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Model risk at central counterparties: Is skin-in-the-game a game changer?*

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Abstract

We investigate empirically how the balance sheet characteristics of central counterparties (CCPs) affect their modelling of credit risk. CCPs set initial margin (IM), i.e., the collateral for transactions, to limit counterparty credit risk. When a CCP's IM model fails on a large scale, the CCP could fail too, losing its skin-in-the-game capital. We find that higher skin-in-the-game is significantly associated with more prudent modelling, in contrast to profits (a proxy for franchise value) and forms of capital other than skin-in-the-game. The results may help to inform the ongoing policy debate on how to incentivise prudent credit risk management at CCPs.

JEL Classification: : F34; F42; G21; G38
Keywords: central counterparties (CCPs), capital, risk-taking

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1 Introduction

Central counterparties (CCPs) have become systemic players in the over-the-counter (OTC) derivatives markets. Regulatory reforms have helped to increase their footprint by, for instance, mandating central clearing for standardised OTC derivatives. The success of CCPs in unwinding trades within weeks of Lehman's failure in 2008 seems to have confirmed the resilience of these institutions. In addition, market forces, such as network externalities, have fuelled the growth of central clearing even further. As a result, almost four fifths of interest rate derivatives and half of credit default swaps are cleared centrally through CCPs, up from one third and one tenth respectively in 2009 (Aramonte and Huang, 2019). Furthermore, CCPs have become very concentrated, with just a handful of them dominating the major product lines (Huang and Takáts, 2020). Large domestically and globally systemically important banks (D-SIBs and G-SIBS) rely critically on the prudent risk management of CCPs.

Thus, the near-failure of NASDAQ Clearing in September 2018 profoundly shocked observers, as it happened amid calm market conditions. When the CCP sought to manage the default of a single trader, Einar Aas, the resulting loss far exceeded his collateral (i.e., the initial margin). The main problem was that the CCP's risk models underappreciated the potential level of volatility of the underlying market and prescribed insufficient margins. This is what we call "model risk" in this paper. When potential volatility materialised, the insufficient collateral exposed the CCP and other non-defaulting members to counterparty credit risk (Bell and Holden, 2018).

The NASDAQ event raises tough questions about model risk. There are many reasons why such model risk might arise: the CCP might not consider a long enough history of past price movements ("look-back period"), might overestimate the correlations across markets, or might underestimate the period needed to close the failing portfolios. To get this right, CCPs need the right incentives: margin models require expert judgment which outside parties are unlikely to be able to provide. Thus, a critical question arises about CCP incentives, in particular about what role do skin-in-the-game (the special capital allocated for credit risk), other capital and profits play as incentives?

We answer this question empirically by investigating model risk – to the best of our knowledge – for the first time. In particular, we focus on the relationship between skin-in-the-game, capital other than skin-in-the-game and profits on the one side, and the effectiveness of portfolio-specific initial margin setting on the other side.

We find that a higher amount of CCP skin-in-the-game is associated with more careful risk modelling. Increased skin-in-the game is associated with less frequent margin breaches (i.e., events when the model implied collateral proves to be insufficient) and other proxies of more prudent modelling. However, we do not find significant relationship between model risk and capital other than skin-in-the-game or profits.

To undertake our analysis, we collect data from quantitative disclosures of 39 CCP groups between Q3 2015 and Q4 2018. The data cover almost all internationally relevant CCPs. The 39 CCP groups have 120 separate CCP product lines. The collected data set contains information such as balance sheets, earnings and the quality of credit risk management at the product line level. In particular, it provides five proxies for model risk: (1) number of margin breaches, (2) achieved coverage, (3) difference between achieved and target coverage, (4) average size of margin breaches and (5) maximum size of margin breaches.

Our work is related to two streams of literature. First, our work adds empirical evidence to the small, but fast growing theoretical literature on incentives and risks resulting from the mutualisation of counterparty credit risk. Biais, Heider, and Hoerova (2012) highlight the diversification benefits from central clearing, but warn of moral hazard in case of fully insured credit risk. Biais, Heider, and Hoerova (2016) show, however, that margin requirements can prevent such moral hazard.[1] Huang (2019) develops this line of thinking towards our question by theoretically examining the link between CCP capitalisation and risk-taking incentives.

