and are used to cover market price movements of the cleared financial instruments. The CCP acts as an intermediary and passes the variation margins to the counterparties thereby bearing no market risk. Variation margins are not used for every type of financial instrument.

[8] A haircut is a discount applied to the value of the margin or default fund contribution to account for the fact that collateral's value could decrease over time. A haircut of e.g. 2% means that only 98% of the value of the security will be counted as margin or default fund contribution.

the time by which they can reasonably be liquidated. EMIR requires CCPs to consider various criteria when determining haircuts, such as the asset type, the maturity of the asset, the historical and hypothetical future price volatility of the asset in stressed market conditions, the wrong-way risk,[9] and the liquidity of the underlying market.

When setting and revising the requested margins from their clearing members or changing haircuts, CCPs must ensure that the margin methodology considers potential procyclical effects. When the CCP would suddenly change e.g. the confidence interval, liquidation period, or lookback period in its margin methodology to deal with increased market stress, this could lead to a big step change in required initial margins. In turn, clearing members would suddenly face a cash outflow potentially leading to financial difficulties. For initial margins to be anti-procyclical, ESMA published in 2018 guidelines stressing that e.g. CCPs should keep in their margin methodology a 25% weight devoted to stressed observations in the lookback period or have to include margin floors based on a 10-year lookback period.

To limit their credit exposures towards their clearing members even further, CCPs are obliged to maintain pre-funded default funds to cover the default losses that may exceed their margin requirements. CCPs need to determine criteria to determine clearing members' contributions to the default fund, which must be proportional to their exposures but have to be of a minimum size. The default fund has to be large enough to enable CCPs to withstand, under extreme but plausible conditions, the default of their clearing member to which they have the largest exposures or of the second and third largest clearing members, if the sum of their exposures is larger. CCPs can establish more than one default fund for the different classes of instruments they clear.

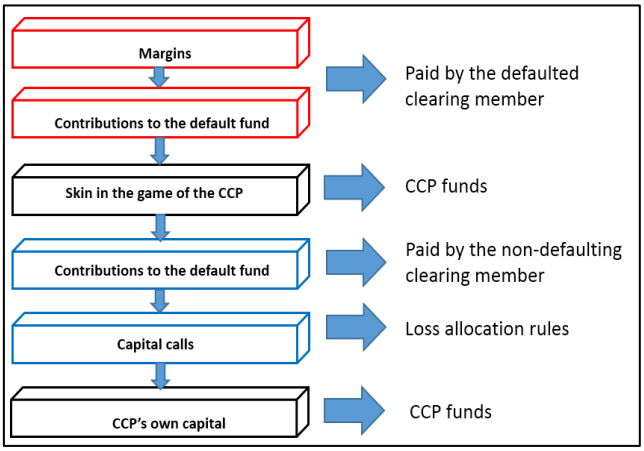
In addition to the margins and default fund contribution of clearing members, CCPs need to maintain sufficient pre-funded available resources to cover additional losses. These financial resources, called 'skin-in-the-game', have to remain freely available and CCPs need to have these on top of their capital requirements. Skin-in-the-game can be considered as an extra capital buffer above the regulatory capital and has to be equal to at least 25% of the latter. In Europe, the default fund and the skin-in-the-game have to be sufficiently large to withstand the default of at least the two clearing members to which the CCP has the largest exposure under extreme but plausible conditions. As explained by Duffie (2014), CCPs having more

[9] Wrong-way risk occurs when e.g. the value of the collateral is negatively correlated with the default of the clearing member posting it. An extreme example would be a clearing member posting its own emitted shares or bonds.

skin-in-the-game have more incentives to impose sufficient margin requirements on their clearing members and to monitor their financial solvency. These CCPs have more capital at stake, which they may want to protect by increasing their monitoring of the financial health of their clearing members.

The EMIR regulation requires European CCPs to maintain default management processes using pre-funded and committed resources from clearing members and themselves. Although default waterfalls can somewhat differ amongst CCPs, a typical default waterfall that is EMIR compliant is shown in Figure 1.

Figure 1 Example of a default waterfall process. Source: Priem (2018).



In the event of a clearing member default, a CCP has to first use the initial margins posted by that defaulting clearing member. When these deem to be insufficient to cover the losses, the CCP needs to use the default fund contributions of the defaulting clearing member. When also these contributions are fully exhausted, the CCP can use its skin-in-the game first followed by the pre-funded contributions of the non-defaulting clearing members, which shows the beginning of the loss mutualization. The default losses that a surviving clearing member then incurs are not directly related to its own transactions. However, CCPs cannot use the margins of non-defaulting clearing members to cover losses resulting from a defaulted clearing member.

When the CCP is still facing losses, it can use its assessment rights and require non-defaulting clearing members to commit additional financial resources. These assessment rights are typically included in their rulebooks and are thus contractually agreed with clearing members. Yet, clearing members must have limited exposures towards CCPs, which implies that the latter cannot use their assessment rights in an unlimited manner. As discussed by

Duffie (2014) and Cont (2015), an obligation to make unlimited guarantee-fund replenishment payments during a crisis could destabilize clearing members and their clients, thereby having procyclical effects. When also these assessment rights deem insufficient, CCPs have to use their own capital since EMIR imposes an obligation on CCPs to have sufficient capital to ensure adequate protection against market, credit, operational, legal, and business risk.

3.2. Asset segregation requirements

The requirements described above show a clear hierarchy between the resources a CCP can use to cover losses. EMIR imposes an obligation on CCPs to keep separate records and accounts enabling them to distinguish the assets and positions held for the account of one clearing member from the assets and positions held for the account of any other clearing member and from its own assets. Accordingly, CCPs need to offer their clearing members the choice between omnibus client segregation and individual client segregation.

In case of omnibus segregation, a CCP has to enable each clearing member to distinguish its accounts from those held for their respective clients. This segregation method ensures that the margins of the clients of one clearing member are not exposed to losses on accounts from other clearing members. However, it puts clients' margins at risk in the event of a default of another client of the clearing member whose margins were posted on that same account. Individual client segregation is available when clearing members distinguish, in the accounts with the CCP, the assets and positions held for the account of a client from those held for the account of other clients. CCPs can thus only use the margin of a client posted on such an account to cover losses related to the default of that particular client.

Upon request, the CCP thus needs to offer the possibility to open more accounts in the name of the clearing member, or for the accounts of their clients. Commingling margins exposes clients to the default risk of the other parties involved (see Velonis, 2013). However, it has the advantage that clearing members or their clients need to post fewer initial margins, as some clients' positions are likely to cancel each other out when being comingled (Braithwaite, 2016). In addition, individual client segregation is more expensive and clearing members might thus need to make a trade-off between a higher level of investor protection and clearing costs. Because the default risk of clearing members also depends on e.g. their national insolvency and securities laws, European legislators offered the choice to clearing members rather than impose a particular level of asset segregation.

3.3. Investment risk management

EMIR allows CCPs to invest e.g. the margins they receive from their clearing members. However, they have to make sure that they are adequately protected and can be returned promptly. Indeed, CCPs typically do not assume market risk in their capacity as a central counterparty, but they are exposed to this type of risk for the investment of the collateral and their own funds (Russo et al., 2002). To reduce their investment risk to the largest extent possible, CCPs' financial resources obtained from their clearing members, as well as their own resources, can only be held in cash (deposits) or invested in highly liquid financial instruments with minimal market and credit risk. CCPs must ensure that they can rapidly liquidate their investments with minimal adverse price effects. As such, CCPs' cash deposits have to be held at authorised financial institutions through highly secured arrangements. Alternatively, CCPs can use central bank deposit facilities or other comparable means provided by central banks. CCPs cannot invest initial margins and default fund contributions in their own securities or those of their parent undertakings or subsidiaries.

3.4. Liquidity risk management

In addition to the resources obtained from the clearing members and the CCP's skin-in-the-game, EMIR requires CCPs to have access to sufficient liquidity to perform their services and activities at all times. CCPs' liquidity risk management frameworks have to be robust to ensure the effectiveness of payment and settlement obligations in all relevant currencies as they fall due. A liquidity framework must also include the assessment of the CCP's future liquidity needs under a wide range of potential stress scenarios. CCPs must not only assess the liquidity risk they face in case they or their clearing members cannot settle their payment obligations in a timely fashion, but also need to consider the level of liquidity of their own investment activity.