Second, we more directly complement the nascent literature that investigates CCP risk management empirically. In this area, Bignon and Vuillemey (2019) describe a high-profile central clearinghouse failure. The documentation of this rare failure is particularly relevant when thinking

[1]In addition, an entire school of papers is dedicated to investigate netting benefits (Duffie and Zhu, 2011; Cont, Kokholm et al., 2014; Duffie, Scheicher, and Vuillemey, 2015). Several others examine how central clearing can alleviate OTC derivative market opacity: Acharya and Bisin (2009), Acharya and Bisin (2014); Koeppl and Monnet (2010, 2013); Koeppl, Monnet, and Temzelides (2012).

about potential triggers for failure. Huang (2019) focuses on the role of CCP skin-in-the-game, including its association with the aggregate amount of collateral or initial margin. We depart from Huang (2019) by focusing explicitly on the model risk of CCP credit risk management. Thus, instead of on-the-aggregate initial margin (IM) size, we look at the performance (i.e., the back-testing) of the margin models. The main reason is that a high aggregate amount of initial margin does not necessarily preclude CCP failures, because initial margin is not fungible across members. A member's IM can only cover risks from his own portfolio. For example, if NASDAQ Clearing had prescribed higher margins on other trades than those of Mr Aas', it would not have safeguarded the CCP in the near failure.

Furthermore, analysing back-testing results as opposed to aggregate IM can help identification by excluding a confounding factor. Namely, a greater amount of skin-in-the-game may induce clearing members to take more risks, because trades are safer due to the CCP's higher loss absorbing capacity. Reflecting this higher risk-taking, the CCP might increase aggregate IM. This effect could confound estimates that aim to analyse the impact of skin-in-the-game based on aggregate IM: it would remain unclear if higher skin-in-the-game induces more risk-taking by members and thereby leads indirectly to higher aggregate IM, or if higher skin-in-the-game increases the CCP's incentive to manage risks more conservatively, which raises aggregate IM. This issue is not present in our approach based on back-testing results: model performance proxies already include the effects of increased risk taking by members. Therefore, while we build on the argument in Huang (2019), we move from investigating aggregate initial margin to portfolio-specific initial margin and model risk.

Our results are relevant for policy. The results suggest that higher skin-in-the-game does reduce CCPs model risks. While our paper does not attempt a normative analysis for the optimal level of skin-in-the-game, we hope it will stimulate further thinking about its potential role for CCPs.

The rest of the paper is organised as follows. Section 2 briefly discusses how CCPs function. Section 3 introduces our three hypotheses. Section 4 details our dataset and Section 5 our proxies for risk management. Section 6 shows our analysis. The final section concludes with caveats and policy implications.

2 Institutional background

CCPs are financial market infrastructures that provide clearing services. CCPs essentially stand between two counterparties (e.g., banks) and assume the credit risk from the contracting parties. In this section, we briefly review how CCPs work. We focus on three features, which are particularly relevant for our argument. First, we highlight how initial margin setting contains information about how a CCP manages counterparty credit risks. Second, we explain why CCP capital is special, in particular the role of skin-in-the-game (SITG). Third, we show how high CCP profitability is.

2.1 Mechanics of central clearing

To understand the workings of a CCP, consider the example of an OTC derivative transaction between two clearing member banks. As clearing members, both banks need to contribute to the CCP's default fund. To mitigate the current credit risk exposure, the two banks settle the marked-to-market profits and losses through variation margin (VM) payments. The losing bank pays VM to the CCP and the CCP pays VM to the winning bank (Faruqui, Huang, and Takáts, 2018).

Credit risk materialises when the losing bank is unable to meet VM calls. Nonetheless, a CCP still needs to pay VM to the winning bank. To cover such potential future exposures, CCPs charge initial margin (IM). CCPs set IM to cover, with a high likelihood, the potential VM payments over a period long enough to close the failing positions in stressed market conditions ("close-out" period). Typically, CCPs model IM as a value-at-risk measure, which is a quantile of the loss distribution (Pirrong, 2011). Many CCPs target higher than the 99th percentile. It is common to set two to ten days as a close-out period for calculating IM, although the precise horizon will vary across derivative products and CCPs.

Back-testing of IM models, and in particular investigating margin breaches, is informative about CCP model risk. A margin breach occurs when the realised loss (i.e., the required VM payment ex post) exceeds the pre-set quantile of the model (i.e., the required IM ex ante). Therefore, less frequent or smaller-sized margin breaches suggest more prudent IM modelling.

Importantly, margin breaches are normal part of CCPs' business. As a CCP targets a quantile of the loss distribution, some VM realisations are expected to exceed the pre-set IM. Furthermore, margin breaches do not necessarily lead to margin calls or clearing member defaults. In fact, following a margin breach, a clearing member almost always pays the VM. Of course, the relatively few cases of non-payment expose the CCPs to potential losses.

2.2 Default waterfall

To withstand losses from the materialisation of a counterparty credit risk event, CCPs rely on a range of resources through the so-called default waterfall (Duffie, Li, and Lubke, 2010). A CCP first uses the collateral (IM and default fund contribution) posted by the defaulting member, i.e., the losing bank which failed to pay VM. Importantly, IM is not fungible across members: a member's IM can only be used to cover its own losses, but not other members' losses (Wang, Capponi, and Zhang, 2019).

The next layer in the waterfall is typically a part of the CCP's own capital, often referred to as "skin in the game" (SITG). The CCP can lose its SITG if the risk model does not work - this makes it relevant, at least theoretically, for CCP incentives (Huang, 2019). Importantly, SITG is not all the CCP‘s capital. The CCP capital other than SITG underwrites, for instance, operational expenses. Finally, unlike banks, CCPs do not have regulatory SITG requirements, which allows for heterogeneity across CCPs.[2]

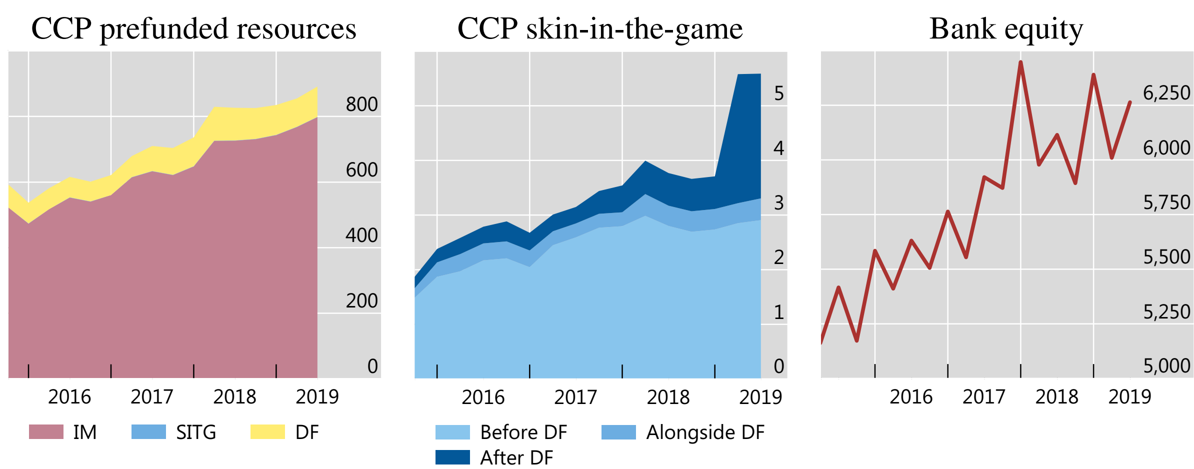
CCPs have resources that are senior to their SITG. They can continue as going concerns even after exhausting their SITG. First, CCPs can rely on clearing members' prefunded resources, such as default fund contributions. Second, CCPs can call on surviving clearing members to provide committed resources. Depending on the rulebook, the CCP can call on the surviving members for more cash or can haircut the receivable VM payments owing to their winning positions (Singh, 2014; Singh and Turing, 2018).

Quantitatively, the overwhelming majority of CCPs' prefunded resources is IM (Figure 1, left-hand panel). Around 90% of all prefunded resources are IM (red area), and only around 10% are default fund contributions (yellow area). The SITG is dwarfed by IM and default fund contributions

[2]The European Market Infrastructure Regulation (EMIR) requires that CCPs' SITG should be at least 25% of their operational capital. Such a requirement, however, is not a binding constraint for CCPs in general.

Figure 1: CCP and bank resources (unit: USD bn)

This figure shows the resources in CCPs and banks. The left-hand panel shows the prefunded resources of CCPs in the Clarus CCPview dataset. The central panel zooms into the different layers of CCP skin-in-the-game (SITG). The right-hand panel shows the equity in large banks.