To fulfill their liquidity requirements under EMIR, CCPs must obtain the necessary credit lines or similar arrangements to cover their liquidity needs in case the financial resources at their disposal are not immediately available. Ideally, cash deposited at central banks of issue is used, but EMIR also allows creditworthy and reliable commercial bank liquidity when CCPs sufficiently consider the risks. CCPs can also borrow from clearing members or group companies, but this cannot be more than 25% of the credit lines obtained by the CCP. When measuring their potential liquidity needs, CCPs have to take into account the liquidity risk

generated by the default of at least the two clearing members to which they have the largest exposures.

4. Are European CCPs significantly different compared to their third-country peers?

In this section, we provide arguments supporting our claim that European CCPs are significantly different in terms of risk management compared to their third-country peers. Although CCPs from all over the world need to adhere to the CPMI-IOSCO Principles for Financial Market Infrastructures, ESMA (2013) provides evidence, in its technical advice on third-country regulatory equivalence under EMIR, that third-country CCPs domiciled in e.g. the USA, Hong Kong, Japan, and Singapore are adhering to regulations that are equivalent as EMIR[10]. Yet, ESMA's legal analysis indicates that they do not seem to follow the same requirements. Empirical analyses are thus useful to examine whether there is truly a significant difference amongst the various CCPs.

Regarding the USA, ESMA (2013) and Cerulus (2012) stress that CCPs authorised in the USA[11] comply with legally binding requirements that are equivalent to EMIR. However, EMIR is generally found more prescriptive on a couple of aspects. For instance, the Commodity Futures Trading Commission (CFTC) and the Securities and Exchange Commission (SEC) regimes require CCPs to use at least a 99% confidence interval in their margin methodology, whereas EMIR requires a 99.5% interval for OTC derivatives, unless the latter have the same risk characteristics as derivatives executed on a regulated market. US CCPs are not required to consider procyclical effects. In case of portfolio margining,[12] they are not limited to a maximum reduction of 80% of the difference between the sum of the initial margins for each instrument calculated on an individual basis and the initial margins based on a combined estimation of the exposure for the combined portfolio. Concerning the type of collateral that CCPs can accept, the CFTC and SEC regimes do not specifically address whether US CCPs may accept the underlying asset of a derivative contract or the

[10] In those countries, there might exist CCPs' internal rules and procedures forming an integral part of the legal and supervisory arrangements, but no information was provided on those.

[11] In the USA, depending on the type of assets being cleared, CCPs are registered and supervised by the CFTC as derivatives clearing organizations (DCO), thereby following the US Commodity and Exchange Act, and/or with the SEC as clearing agencies following the Exchange Act. The Federal Reserve is tasked with the supervision and regulation of systemic market infrastructures and financial stability.

[12] CCPs can offset or reduce the required margins across instruments which they clear if the price risk of one of the instrument is significantly and reliable correlated to the price risk of the other financial instruments (see ESMA, 2017).

financial instrument that generates the exposure to them as collateral. US CCPs are also not required to demonstrate that they conservatively calculated adequate haircuts.

Regarding the size of the default fund, US CCPs must maintain sufficient financial resources to meet their financial obligations to their clearing members, notwithstanding a default of the clearing member creating the largest financial exposure for them. EMIR is more prescriptive, as the CCPs' default funds must also enable them to withstand the default of the clearing member to which the CCP has the second and third largest exposures, if the sum of their exposures are greater than the clearing member to which the CCP has the largest exposure. US CCPs are not specifically required to apply the same default waterfall sequence as prescribed under EMIR. According to Armakolla and Laurent (2017), the provision of skin-in-the-game is mandatory in the European Union, but not in the USA.

Furthermore, EMIR is more detailed regarding the segregation requirements compared to US law. Regarding investment risk management, ESMA (2013) concludes that the CFTC regime is not as strict as EMIR concerning the financial instruments that are considered highly liquid. This implies that US CCPs might invest in financial instruments that would not be permissible under EMIR. Concerning liquidity risk management, EMIR is also more prescriptive, as EU CCPs must maintain sufficient liquidity to fulfill their settlement obligations as they fall due, which could be intraday. US CCPs, however, must maintain liquidity to fulfill their obligations during a one-day settlement cycle.

Not only compared to the USA can European legislation for CCPs be seen as more prescriptive. For CCPs domiciled in Hong Kong[13] and Japan[14], the applicable regulation is less prescriptive than the ones for EU CCPs. CCPs in Hong Kong and Japan are not specifically required to call and collect margins on an intraday basis when predefined thresholds are exceeded. Qualified and independent parties or authorities also do not need to validate their margin models. When calculating the initial margins, they are not required to use a specific confidence interval nor to use historical volatility data from at least the latest

[13] CCPs in Hong Kong are supervised by the HKMA and the SFC. The HKMA is responsible for maintaining monetary and banking stability, while the SFC has the duty to foster orderly securities and future markets, protect investors, reduce systemic risk and maintain financial stability. The Clearing and Settlement Systems Ordinance (CSSO) and the Securities and Futures Ordinance (SFO) are the main legal texts.

[14] CCPs in Japan are supervised by the Japan Financial Services Agency (JFSA), which is responsible for the prudential and conduct regulation of deposit-takers, insurers, and market participants. The Bank of Japan (BoJ) has the responsibility to oversee financial system stability, payments, and clearing and settlement systems. The Financial Instruments and Exchange Act (FIEA) of 2006 establishes the supervisory framework for CCPs clearing securities and financial derivatives. The Commodity Derivatives Act (CDA) of 2009 provides the supervisory framework for CCPs clearing commodities.

12-month period that captures a full range of market conditions, including periods of stress. Even more, CCPs in Hong Kong and Japan are not required to take into account the procyclical effects of revisions to their margin levels. No requirements are in place for these CCPs to only accept highly liquid assets as collateral.

Concerning the default waterfall, CCPs domiciled in Hong Kong and Japan are not specifically required to apply the same default waterfall sequence as prescribed under EMIR for EU CCPs. They are also not required to include a prescribed amount of skin-in-the-game. CCPs in Hong Kong and Japan need to manage their investment risk, but they are not obliged to invest only in highly liquid assets. Even more, they are not required to deposit cash collateral at a central bank and can invest in their own securities. Also regarding liquidity risk management, these CCPs do not need to take the default of the two clearing members to which they have the largest exposure into account. CCPs in Hong Kong and Japan are subject to an omnibus segregation regime, while EMIR imposes EU CCPs to offer the choice between omnibus and individual client segregation.

Concerning Singapore, we can draw the same conclusions as for Hong Kong and Japan, although the legislation differs in that CCPs in Singapore[15] need to adhere to segregation requirements equivalent to those of EMIR.

5. Variables and model

To examine whether the risk management of EU CCPs is significantly different from those outside the EU, we run, besides univariate tests, binomial logit models with the 'EU' dependent variable coded one for a CCP domiciled in the European Union, and zero otherwise.[16] Logistic regression is a standard probabilistic statistical classification model being used extensively across multiple disciplines. The methodology's main goal is, based on several criteria, to classify or discriminate between one or several groups. The model requires the dependent variable to be nonmetric and the independent variables to be metric. Hence, it is used for predicting the outcome of a categorical variable based on one or more predictor variables (Liu et al., 2014).

[15] In Singapore, the regulation and supervision of financial market infrastructures are entrusted to the MAS, which is Singapore's central bank and financial sector regulator. The MAS' responsibilities are stated in the Securities and Futures Act (SFA).

[16] In this analysis, the UK CCPs are still considered as being European CCPs, given that their data dates back from when the UK was part of the European Union and UK CCPs were obliged to follow the EMIR requirements.

In this article, the question is then also to, given the observed risk-characteristics of the CCPs under consideration, to accurately classify them into EU and non-EU groups. One major advantage of using logistic models for discriminant analysis (rather than a linear discriminant function, which we use as a robustness check; see infra) is that these are less prone to underlying assumptions, such as a jointly normal distribution and equal covariance matrices of the independent variables (see Press and Wilson, 1978). As the level of the independent variables is likely to be correlated and driven by the applicable legislation, a logistic regression model being more robust seems most suitable to address our research question.[17] The independent variables are being displayed in Table 1.

Table 1 Dependent and explanatory variables.

This table displays the measurement of all dependent and explanatory variables. The last column reports their expected sign in our multivariate regression model. The numbers in the table refers to the fields of the CPMI-IOSCO PQD framework.