Source: Clarus CCPview, Fitch

(blue area). SITG amounts to only around USD 5 billion (centre panel), with some recent increases after the Nasdaq Clearing debacle. In sum, CCP capital is very sparse, as compared with other collateral or with bank capital (right-hand panel).

Therefore, SITG plays a limited role in absorbing credit losses. Our inquiry, however, focuses on its incentive role: that is, whether CCPs with higher SITG manage model risk more prudently, i.e., whether they set IM in such a way as to have fewer or smaller margin breaches. While, as we discussed, theory suggests such a possibility, it is unclear, given the relatively small size of SITG, whether such an incentive effect is actually detectable.

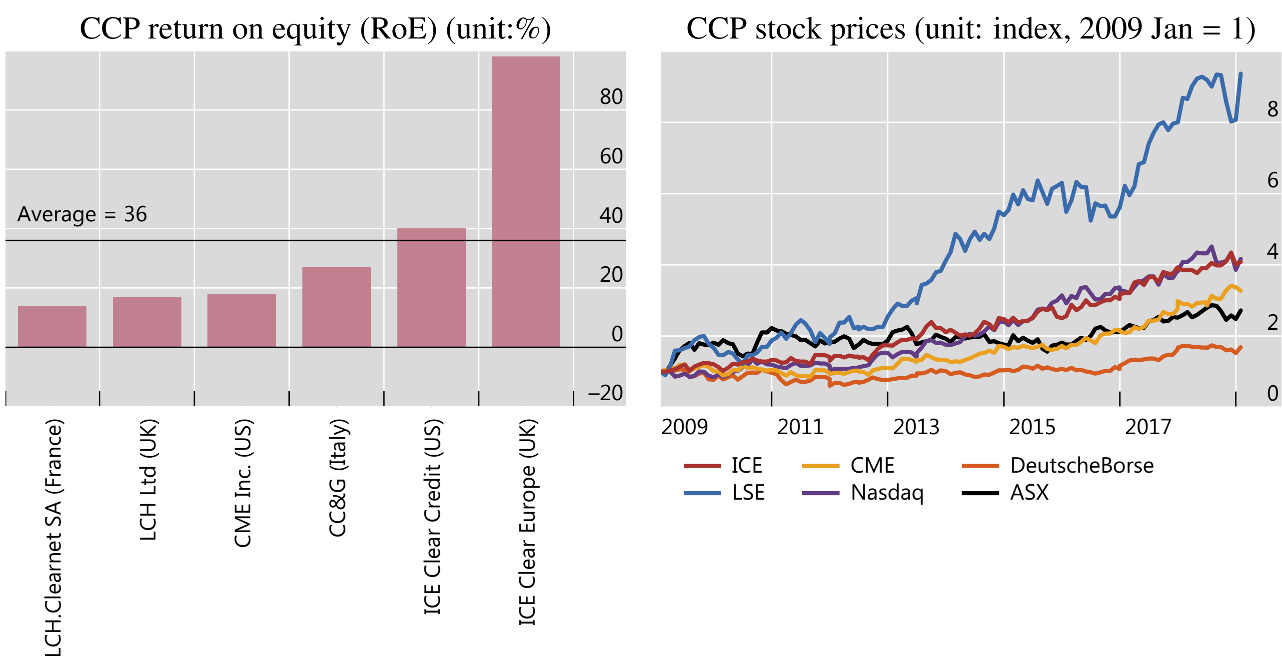
2.3 CCP profitability

CCPs are very profitable. This is, in part, due to network externalities and geographical fragmentation. For the major CCPs, the average return-on-equity (RoE) was 36% at end-2018 (Figure 2, left-hand panel). This is much higher than bank profitability, which has hovered at around 10% since the global financial crisis (CGFS, 2018).

Furthermore, the high profitability is reflected in market valuations and franchise values. The

Figure 2: CCP profitability and market valuation

The left-hand panel shows the return on equity of major CCPs at end-2018. The right-hand panel shows the stock prices of major CCP groups, with 2009 January 1 as the benchmark.



Sources: Clarus CCPview, Bloomberg

stock prices of major CCPs have greatly appreciated since the global financial crisis (right-hand panel). Mandatory clearing for standardised derivatives, which took effect in 2012, could have further contributed to increasing valuations afterwards. While mandates increased the total demand for central clearing, they, of course, did not mandate the use of specific CCPs: CCPs still have to compete for members. High profitability is relevant for our inquiry, because it might incentivise CCPs to model risks prudently as otherwise CCP owners would risk losing a highly valuable franchise.