Dependent variable	**Definition**
EU	Dummy variable that equals one for a CCP domiciled in the European Union, and zero otherwise.
Explanatory variables	
Credit risk	
TOTAL DWF	The natural log of the total default waterfall, including all held post-haircut initial margins and (prefunded and committed) default fund contributions of clearing members and the CCP (4_1_1 + 4_1_2 + 4_1_3 + 4_1_5 + 4_1_6 + 4_1_7 + 4_1_8 + 4_1_9 + 4_1_10 + 6_2_15).
PERCIMDF	The percentage of initial margin (6_2_15) being part of the default waterfall (TOTAL DWF).
HAIRCUT DF	The percentage haircut applied, calculated as (the total pre-haircut value of default resources (4_3_15) – the total post-haircut value of default resources (4_3_15)) divided by the total pre-haircut value of default resources (4_3_15).
HAIRCUT IM	The percentage haircut applied, calculated as (the total pre-haircut amount of initial margin held (6_2_15) – the total post-haircut value of initial margin held (4_3_15)) divided by the total pre-haircut amount of initial margin held (4_3_15).
Asset segregation	
OMSEGR	The percentage of total client positions held in omnibus accounts (14_1_2).
INDSEGR	The percentage of total client positions held in individually segregated accounts (14_1_1).
LSOCSEGR	The percentage of total client positions held in legally segregated but operationally comingled (LSOC) accounts (14_1_3).
NOSEGR	The percentage of total client positions held in comingled house and client accounts (14_1_4).
Investment risk	
CASHDEPCBI	The percentage of total clearing member cash held as cash deposits at central banks of issue of the currency deposited (16_2_2).
Liquidity risk	
LIQUID RESOURCES	The natural log of the sum of the amount of cash deposited at a central bank of issue of the currency (7_1_2), cash deposited at other central banks (7_1_3), secured cash deposited at commercial banks (7_1_4), unsecured cash deposited at commercial banks (7_1_5), secured committed lines of credit including committed foreign exchange swaps and committed repos (7_1_6), unsecured committed lines of credit (7_1_7), highly marketable collateral held in custody and investments that are readily available and convertible into cash with prearranged and highly reliable funding arrangements (7_1_8), other liquid resources (7_1_9), and supplementary liquidity risk resources (7_2_1).
Control variables	
EQUITY	Dummy variable that equals one for a CCP that clears equity transactions, and zero otherwise.
FIXED INCOME	Dummy variable that equals one for a CCP that clears fixed income transactions, and zero otherwise.

[17] As the legislations, being different between EU and non-EU CCPs, have an influence on the independent variables, we acknowledge that a potential reverse causality issue might be present, leading to biased standard errors and significant tests somewhat higher (see O'Neil Shermer et al., 2012). In order to rule out that endogeneity issues drive our results, we conducted detailed univariate tests as well as sensitivity tests (e.g. discriminant analyses and random forest analyses). Although the latter might suffer from similar issues, which we cannot completely rule out, the multitude of different tests point out to the same conclusions.

COMMODITYDER	Dummy variable that equals one for a CCP that clears commodity derivatives, and zero otherwise.
FXDER	Dummy variable that equals one for a CCP that clears FX derivatives, and zero otherwise.
INTERESTDER	Dummy variable that equals one for a CCP that clears interest rate derivatives, and zero otherwise.
OTHERINSTR	Dummy variable that equals one for a CCP that clears other financial instruments, such as credit default swaps, and zero otherwise.
MEDIUMCONCAV	For clearing services with 25 or more members, the percentage of open positions held by the largest five clearing members whereby the average over the quarter is taken.
AVVALUE	The natural log of the average daily notional value of cleared trades (23_1_2).
TOTASSETS	The natural log of the total assets of the CCP (15_2_4)
NUMBERGCM	The natural log of the number of general clearing members (18_1_1)

We use proxies for the counterparty credit risk, asset segregation, investment risk, and liquidity risk management of CCPs based on the data available in our PQD database. Our hypothesis that EU CCPs are significantly different compared to their non-EU peers is analyzed by running the following regression:

$$\begin{aligned} \text{EU} = {} & \beta_0 + \beta_1 TOTALDWF + \beta_2 PERCIMDF + \beta_3 HAIRCUT\ DF + \beta_4 HAIRCUT\ IM + \beta_5 OMSEG + \beta_6 INDSEGR + \beta_7 CASHDEPCBI \\ & + \beta_8 EQUITY + \beta_9 FIXED\ INCOME + \beta_{10} COMMODITYDER + \beta_{11} FXDER + \beta_{12} INTERESTDER + \beta_{13} MEDIUMCONCAV + \varepsilon \end{aligned} \quad (1)$$

Related to the size and composition of the default waterfall, we use the total size of funds in the default waterfall (TOTAL DWF), the fraction that initial margins represent of the total default waterfall (PERCIMDF), and the haircuts that are applied to the default fund contributions (HAIRCUT DF) and initial margins (HAIRCUT IM). If EU CCPs are different from non-EU CCPs regarding counterparty risk management, we expect to observe a significant influence of these variables on EU.

In addition to the counterparty credit risk variables, we construct OMSEGR, INDSEGR, LSOCSEGR, and NOSEGR to capture the level of asset segregation, and thus the level of protection of non-defaulting clearing members. We compute these variables as the percentage of total client positions held in omnibus, individual segregated, legally segregated but operationally commingled (LSOC), and completely comingled house and client accounts, respectively.[18] Keeping in mind that segregation is an important method to protect the collateral of clearing members and their clients in case of a default, we expect a significant impact for these variables is EU CCPs are different with respect to asset segregation than non-EU ones.

[18] In Europe, EMIR only allows form omnibus and individual client segregation. No segregation would namely give no or little protection of the posted initial margin, as the client would be fully at risk by the failure of the CCP or other clearing members. LSOCSEGR and NOSEGR are reporting field, however, in the CPMI-IOSCO PQD data. Legally segregated but operationally comingled (LSOC) accounts are mostly used in the USA where the exposure of each client is tracked and legally segregated but not operationally segregated on e.g. different accounts. The main goal of LSOC is thus to protect against fellow client default risk without losing the operational benefits of combining client accounts. Indeed, the maintenance of separate accounts is more costly, which is avoided in case of LSOC accounts.

To examine whether EU CCPs are significantly different with respect to investment risk management, we construct CASHDEPCBI, which is the percentage of total clearing members' cash held as cash deposits at central banks of issue of the currency. This variable namely measures the most liquid type of funding a CCP might have. Furthermore, we proxy for how CCPs manage their liquidity risk by constructing the LIQUID RESOURCES variable, which is the total amount of liquid resources readily available to CCPs. If EU CCPs are different from their non-EU peers, CASHDEPCBI and LIQUID RESOURCES should have a significant impact on EU.

As for the control variables, we account for the fact that there exists a significant level of diversity in terms of financial products being cleared. Some CCPs are specialized and only deal with a single asset class, such as equities or commodity derivatives, while others clear a broad spectrum of financial instruments. The asset class, however, determines e.g. the initial margin and haircut methodology of a CCP, as these take the fluctuation of the prices of the assets (volatility) into consideration. Indeed, the larger the volatility of security prices - which is dependent on the asset class that the CCPs clear - the larger the tail risk, and thus the level of initial margins and default fund contributions that the CCPs need to ask from their clearing members (see Gregory 2014). Controlling for the asset classes that the CCP clears will rule out that the explanatory variables of interest merely reflect CCPs' business activity rather than their risk management practices.

Also, we control for the concentration risk that CCP face with MEDIUMCONCAV, which is the percentage of open positions held by the largest five clearing members for clearing services with 25 or more members.[19] CCPs' clearing members that clear a large portion of a given asset need to pay additional margin to cover the cost of closing out the concentrated position in case they would default (ISDA, 2019). As CCPs need to take their concentration risk into account when constructing their margin models, not controlling for the concentration risk of a CCP could lead to a situation where the margin and default fund variables reflect concentration risk rather than credit risk management. In addition, certain CCPs could opt to be less stringent on their margin calls in case the risk is spread over numerous accounts compared to when there is a large concentration risk. By controlling for concentration risk, we improve the construct validity of our variables.

[19] The data that is provided by CCPs on concentration is at the clearing service level and not at the CCP level. Hence, the figures needed to be aggregated to compute the estimate of concentration.

Furthermore, we control for the size of the CCP, which might influence a CCP's credit, liquidity, and investment risk. According to the ESRB (2017), initial margins and default fund contributions are related to the amount of risk generated by the transactions submitted for clearing, which therefore reflect the scale of a CCP's activity from the perspective of counterparty credit risk mitigation. In order thus to rule out that e.g. TOTAL DWF suffers from validity issues by capturing the size of the CCP rather than the total funds available to address credit risk, the size of the CCP should be controlled for. We use three proxies measuring different aspects of CCP size: a) the value of transactions submitted to a CCP for clearing (AVVALUE)[20], b) the total assets of the CCP (TOTASSETS), and c) the number of (general) clearing members (NUMBERGCM).[21] The latter is indeed a proxy for the size of the CCP as CCPs with more stringent membership requirements may be perceived as smaller CCPs because of fewer clearing members using their service (see ESRB, 2017).

6. Data

This study relies on a global sample of CCPs using the CPMI-IOSCO public quantitative disclosure (PQD) framework. Under this framework, CCPs need to provide quantitative disclosures on a principle-by-principle basis against the CPMI-IOSCO Principles for Financial Market Infrastructures (except for those for which quantitative disclosures are not applicable). Since December 2015, CCPs have been publishing their quarterly data on their websites for the users to obtain a macroprudential view of e.g. CCPs' margin and haircut requirements, investment policies, liquidity risk management as well as concentration risk exposures (ESRB 2018). According to CPMI and IOSCO, this disclosure will allow stakeholders (i.e. authorities, clearing members, and the public) to compare CCPs' risk controls and gain a clear understanding of the risks associated with using a specific CCP.

We ended up with a final sample of 35 CCPs providing quarterly information over the period Q3 2015 until Q3 2018, leading to 408 observations, after applying the following sample selection criteria. First, we analyzed the public websites of 68 CCPs located all over the world. These CCPs were found from the ESMA list of authorised and recognised CCPs, the

[20] As no information on the market values that are cleared is available in the PQD data, the size indicator is based on notional values (see ESRB, 2017).

[21] Different membership statutes exist amongst CCPs but they typically have a tiered membership structure in which they restrict participation to a subset of financial institutions that can fulfill their membership requirements. General clearing members are entities that have been approved by the CCP for clearing their own transactions and the transactions on behalf of all of their clients. Direct clearing members are then clearing members that have the right to clear their own transactions and those of a subset of clients, such as affiliated non-clearing members. Indirect clearing members are clients of a general or direct clearing member.

members of CCP12, and the IMF's detailed assessments of CCPs' observance with the IOSCO objectives and principles of securities regulation.

Second, 17 CCPs were removed from the sample as they did not publish the PQD data.. As there is no legal basis to compel CCPs to disclose all the required data, not all CCPs decided to provide it on their website.

Finally, we removed six CCPs that provided the data but in a substantially different format, which made a comparison with the other CCPs likely erroneous. That is, to improve comparability across CCPs, the global Association of Central Counterparties (CCP12) developed a common template for the publication of the PQD data to improve the consistency and standardization of reporting. Most CCPs use the spreadsheet template, but certain CCPs decided to use somewhat different numbering or presentation of the data. All reported figures of non-EU CCPs were converted into EUR by applying the relevant exchange rate at the reporting date.

Table 2 displays the geographical distribution of the sample. The 35 CCPs in our retained sample involve 14 EU CCPs and 21 third-country CCPs. Most non-EU CCPs are located in the United States of America, followed by Canada, Hong Kong, Japan, and Singapore.

Table 2 Geographical distribution of the sample.

This table displays the distribution of the CCPs' country over the period 2015–2018.

CCP Country	N
Australia	1
Austria	1
Brazil	1
Canada	2
France	1
Germany	1
Hong Kong	2
Hungary	1
Italy	1
Japan	2
Poland	1
Portugal	1
Russia	1
Singapore	2
South Africa	1
Spain	1
Sweden	1
Switzerland	1
The Netherlands	2
United Kingdom	3
United States of America	8
Total	**35**

7. Summary statistics

7.1 Univariate analysis of the explanatory variables

Table 3 reports summary statistics on the explanatory variables, both for the full sample and the subsamples of EU and third-country CCPs.[22] The Table also displays the results of parametric *t*-tests, non-parametric Wilcoxon rank-sum tests, and Chi-square test to examine whether the explanatory variables have significant different values for the two groups of CCPs. To limit the influence of outliers, we winsorized variables at 10%–90%.

Table 3 Univariate analysis of the exploratory variables

This table reports summary statistics and univariate results for the explanatory variables both for the full sample and for the subsamples of EU and third-country CCPs. The table also displays the results of parametric *t*-tests, non-parametric Wilcoxon rank-sum tests, and Chi-square tests to examine whether the exploratory variables have significantly different values across these two groups of CCPs. All explanatory variables are winsorized at 10%–90% to remove extreme values in either tail of the distribution. Table 1 presents a definition of all variables. For the variables of which the natural log is calculated, this table provides the results before the log transformation in order to facilitate the interpretation.

Variable	Total Sample		EU CCPs		Third-country CCPs		*p*-value		
	Mean	Median	Mean	Median	Mean	Median	Parametric *t*-test	Wilcoxon rank-sum test	Chi-square test
Credit risk									
TOTAL DWF	14,077,541,033	5,714,550,726	15,838,193,916	6,678,372,756	12,111,097,554	4,761,102,266	0.1947	0.5132	
PERCIMDF	0.7621	0.7730	0.7294	0.7403	0.7987	0.8239	**0.0037**	**0.0044**	
HAIRCUT DF	0.0121	0.0075	0.1087	0.0049	0.0129	0.0087	0.1509	**0.0471**	
HAIRCUT IM	0.0332	0.0237	0.0306	0.0326	0.0352	0.0203	0.1651	0.4324	
Asset segregation									
OMSEGR	0.5940	0.7200	0.8545	0.9458	0.4552	0.3331	**<0.0001**	**<0.0001**	
INDSEGR	0.2491	0.0484	0.1382	0.0542	0.3081	0.0000	**<0.0001**	0.1467	
LSOCSEGR	0.0050	0.0000	0.0000	0.0000	0.0076	0.0000	**<0.0001**	**<0.0001**	
NOSEGR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA	
Investment risk									
CASHDEPCBI	0.3574	0.0626	0.4939	0.5700	0.2300	0.0000	**<0.0001**	**<0.0001**	
Liquidity risk									
LIQUID RESOURCES	12,252,011,537	4,326,651,115	18,147,304,938	4,679,383,827	5,676,491,974	4,198,849,300	**<0.0001**	**0.0003**	
Control variables									
EQUITY	0.5443	1.0000	0.7874	1.0000	0.3529	0.0000			**<0.0001**
FIXED INCOME	0.6000	1.0000	0.7068	1.0000	0.5158	1.0000			**0.0002**
COMMODITYDER	0.6126	1.0000	0.6436	1.0000	0.5882	1.0000			0.3082
FXDER	0.4101	0.0000	0.2873	0.0000	0.5067	1.0000			**<0.0001**
INTERESTDER	0.5392	1.0000	0.5977	1.0000	0.4932	1.0000			**0.0492**
OTHERINSTR	0.5659	1.0000	0.5144	1.0000	0.6063	1.0000			**0.0847**
MEDIUMCONCAV	0.4306	0.4581	0.3827	0.3867	0.4671	0.5063	**<0.0001**	**<0.0001**	
AVVALUE	120,878,832,103	18,662,851,784	90,471,553,381	9,910,291,043	141,283,716,509	31,110,158,281	**0.0592**	**0.0060**	
TOTASSETS	23,756,723,279	1,125,134,772	47,777,564,960	6,308,836,842	5,640,446,033	864,747,000	**<0.0001**	**<0.0001**	
NUMBERGCM	41.01	27.50	46.06	32	36.35	13	**0.0202**	**0.0015**	

To facilitate the reading of the Table, for the variables of which the natural log is calculated, Table 3 displays the results in absolute values (i.e. before the logarithmic transformation).

[22] CCPs can provide the PQD data at three distinct levels: a) at the CCP level aggregating all clearing activities, b) at the default fund level referring to the various default funds that the CCP manages, and c) at the clearing service level in case a CCP covers different clearing services with one default fund (see Armakolla and Bianchi, 2017). In order to compare CCPs that have a diversity of business models with respect to clearing services and the usage of default funds (one for all services or multiple per service), we follow the approach of the ESRB (2018) and aggregate all information at the CCP level.

We observe that the average value of TOTAL DWF equals 14 billion EUR. EU CCPs and third-country CCPs do not significantly differ concerning the size of funds in their default waterfalls. As PERCIMDF averages to 76.21%, initial margins are the main building block of the default waterfall. Interestingly, EU CCPs seem to have, on average, a lower fraction of initial margins compared to third-country CCPs. CCPs, on average, do not impose large haircuts on their default funds (i.e. 1.21%), while the haircuts on initial margins average to around 3%. The statistical tests do not seem to indicate a robust significant difference between the two groups of CCPs.