3 Hypotheses

Exposing capital to losses encourages prudent behaviour. There is an extensive literature on the role of capital-at-risk in banks (Diamond and Rajan, 2000; Hellmann, Murdock, and Stiglitz, 2000). The evidence shows that a higher level of capital is associated with less risk-taking (Furlong and Keeley, 1989): a larger amount of capital implies that shareholders stand to lose more if losses materialise, and therefore they internalise more potential losses when managing risks.

In the same vein, Huang (2019) examines the role of CCP SITG. The author provides a theoretical model and empirical evidence that a higher CCP SITG is associated with a higher aggregate IM requirement.

In this paper, as we focus on the model risk of CCP credit risk management, we depart from aggregate margin levels. We look at the back-testing results of the margin models. The reason is that a high aggregate amount of initial margin does not necessarily preclude CCP failures, if initial margin does not cover risks from a particular trader's portfolio. Furthermore, the back-testing results can identify CCP incentives and risk-taking better than do aggregate IM-based investigations. The reason is that increased skin-in-the-game may induce risk-shifting from the members. Thereby, aggregate IM might increase as a result of greater risk-taking by the members, and not on account of the CCP's heightened incentive to manage counterparty credit risk. This effect can confound estimates based on aggregate IM, but is not present in our approach based on back-testing results. Thus, that is our first hypothesis.

Hypothesis 1: *A higher CCP skin-in-the-game (SITG) is associated with more prudent credit risk management.*

A related argument is that CCP capital other than SITG should not affect credit risk management. As mentioned in Section 2, when a credit event happens, the operating capital, i.e., capital other than SITG, is not exposed to credit losses. Therefore, such operating capital should not provide incentives for credit risk management. That leads to our next hypothesis.

Hypothesis 2: *A higher amount of CCP operating capital is not associated with more conservative risk management.*

Apart from capital, profitability can also play a role. One potential channel runs through franchise value. There is evidence that a higher franchise value is associated with lower risk-taking (Keeley, 1990). The logic is similar to the one we discussed with the SITG: a higher franchise value means a more highly valued business – even if such a valuation is not reflected in accounting capital – which in turn implies higher potential losses for shareholders if losses were to materialise ("franchise value" channel). This could be especially relevant as CCPs tend to be very profitable, and profitability is a solid indicator for franchise value.

However, the causation can also run in the opposite direction: firms that take more risk could see higher profits – at least temporarily. Therefore, higher credit risk can lead to higher profits ("risky profit" channel).

In sum, the empirical evidence might inform which, if any, channel dominates. Our third hypothesis summarises the opposing "franchise value" and "risky profit" channels.

Hypothesis 3: *The relationship between profits and risk management depends on the relative strength of two channels: (1) The "franchise value" channel suggests that a higher profit is associated with higher franchise value (to the degree profitability is persists) and thereby it is associated with more prudent credit risk management. (2) In contrast, the "risky profit" channel suggests that higher profits result from less prudent risk management.*

We identify these two contradicting channels in our empirical approach.

4 Data

We use public CCP quantitative disclosures to test these hypotheses. The CPMI-IOSCO Principles for financial market infrastructures (CPMI-IOSCO, 2012, 2015) require CCPs to regularly publish these data to improve transparency. We use the disclosure data collected from Clarus FT's CCPView.

Our data set is in panel form. The time series ranges from 2015 Q3 to 2018 Q4 at a quarterly frequency, i.e., 14 quarters. The data set spans 120 CCP entities or product lines (which are grouped into 39 CCP groups). Therefore, the full panel has at most 1,680 observations.

We divide our data description into three categories (Table 1): (i) default waterfall (Panel A), (ii) financial information (Panel B), and (iii) credit risk management (Panel C). These correspond to the three principles in the quantitative disclosures: Principle 4: Credit risk; Principle 6: Margin; and Principle 15: General business risk. Here we discuss the first and second category (Panels A and B) – and return to the third (Panel C) in the next section, when discussing risk management.