Regarding the level of asset segregation, CCPs have mostly omnibus segregated accounts (i.e. 59.40%), followed by individual segregated accounts (i.e. 24.91%). LSOC accounts are rarely used and not a single CCP comingles the securities of its clearing members with its own assets. Interestingly, EU CCPs seem to have almost twice as many omnibus accounts compared to third-country CCPs. Given the low values of LSOCSEGR and NOSEGR, these variables are no longer used in the multivariate analyses.

Regarding investment risk management, CASHDEPCBI averages to 35.74% with EU CCPs holding a significantly larger percentage of the collateral they receive from clearing members as cash deposits at a central bank. Regarding liquidity risk management, Table 3 shows a similar pattern for LIQUID RESOURCES where the average CCP has a total of 12 billion EUR of liquid resources available and EU CCPs having almost three times as many liquid resources compared to their third-country peers.

As for the control variables, CCPs clearing equity, fixed income, commodity derivatives, and interest rate derivatives are more prevalent in the European Union, while third-country CCPs clear more FX derivatives and other financial instruments, like credit default swaps, compared to EU ones. In terms of concentration risk, MEDIUMCONCAV has an average value slightly above 40%, in line with the findings of the ESRB (2017). The five largest clearing members thus account for somewhat more than 40% of the open positions. MEDIUMCONCAV takes on significantly larger value for third-country CCPs compared to EU CCPs.

CCPs in our sample clear, on average, for 121 billion EUR a day, where non-EU CCPs have significantly larger values cleared compared to EU CCPs. Yet, EU CCPs seem to be significantly larger in terms of total assets. CCPs have on average 41 general clearing members, with EU CCPs having significantly more of them compared to third-country CCPs.

7.2 Univariate analysis of the composition of the default waterfall

Table 4 provides a more granular comparison of the composition of the default waterfall between EU and non-EU CCPs.

Table 4 Univariate analysis of the composition of the default waterfall

This table examines in more details the composition of the default fund and compares EU CCPs and third-country CCPs in this respect. All represented variables are winsorized at 10%−90% to remove extreme values in either tail of the distribution. The prefunded clearing member contributions are calculated as 4_1_5 divided by TOTAL DWF. The amount of pre-funded skin-in-the-game equals (4_1_1 + 4_1_2 + 4_1_3) divided by TOTAL DWF. Committed clearing member contributions are calculated as (4_1_9 + 4_1_8) divided by TOTAL DWF. Committed own CCP capital is obtained by dividing 4_1_7 by TOTAL DWF. The numbers refer to the fields of the CPMI-IOSCO PQD framework.

Variable	Total Sample		EU CCPs		Third-country CCPs		*p*-value	
	Mean	Median	Mean	Median	Mean	Median	Parametric *t*-test	Wilcoxon rank-sum test
TOTAL DWF	14,077,541,033	5,714,550,726	15,838,193,916	6,678,372,756	12,111,097,554	4,761,102,266	0.1947	0.5132
Composition								
Prefunded clearing member contributions	0.0784	0.0615	0.0856	0.0821	0.0702	0.0226	0.1006	**0.0186**
Prefunded skin-in-the-game	0.0174	0.0022	0.0176	0.0020	0.0172	0.0025	0.9257	0.4795
Committed clearing member contributions	0.1042	0.0978	0.1526	0.1526	0.0507	0.0027	**<0.0001**	**<0.0001**
Committed Own CCP capital	0.0008	0.0000	0.0011	0.0000	0.0005	0.0000	**0.0273**	**0.0035**
PERCIMDF	0.7621	0.7730	0.7294	0.7403	0.7987	0.8239	**0.0037**	**0.0044**

Although EU CCPs have fewer initial margins as part of their default waterfall relative to non-EU CCPs (see table 3), their default waterfall seems to consist more out of prefunded clearing member contributions. The amount of prefunded skin-in-the-game of CCPs is, on average, only 1.74 % of the total default waterfall, which is comparable to the findings of the ESRB (2017). No significant differences between EU CCPs and third-country CCPs exist for this variable. In terms of committed clearing member contributions and committed own CCP capital, EU CCPs have significantly larger percentages compared to third-country CCPs. Table 4 thus indicates that EU CCPs compensate for having a smaller percentage of initial margins by requesting more clearing member contributions.

7.3 Univariate analysis of the form of the pre-funded default fund

Table 5 displays in more detail the form of the pre-funded default fund contributions in terms of the collateral required by CCPs.

Table 5 Univariate analysis of the form of the pre-funded default fund

This table examines in more details the form of the pre-funded default fund (post-haircut) and compares EU CCPs and third-country CCPs in this respect. All represented variables are winsorized at 10%−90% to remove extreme values in either tail of the distribution. The cash deposited at a central bank of issue is calculated as 4_3_1 divided by 4_3_15. Cash deposited at other central banks of issue is generated by dividing 4_3_2 by 4_3_15. Cash (secured) deposited at commercial banks is calculated as 4_3_3 divided by 4_3_15. Cash (unsecured) deposited at commercial banks is obtained by dividing 4_3_4 by 4_3_15. Domestic sovereign government bonds is obtained by dividing 4_3_5 by 4_3_15. Other sovereign government bonds is calculated as 4_3_6 divided by 4_3_15. Agency bonds equals 4_3_7 divided by 4_3_15. State / municipal bonds is calculated as 4_3_8 divided by 4_3_15. Corporate bonds equals 4_3_9 divided by 4_3_15. Equities is obtained by dividing 4_3_10 by 4_3_15. Gold equals 4_3_11 divided by 4_3_15. Other commodities is generated by dividing 4_3_12 by 4_3_15. Mutual funds / UCITS is obtained by dividing 4_3_13 by 4_3_15. Significant test results for average and median values of zero indicate that numbers are smaller than 0.0001 but non-zero. The numbers refer to the fields of the CPMI-IOSCO PQD framework.

Variable	Total Sample		EU CCPs		Third-country CCPs		*p*-value	
	Mean	Median	Mean	Median	Mean	Median	Parametric *t*-test	Wilcoxon rank-sum test
Cash deposited at a central bank of issue	0.2180	0.0000	0.3461	0.3287	0.1140	0.0000	**<0.0001**	**<0.0001**
Cash deposited at other central banks of issue	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Cash (secured) deposited at commercial banks	0.2271	0.0000	0.3461	0.1111	0.1140	0.0000	**<0.0001**	**<0.0001**
Cash (unsecured) deposited at commercial banks	0.2391	0.0231	0.0436	0.0001	0.3922	0.1930	**<0.0001**	**<0.0001**
Domestic sovereign government bonds	0.1959	0.0833	0.1274	0.0501	0.2495	0.1456	**<0.0001**	**0.0016**
Other sovereign government bonds	0.0194	0.0000	0.0391	0.0000	0.0040	0.0000	**<0.0001**	**<0.0001**
Agency bonds	0.0026	0.0000	0.0042	0.0000	0.0014	0.0000	**0.0002**	**0.0039**
State / municipal bonds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Corporate bonds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0362**	**0.0344**
Equities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.4481**	**0.3373**
Gold	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Other commodities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Mutual funds / UCITS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA

Usually, they require as collateral from their clearing members cash deposits at a central bank of issue, secured cash deposited at commercial banks, unsecured cash deposited at commercial banks, and domestic sovereign government bonds. Other sovereign government bonds are rarely accepted and other types of financial instruments, such as state / municipal bonds, corporate bonds, equities, gold, other commodities, and mutual funds, are (almost) not accepted.

When comparing EU and non-EU CCPs, the pre-funded default fund contribution of EU CCPs consists significantly more often of cash deposits at a central bank of issue and secured cash deposited at commercial banks. Third-country CCPs accept relatively more unsecured cash deposited at commercial banks and domestic sovereign government bonds as collateral.

7.4 Univariate analysis of form of initial margins held by the CCP

Table 6 displays in more detail the form / type of initial margins received from clearing members.

Table 6. Univariate analysis of the form of held initial margins

This table examines in more details the format of the held initial margins pre-funded default fund (post-haircut) and compares EU CCPs and third-country CCPs in this respect. All represented variables are winsorized at 10%–90% to remove extreme values in either tail of the distribution. The cash deposited at a central bank of issue is calculated as 6_2_1 by 6_2_15. Cash deposited at other central banks of issue is generated by dividing 6_2_2 by 6_2_15. Cash (secured) deposited at commercial banks is calculated as 6_2_3 divided by 6_2_15. Cash (unsecured) deposited at commercial banks is obtained by dividing 6_2_4 by 6_2_15. Domestic sovereign government bonds is obtained by dividing 6_2_5 by 6_2_15. Other sovereign government bonds is calculated as 6_2_6 divided by 6_2_15. Agency bonds equals 6_2_7 divided by 6_2_15. State / municipal bonds is calculated as 6_2_8 divided by 6_2_15. Corporate bonds equals 6_2_9 divided by 6_2_15. Equities is obtained by dividing 6_2_10 by 6_2_15. Gold equals 6_2_11 divided by 6_2_15. Other commodities is generated by dividing 6_2_12 by 6_2_15. Mutual funds / UCITS is obtained by dividing 6_2_13 by 6_2_15. Significant test results for average and median values of zero indicate that numbers are smaller than 0.0001 but non-zero. The numbers refer to the fields of the CPMI-IOSCO PQD framework.

Variable	**Total Sample**		**EU CCPs**		**Third-country CCPs**		***p*-value**	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Parametric *t*-test**	**Wilcoxon rank-sum test**
Cash deposited at a central bank of issue	0.1083	0.0000	0.1688	0.0542	0.0608	0.0000	**<0.0001**	**<0.0001**
Cash deposited at other central banks of issue	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Cash (secured) deposited at commercial banks	0.1966	0.0157	0.2685	0.1294	0.1405	0.0000	**<0.0001**	**<0.0001**
Cash (unsecured) deposited at commercial banks	0.2565	0.0362	0.0731	0.0037	0.3996	0.1420	**<0.0001**	**<0.0001**
Domestic sovereign government bonds	0.2112	0.1565	0.1895	0.1651	0.2283	0.0266	**0.0820**	0.1806
Other sovereign government bonds	0.0577	0.0000	0.1099	0.0750	0.0167	0.0000	**<0.0001**	**<0.0001**
Agency bonds	0.0057	0.0000	0.0085	0.0000	0.0035	0.0000	**<0.0001**	**0.0002**
State / municipal bonds	0.0069	0.0000	0.0095	0.0000	0.0048	0.0000	**0.0046**	0.7551
Corporate bonds	0.0145	0.0000	0.0182	0.0000	0.0118	0.0000	**0.0957**	**0.0404**
Equities	0.0178	0.0000	0.0134	0.0000	0.0211	0.0000	**0.0273**	**0.0907**
Gold	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0002**	**0.0004**
Other commodities	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Mutual funds / UCITS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA

CCPs, on average, received from their clearing members mainly cash deposited at a central bank of issue, secured cash deposited at commercial banks, unsecured cash deposited at commercial banks, and domestic sovereign government bonds.

When comparing EU and non-EU CCPs, the initial margins of EU CCPs are significantly more constituted out of cash deposited at a central bank of issue and secured cash deposited at commercial banks. Third-country CCPs have relatively more unsecured cash deposited at commercial banks.

7.5 Univariate analysis of CCPs' investments of clearing members' cash collateral

Table 7 provides a granular view of CCPs' investments of their clearing members' cash collateral.

Table 7 CCP investments of clearing members' cash.

This table examines in more details investments of CCPs and compares EU CCPs and third-country CCPs in this respect. All represented variables are winsorized at 10%−90% to remove extreme values in either tail of the distribution. Cash deposits at other central bank of posits equals 16_2_3. Cash (secured) deposits at commercial banks equals 16_2_4. Cash (unsecured) deposits at commercial banks equals 16_2_5. Cash invested in money market funds equals 16_2_6. Cash deposits in other form equals 16_2_7. Cash invested in domestic sovereign government bonds equals 16_2_10. Cash invested in other sovereign government bonds equals 16_2_11. Cash invested in agency bonds equals 16_2_12. Cash invested in state or municipal bonds equal 16_2_13. The numbers refer to the fields of the CPMI-IOSCO PQD framework.

Variable	Total Sample		EU CCPs		Third-country CCPs		*p*-value	
	Mean	Median	Mean	Median	Mean	Median	Parametric *t*-test	Wilcoxon rank-sum test
CASHDEPCBI	0.3574	0.0626	0.4939	0.5700	0.2300	0.0000	**<0.0001**	**<0.0001**
Cash deposits at other central banks	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Cash (secured) deposits at commercial banks	0.2914	0.0800	0.4733	0.4308	0.1372	0.0000	**<0.0001**	**<0.0001**
Cash (unsecured) deposits at commercial banks	0.3213	0.0611	0.0574	0.0090	0.5643	0.5413	**<0.0001**	**<0.0001**
Cash invested in money market funds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Cash deposits in other forms	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Cash invested in domestic sovereign government bonds	0.0987	0.0000	0.1078	0.0074	0.0905	0.0000	0.4176	**0.0003**
Cash invested in other sovereign government bonds	0.0257	0.0000	0.0552	0.0000	0.0009	0.0000	**<0.0001**	**<0.0001**
Cash invested in agency bonds	0.0034	0.0000	0.0064	0.0000	0.0008	0.0000	**<0.0001**	**<0.0001**
Cash invested in state or municipal bonds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA

In general, CCPs have, on average, mostly cash deposits at the central bank of issue or commercial banks. They also invest significantly in domestic sovereign government bonds. No clearing members' cash is invested in cash deposits at other central banks, in money market funds, deposits in other form, or in state / municipal bonds.

Interestingly, EU CCPs have significantly more cash deposited at the central bank of issue and secured cash deposits at commercial banks, while third-country CCPs have more unsecured cash deposits at commercial banks.

7.6 Univariate analysis of CCPs' liquid resources

Table 8 examines in more detail CCPs' liquid resources and compares EU and third-country CCPs in this respect.

Table 8 Univariate analysis of liquid resources

This table examines in more details the liquid resources of CCPs and compares EU CCPs and third-country CCPs in this respect. All represented variables are winsorized at 10%−90% to remove extreme values in either tail of the distribution. Cash deposited at a central bank of issue is generated by dividing 7_1_2 by the exponential of LIQUID RESOURCES. The same denominator is taken for all the other liquidity variables. The following numerators are taken: cash deposited at other central banks of issue = 7_1_3; cash (secured) deposited at commercial banks = 7_1_4; cash (unsecured) deposited at commercial banks = 7_1_5; secured committed lines of credit = 7_1_6; unsecured committed lines of credit = 7_1_7; highly marketable collateral readily available and convertible = 7_1_8. The numbers refer to the fields of the CPMI-IOSCO PQD framework.

Variable	Total Sample		EU CCPs		Third-country CCPs		*p*-value	
	Mean	Median	Mean	Median	Mean	Median	Parametric *t*-test	Wilcoxon rank-sum test
Cash deposited at a central bank of issue	0.2113	0.0004	0.2887	0.1795	0.1250	0.0000	**0.0006**	**<0.0001**
Cash deposited at other central banks of issue	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	NA
Cash (secured) deposited at commercial banks	0.1358	0.0110	0.2006	0.0000	0.0635	0.0000	**<0.0001**	**<0.0001**
Cash (unsecured) deposited at commercial banks	0.0804	0.0000	0.0256	0.0021	0.3594	0.1272	**<0.0001**	**0.0005**
Secured committed lines of credit	0.1342	0.0000	0.1582	0.0000	0.1074	0.0000	0.2041	0.1614
Unsecured committed lines of credit	0.0804	0.0000	0.0496	0.0084	0.1149	0.0000	**0.0332**	0.3465
Highly marketable collateral readily available and convertible	0.1999	0.1001	0.2267	0.2025	0.1697	0.0000	0.1678	**<0.0001**

This table illustrates that CCPs have mainly cash deposited at a central bank of issue, secured cash deposited at commercial banks, secured committed lines of credit, and highly marketable collateral, as liquid resources.

EU CCPs have significantly more cash deposited at a central bank of issue and secured cash deposited at commercial banks, while third-country CCPs rely significantly more on unsecured cash deposited at commercial banks and unsecured committed lines of credit. According to the ESBR (2017), CCPs relying for a higher degree on commercial banks or lines of credit as opposed to central bank deposits may be exposed to higher risks, particularly if liquidity providers are, at the same time, clearing members of the CCP.