Table 1: Summary statistics

This table summarizes the variables. The summary statistics are taken across CCPs and quarters. The variables are divided into three groups: Panel A reports the statistics for variables in CCP default waterfall. Panel B shows the balance sheet variables for CCPs. Panel C presents the risk management variables. Note that Equity is the sum of SITG and Other equity.

	mean	std	Min	median	max
Panel A: Default waterfall					
Initial margin IM ($bn)	9	19	0.0002	3	138.1
Skin-in-the-game SITG ($bn)	0.039	0.0595	0.00001	0.0164	0.272
Default fund DF ($bn)	1.3	2.2	0.0002	0.3	15
Panel B: Financial information					
Return-on-equity (RoE)	20%	27%	-29%	13%	169%
Profit ($m)	117.1	309.2	-14.46	51.9	4063.4
Equity ($bn)	1.4	4.6	0.02	0.3	26
Other equity ($bn)	1.4	4.6	0.01	0.2	25.8
Assets ($bn)	71.7	113.6	0.08	21.7	470.3
Panel C: Credit risk management					
Number of breaches	12.6	37.7	0	1	394
Number of trades in margin model	148492	1038522	239	13154	14148135
Target coverage (%)	99.2	0.3	99	99	99.9
Achieved coverage (%)	99.9	0.03	96.17	100	100
Difference between achieved and target (%)	0.7	0.6	-8.96	0.9	1
Maximum breach size ($m)	61.6	130.1	0.01	7.2	1228
Average breach size ($m)	4.7	9.1	0.01	1.4	67.1

Sources: CCP quantitative disclosures and authors' calculations.

Default waterfall data reveal that IM and DF account for the majority of the default waterfall in our sample (Table 1, panel A). The average of IM at a given entity is around USD 9 billion and that of the default fund is around USD 1.3 billion. Compared with IM and DF, SITG is small, with an average value of USD 40 million. These data are consistent with the CCP data discussed in the Institutional Background section. In addition, all three variables are heavily skewed to the right with median values far below the averages. Furthermore, all variables show high variation, with a standard deviation almost twice as large as the average. Importantly, the average CCP equity (i.e., the sum of skin-in-the-game and other operational capital) is around USD 1.4 billion. Therefore, most CCP capital is operational capital and is not exposed to credit losses.

The financial information also reveals high CCP profits (Table 1, panel B). Return-on-equity (RoE) is 20% on average across entities in the sample period, with the maximum reaching 169% – again showing that our sample is consistent with the broad CCP picture discussed in the institutional background section. In absolute value, profits average of USD 117 million. Yet, as discussed before, CCPs have very little equity, giving rise to high RoEs.

5 Proxies for model risk management

CCP quantitative disclosures also contain some information on risk management (Table 1, panel C). CCPs back-test IM models regularly and report the results in the quantitative disclosures. The back-testing shows from various perspectives how carefully CCPs set individual, portfolio-specific IM to manage counterparty credit risk.

This portfolio-specific IM is relevant for CCP credit risk exposure, because IM is not fungible. The CCP cannot use IM from other members to cover credit losses. Therefore, to manage credit risk exposure CCPs need to manage individual portfolio-specific IM.

As mentioned in the background discussion, CCPs calculate IM as a value-at-risk measure, which is essentially a quantile of the expected loss distribution. The PFMI requires that CCPs should cover at least 99% of the losses with their initial margin modelling, although CCPs can (and sometimes do) target higher quantile (CPMI-IOSCO, 2012). We denote the level targeted by CCPs as target coverage.

Naturally, actual VM payments are expected to exceed the calculated IM with some small probability. These events are margin breaches. Because of margin breaches, the target coverage reported is almost always less than 100%. Importantly, margin breaches do not necessarily lead to default. When the frequency and the size of margin breaches indicate poor model performance, a CCP should recalibrate the model for required IM. Furthermore, the CCP might, but does not have to, issue margin calls. If the clearing member meets the margin call in time (i.e., pays the required margin), then no credit event takes place.

We propose five main metrics for margin breaches to capture the degree of prudence of a CCP's credit risk management:

- The number of breaches
- Achieved coverage
- Difference between achieved and target coverage
- Average size of margin breaches
- Maximum size of margin breaches

First, the number of margin breaches is one straightforward metric of risk management. Controlling for CCP size, it can inform us how conservatively the CCP sets its margins.