8. Multivariate results

8.1 Correlation analysis

Table 9 displays pairwise correlations among the various continuous explanatory variables.[23]

Table 9 Correlation matrix

This table displays pairwise correlations among the continuous variables. Table 1 presents a definition of all variables. All explanatory variables are winsorized at 10%–90% to remove extreme values in either tail of the distribution. *p*-values are reported between parentheses. * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$.

1) TOTAL DWF
2) PERCIMDF
3) HAIRCUT DF
4) HAIRCUT IM
5) OMSEGR
6) INDSEGR
7) CASHDEPCBI
8) LIQUID RESOURCES
9) MEDIUMCONCAV
10) AVVALUE
11) TOTASSETS
12) NUMBERGCM

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	0.32***	1.00										
	(<0.01)											
3	0.35***	-0.16**	1.00									
	(<0.01)	(0.04)										
4	0.08	-0.10	0.14**	1.00								
	(0.29)	(0.22)	(0.01)									
5	-0.08	-0.57***	0.08	-0.04	1.00							
	(0.32)	(<0.01)	(0.23)	(0.49)								
6	**0.80*** **	0.61***	-0.30***	0.06	-0.62***	1.00						
	(<0.01)	(<0.01)	(<0.01)	(0.36)	(<0.01)							
7	-0.08	-0.13	0.32***	0.08	0.14**	-0.25***	1.00					
	(0.38)	(0.11)	(<0.01)	(0.13)	(0.04)	(<0.01)						
8	0.13	0.63***	0.32***	0.57***	-0.33***	0.16*	0.63***	1.00				
	(0.17)	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(0.08)	(<0.01)					
9	-0.62***	-0.06	-0.03	0.06	0.31***	-0.01	-0.06	-	1.00			
	(<0.01)	(0.49)	(0.64)	(0.31)	(<0.01)	(0.91)	(0.49)	0.33***				
								(<0.01)				
10	**0.78*** **	0.25***	0.19***	0.02	-0.17**	-0.15*	0.25**	**0.90*** **	-0.27***	1.00		
	(<0.01)	(0.01)	(<0.01)	(0.76)	(0.03)	(0.06)	(0.01)	**(<0.01)**	(<0.01)			
11	**0.75*** **	0.16*	0.00	0.11*	-0.18***	0.23***	0.16*	0.60***	-0.24***	0.62***	1.00	
	(<0.01)	(0.05)	(0.96)	(0.06)	(0.01)	(<0.01)	(0.05)	(<0.01)	(<0.01)	(<0.01)		
12	**0.77*** **	0.05	0.35***	0.01	-0.21***	-0.06	0.08	**0.86*** **	-0.35***	0.82***	0.74***	1.00
	(<0.01)	(0.38)	(<0.01)	(0.92)	(<0.01)	(0.36)	(0.38)	**(<0.01)**	(<0.01)	(<0.01)	(<0.01)	

TOTAL DWF, LIQUID RESOURCES, AVVALUE, TOTASSETS, and NUMBERGCM are heavily correlated, which can be explained by the fact that the size of the default waterfall indeed depends on the CCPs' level of activity and size (see supra). When a CCP has (a) large default fund(s), it also has a substantial amount of liquid resources available in case a clearing member defaults (see supra).

To deal with multicollinearity issues in the logistic regression models, we do not include the correlated variables simultaneously. Nevertheless, we test whether CCP size variables have a significant influence on CCP risk measures.

[23] Median imputation needed to be used because it was not possible to estimate the logistic regression models without imputing missing values of the independent variables. The correlation matrix displays values post imputation. CCPs do not need to include any information in the PQD that could result in the disclosure of confidential and proprietary information. This high level of discretion on what can be considered as confidential or proprietary explains the high number of missing values. The results are not significantly different when other imputations, like the insertion of mean values, are used.

8.2 Multivariate logistic regression analysis

Table 10 reports the outcome of the multivariate logistic regression models as with 408 observations. Column 1 displays the results of our baseline model. The other columns report the result of different specifications, using alternative proxies or tackling multicollinearity issues. In model 2, the TOTAL DWF variable is replaced with LIQUID RESOURCES, while the TOTASSETS variable is included to account for the CCP size. Model 3 considers alternatively the AVVALUE instead of TOTASSETS as a proxy for CCP size, while Model 4 uses NUMBERGCM. Model 5 investigates whether the results change when we drop PERCIMDF out of model 4. In Model 6, we drop MEDIUMCONCAV and replace LIQUID RESOURCES with TOTAL DWF, while column 7 adds AVVALUE to model 6. Overall, the estimated models have acceptable McFadden R-Squares.

The results displayed in Table 10 reveal that neither TOTAL DWF nor PERCIMDF have a consistent significant influence on EU, while HAIRCUT DF and HAIRCUT IM have a significant negative influence. These findings suggest that EU CCPs seem to apply lower haircuts relative to their third-country peers. Keeping in mind that EU CCPs request more secured liquid assets (see supra), they can indeed afford to apply lower haircuts. Although the analysis of variation margins is out of scope in this article, we explored whether EU CCPs collect significantly more variation margins compared to non-EU CCPs without finding significant differences.

Table 10 Multivariate logistic regression analyses

This table displays the results of the logistic regressions as to sample of 408 observations. EU is the dependent variable. Table 1 presents a definition of all variables. All explanatory variables are winsorized at 5%–95% to remove extreme values in either tail of the distribution. *p*-values are reported between parentheses. * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$.

	Baseline Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)
Intercept	2.2328 (0.6174)	-15.1005*** (<.0001)	-14.2921*** (<.0001)	-13.0966*** (<.0001)	-13.9116*** (0.0012)	-3.3942 (0.3362)	-2.1225 (0.6279)
Credit risk							
TOTAL DWF	-0.2189 (0.3200)					-0.1226 (0.4761)	0.5844** (0.0295)
PERCIMDF	0.5552 (0.8060)	-2.9986 (0.1763)		-3.7471*** (0.0092)		2.1492 (0.3121)	1.9185 (0.4250)
HAIRCUT DF	-23.5661* (0.0582)	-25.5247** (0.0497)	6.2259 (0.6738)	-27.5161** (0.0338)	5.7404 (0.6982)	-26.2008** (0.0180)	1.6413 (0.9089)
HAIRCUT IM	-16.4307** (0.0177)	-23.8810*** (0.0029)	-39.2154*** (<.0001)	-20.5923** (0.0160)	-38.5568*** (<.0001)	-20.0436*** (0.0006)	-18.5014** (0.0125)
Asset segregation							
OMSEGR	7.3021***	9.4468***	10.0809***	9.8656***	10.0433***	3.8211***	6.8699***

	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
INDSEGR	2.9219***	4.4606***	3.1273**	4.9103***	3.4347***	0.6035	0.6223
	(0.0022)	(0.0001)	(0.0162)	(<.0001)	(0.0066)	(0.4839)	(0.5507)
Investment risk							
CASHDEPCBI	4.5150***	3.7708***	5.6204***	3.5941***	5.5160***	2.4415***	6.1958***
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
Liquidity risk							
LIQUID RESOURCES		0.5028***	1.3913***	0.4893***	1.4205***		
		(0.0042)	(<.0001)	(0.0096)	(<.0001)		
Control variables							
EQUITY	4.0655***	3.9136***	6.5779***	3.8217***	6.2535***	3.5210***	6.3061***
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
FIXED INCOME	-0.9645*	-0.1087	-2.4005***	0.1443	-2.1080***	-0.7580*	-3.5839***
	(0.0324)	(0.7281)	(0.0053)	(0.7841)	(0.0066)	(0.0822)	(<.0001)
COMMODITYDER	1.6554***	1.9175***	2.3380***	2.2190***	2.4130***	1.4532***	1.5250***
	(0.0024)	(0.0013)	(0.0006)	(0.0003)	(0.0003)	(0.0027)	(0.0083)
FXDER	-1.4617***	-1.8556***	-2.4527***	-1.9351***	-2.3990***	-1.5649***	-1.3961***
	(0.0017)	(0.0008)	(<.0001)	(0.0003)	(<.0001)	(0.0001)	(0.0033)
INTERESTDER	-2.0229***	-2.9685***	-2.9497***	-3.2424***	-2.9807***	-0.2216	-1.8205***
	(0.0036)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(0.5587)	(0.0013)
MEDIUMCONCAV	-12.3736***	-	-15.8519***	-	-		-
	(<.0001)	13.2898***	(<.0001)	13.3013***	15.7160***		14.3596***
		(<.0001)		(<.0001)	(<.0001)		(<.0001)
AVVALUE			-0.8793***		-0.8502***		-0.5879***
			(<.0001)		(<.0001)		(<.0001)
TOTASSETS		0.1591*					
		(0.0778)					
NUMBERGCM				0.5057			
				(0.1348)			
McFadden R-square	0.5116	0.5511	0.6615	0.5495	0.6570	0.4057	0.5752
AIC	299.90	279.93	218.47	280.83	217.31	356.88	266.48
Number of observations	408	408	408	408	408	408	408

Regarding asset segregation, OMSEGR and INDSEGR are significantly positive, illustrating that omnibus and individual client segregation is more common at EU CCPs. In terms of investment risk management, CASHDEPCBI is significantly positive. Regarding liquidity risk management, the LIQUID RESOURCES variable has a significant and positive influence on EU CCPs, suggesting that EU CCPs have significantly more liquid resources compared to their third-country peers.

Regarding the control variables, the dummy variables representing the type of financial instruments that the CCP clears - where OTHERINSTR is used as a reference category - have a significant influence on EU CCPs. MEDIUMCONCAV is significantly negative, which allows concluding that EU CCPs are facing a lower concentration risk relative to their non-EU peers. Quantitatively similar results are found when calculating this variable based on the initial margins posted by the clearing members. Also, similar results were obtained when constructing this variable for the ten largest clearing members instead of the five largest ones. Similar conclusions can also be drawn when the peak value is taken of the percentage of open positions held by the largest five or ten clearing members rather than the average value. Yet, we failed to find a significant influence when this variable was calculated based on clearing

services with ten or more members but less than 25 because not many CCPs in our sample had clearing services falling into this PQD category.

As for the size of the CCP, we observe different signs for AVVALUE and TOTASSETS, while the NUMBERGCM variable is not found to be significant. EU CCPs thus seem to clear less in terms of value compared to third-country CCPs, while they are significantly larger in terms of assets on their balance sheets. Qualitatively similar results are obtained when we use the natural logarithm of the number of direct clearing members rather than general clearing members. No information was available, however, on the number of indirect clearing members.

8.3 Robustness tests

Several tests were implemented to test the robustness of our findings. First, we bootstrapped the logistic regression models whereby we chose a replication factor of 1000. Second, we ran fixed effect models where we clustered the standard errors based on the reporting date to take e.g. the general market state into consideration and/or when we clustered at the CCP level. Third, we ran random effect logit models. These analyses were run to rule out the argument that EU CCPs differ from non-EU CCPs because their markets in which they are active are significantly different. Finally, we also estimated linear discriminant and random forest analyses (machine learning) as an alternative specification to the logistic regressions to investigate whether significant differences between the two CCP groups exist. We found qualitatively similar results for all these alternative specifications.

Finally, we analyzed whether EU CCPs were significantly different from a) the non-EU CCPs that ESMA previously recognised and b) the non-EU CCPs that were not recognised, by running multinomial logistic regression models. The results indicate that we cannot draw different conclusions for recognised CCPs and non-recognised CCPs vis-à-vis EU CCPs.

9. Limitations and future research

Although we find significant evidence that European CCPs are different compared to their third-country peers, the obtained results suffer from a couple of shortcomings, which an update of the CPMI-IOSCO PQD framework might address.

As there exist significant differences between individual CCPs' business models, membership structures, initial margin methodologies,[24] and products cleared, the value of indicators aggregating the various numbers is sometimes limited (ESRB, 2018). Although we controlled for the product types that CCPs clear, the CPMI-IOSCO PQD data does not allow us to accurately control for the differences in business models, margin methodologies, and membership structures that exist between the various CCPs in our dataset.[25] In case third-country CCPs would have e.g. stricter access requirements for clearing members compared to European ones, they might face a smaller need to request more initial margins or default fund contributions to cover their credit risk exposure. Having sufficient initial margins and default fund contributions are indeed only two aspects of the counterparty credit risk management of CCPs.

Furthermore, the CPMI-IOSCO PQD data faces several caveats that make the comparability of CCPs difficult. The information does not explicitly mention whether CCPs have calculated margins either at the level of the portfolio of financial instruments or at the financial instrument level itself. It is also not clear whether CCP systemically report margins at the end of the quarter or take the average over the quarter. As documented by Armakola and Bianchi (2018), initial margins might change at a high frequency for certain asset classes, making the value provided at the end of the quarter potentially biased because of end-of-period developments. Nevertheless, we have no indication that this data caveat is observed more frequently in or outside of Europe, thereby affecting our main conclusions.

10. Conclusions

In this article, we first empirically examine CCPs' risk management and analyze how they actually manage their counterparty credit risk, liquidity risk, and investment risk. In this respect, we analyze the size and compositions of their default waterfalls (i.e. initial margins and default fund contributions of their clearing members) and haircut decisions. We thereby analyze whether CCPs' clearing members' assets are sufficiently protected in case of another clearing member's default of when the CCP would face financial difficulties, by studying the level of asset segregation that CCPs offer. As CCPs are allowed to invest the financial resources obtained from clearing members, we also examine whether CCPs invest in high-

[24] According to Russo et al. (2002), all clearing houses in both the European Union and the United States apply similar techniques. Hence, the choice of the e.g. initial margin methodology is less likely to have a significant influence on our findings.

[25] CCPs are not always providing information on their margin models, used confidence intervals, back-testing procedures, etc. in an accurate and harmonized manner.

quality liquid assets that can be readily available when needed. Finally, we empirically analyze the total amount of liquid resources available to CCPs, as liquidity risk management is of utmost importance to these systemic institutions.

We are the first to empirically explore whether European CCPs are significantly different compared to their third-country peers. Until now, scholars and ESMA published detailed legal analyses comparing EU and non-EU legislation. Yet, scholars had never empirically tested whether the legal conclusions are economically reflected in practice. Although our empirical results do not find a significant difference for the size and composition (i.e. the percentage of initial margin) of the default waterfall between the two groups of CCPs, EU CCPs request significantly more cash deposits at a central bank of issue and secured cash deposited at commercial banks relative to non-EU CCPs which accept more unsecured cash deposits at commercial banks. Therefore, EU CCPs face a smaller need to impose stringent haircuts. Regarding the level of segregation, omnibus and individual client segregation are significantly more prevalent at EU CCPs.

Regarding investment risk management, EU CCPs tend to have a significantly larger portion of cash deposits at a central bank, while third-country CCPs have more unsecured cash deposits at commercial banks. Finally, EU CCPs are different concerning liquidity risk management, as they have a significant larger amount (i.e. almost three times as many) of liquid resources compared to non-EU CCPs.

In our opinion, these findings could be useful for European legislators and various market authorities, such as ESMA. On 13 June 2017, the European Commission published a proposal for amendments to EMIR, which the European Parliament, the European Council, and the European Commission politically agreed on 13 March 2019. In the amendment, the framework for recognition and supervision of third-country CCPs was enhanced and a two-tier system for third-country CCPs based on their systemic importance has been introduced. Where a third-country CCP is considered systemically important or is likely to become so for the Union or one or more of its Member States, such CCP would be classified as a Tier 2 CCP. These CCPs would only be permitted to provide clearing services or activities in the Union if they meet additional conditions.

Until now, equivalence decisions have been based on an outcome-based assessment of the full set of requirements applying at the domestic jurisdiction level, including proportionality considerations based on e.g. the CCPs' activity level in the European Union. Where no

proportionality considerations were applied and major gaps / differences were present between the requirements applying in a third country and EMIR, the European Commission included, in its equivalence decision, specific conditions addressing those gaps and differences. The CCPs established in that country then had to comply with those specific conditions for ESMA to be able to recognize them. ESMA could now consider the findings of this article when recognizing and supervising these CCPs by adopting a stringent approach to make sure that recognised third-country CCPs do not pose any risk to European clearing members. It is indeed essential that non-EU CCPs do not lower their risk management standards below Union standards, leading to regulatory arbitrage.

Our findings are also useful for non-EU CCPs and their regulators. As the evidence suggests that third-country CCPs are different from EU ones, it is in their own interest to upgrade their risk management standards if they do not want to be perceived as less safe compared to EU CCPs. However, it is unclear whether these higher risk management standards have clear benefits for the real economy. Indeed, asking collateral of higher quality to clearing members is more protective from the CCP's point of view, but it makes central clearing perhaps costlier, thus increasing the transaction costs. Future research should examine whether higher risk management standards for EU CCPs are beneficial for clearing members or whether they are too severe and thus an unnecessary burden.

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