Second, achieved coverage scales margin breaches by the number of observations as the following formula shows:

$$\textit{Achieved coverage} = 1 - (\textit{Number of margin breaches})/(\textit{Number of observations})$$

Achieved coverage shows the proportion of observations that did not result in a margin breach. Its advantage over the simple number of breaches is that it scales the number of breaches to the number of trades.

Third, the difference between achieved and target coverage provides another angle. Not all product lines target the same level of coverage. While the PFMI requires at least 99% coverage, most CCPs aim for a higher level. The difference between achieved and target coverage tells us how close CCPs are to their own targets.

Fourth, the average size of margin breach provides yet another angle on risk management. The reason is that not only the frequency, but also the size of the margin breach matters for CCP credit risk.

Finally, we also look at the maximum size of breaches in a CCP entity. The discussion of the default waterfall has shown that CCPs have a number of credit risk-absorbing layers. Small breaches therefore do not constitute a major risk. This would suggest considering the largest ones. The difference is not trivial: the maximum breach in our sample reaches USD 1.3 billion, while the average margin breach is around USD 5 million.

Notably, the CCP quantitative disclosure data report the margin breaches for the past 12 months. Hence, the raw reported variables are autocorrelated. To address the autocorrelations, we use only the annual data of the size measures, i.e., the average size and the maximum size of margin breaches. For the frequency measures, we calculate the quarterly increment in the number of breaches, and use that to calculate the achieved coverage and the difference between the achieved and the target coverage. Appendix A reports the calculation of the quarterly increment in the number of breaches.

There is also one caveat here: these five metrics do not equal risk management but only proxy it, and do so from different perspectives. One could argue that risks matter most when dealing with extreme-sized shocks, which – absent prudent risk management – could bring a CCP to a (near-)failure. Fortunately, we do not observe such shocks on a quarterly basis. However, this also means that we need to rely on more frequently available proxies, such as our metrics on margin breaches, to study CCP risk management econometrically.[3]

The advantage of the above five proxies is that they provide observations on a quarterly basis. Margin breaches might be rare relative to the number of transactions, but the huge number of transactions generates a steady stream of breaches each quarter for our empirical analysis. Therefore,

[3] In addition, some of these measures are set in ratios (Achieved coverage and Difference between achieved and target coverage) while the others are set in absolute numbers (number of breaches, average size of margin breaches and maximum size of margin breaches). Therefore, we also control for the size of the CCP product line.

we are able to deploy econometric tools to analyse all five of the main metrics proposed above.

6 Regression analysis

We test our hypotheses in a panel regression framework. Formally, we estimate the following regression:

$$RiskManagement_{i,t} = \beta_0 + \beta_1 SITG_{i,t} + \beta_2 OtherEquity_{i,t} + \beta_3 Profit_{i,t} + \gamma ControlVariables_{i,t} + \alpha_t + \iota_i + \varepsilon_{i,t} \tag{1}$$

Following the usual panel notation, throughout index i stands for CCP entities (product lines) and t stands for quarters.

Our dependent variable $RiskManagement_{i,t}$ denotes one of the five proxies defined in the previous section (number of breaches; achieved coverage; difference between achieved and target coverage; average size of margin breaches; and maximum size of margin breaches). We use these five proxies in five different sets of equations.

Our main explanatory variables stem from the three hypotheses we test: skin-in-the-game, other equity and profit.[4] In addition, we apply controls to avoid confounding effects: $ControlVariables_{i,t}$ includes total IM and total asset. Finally, we apply both entity and time fixed effects to capture unobserved CCP business line heterogeneity (such as ownership structure, governance and product-specific features) and time-varying market conditions, respectively.

6.1 The role of SITG and other equity

Our first set of regressions examines the frequency measures of margin breaches (Table 2, first line). Consistent with Hypothesis 1, we find that a higher SITG reduces the number of breaches (Model 1), whether or not we control for aggregate IM size (Model 2). Furthermore, increased skin-in-the-game is associated with higher achieved coverage (Models 3–4). Finally, we observe

[4]Recall that the profit variable is potentially endogenous. It might not only affect modelling via the "franchise value" channel, but it can also be driven by risk-taking via the "risky profit" channel - as described in Hypothesis 3.

the same qualitative relationship for our third frequency measure, the difference between achieved and target coverage (Models 5–6). The frequency-based risk measure results imply that a CCP with a higher SITG has more prudent risk management.

Table 2: Regression results for the frequency of margin breaches

This table presents the regression results for the frequency of margin breaches. The dependent variable in model (1) and (2) is the number of margin breaches (Number of Breaches), that in model (3) and (4) is the achieved coverage ratio (Achieved coverage), and that in model (5) and (6) is the difference between the achieved coverage and the target coverage (Diff coverage). The independent variables are skin-in-the-game (SITG), CCPs' other capital than SITG (Other Equity), profitability (Profits), initial margin (IM), and total asset (Asset). The panel regressions incorporate the time and CCP entity fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)
	Number of Breaches	Number of Breaches	Achieved coverage	Achieved coverage	Diff coverage	Diff coverage
SITG	**-0.11**	**-0.24****	**0.13****	**0.07***	**0.15*****	**0.09****
	(-1.55)	**(-2.07)**	**(2.39)**	**(1.96)**	**(2.72)**	**(2.35)**
Other Equity	**1.41**	**1.16**	**-0.82**	**-1.09*****	**-1.32****	**-1.38*****
	(0.96)	**(0.60)**	**(-1.59)**	**(-3.34)**	**(-2.63)**	**(-3.54)**
Profit	**0.00**	**0.00**	**-0.00**	**-0.00**	**-0.00**	**-0.00**
	(1.46)	**(0.15)**	**(-1.50)**	**(-1.45)**	**(-1.33)**	**(-1.32)**
IM		-0.15		-0.05		0.01
		(-0.66)		(-1.09)		(0.10)
Asset		-0.01		0.01*		0.01*
		(-0.22)		(1.83)		(1.78)
Constant	14.76***	43.92***	9990.07***	9992.18***	137.81***	143.20***
	(4.29)	(6.29)	(3738.72)	(5119.94)	(54.60)	(63.79)
R-sq	0.003	0.008	0.016	0.010	0.000	0.000
N	603	557	603	557	603	557
t statistics in parentheses						
* $p < 0.10$	** $p < 0.05$	*** $p < 0.01$				

Consistent with Hypothesis 2, CCPs' other equity than SITG is not significantly correlated with frequency-based measures (Table 2, second line). Increased other equity is not significantly associated with the number of breaches (Models 1 and 2). In contrast, a higher other equity seems to significantly reduce achieved coverage at least in one specification (Model 4) and the difference between achieved and target coverage (Models 5 and 6). The results imply that a CCP with a higher other equity does not necessarily have a more prudent risk management, which is consistent with Hypothesis 2.

The insignificant coefficients on profit (Table 2, third line) suggest that both channels, the "franchise value" and "risky profit" channels described in Hypothesis 3 may play a role in the model risk of credit risk management. This prompts us to further investigate these channels in the next subsection.

Next, we turn to the size measures of margin breaches (Table 3). In these regressions we use annual frequency data to avoid overlapping windows, because CCPs are required to report the average and the maximum size of margin breaches over the past 12 months. Thus the number of observation falls substantially. Nonetheless, consistently with Hypothesis 1, SITG plays a significant role in reducing the size of margin breaches, both the average size and the maximum size. Therefore, a CCP with a higher SITG seems to have smaller model risk for credit risk management, and hence more prudent risk management. Equity other than SITG seems to be marginally significant in reducing the size of margin breaches, slightly contradicting Hypothesis 2. In addition, profit does not show a significant impact on the size of margin breaches, which suggests both channels in Hypothesis 3 are at work.

In sum, our results are strongly consistent with Hypothesis 1: a CCP with a higher SITG seems to have smaller model risk for credit risk management, and hence more prudent risk management. The results also broadly support Hypothesis 2: there is no consistent, statistically significant relationship between other capital and CCP risk management. However, these results are somewhat weaker, as some coefficient estimates become significant, albeit with opposing signs. Finally, our results are also consistent with Hypothesis 3 in the sense that they suggest that both channels are at work. The results also highlight the need to investigate the two channels of Hypothesis 3 in more detail, which we now undertake.

6.2 "Franchise value" vs "risky profit"

Recall that Hypothesis 3 stated that two contradictory channels affect the relationship between profits and CCP risk management prudence. The "franchise value" channel implies that higher profits mean higher franchise value, which in turn implies more prudent risk management and modelling at the CCP. In contrast, the "risky profit" channel suggests that higher profits result from

Table 3: Regression results for the size of margin breaches

This table presents the regression results for the size of margin breaches. The dependent variable in model (1) and (2) is the average size of margin breaches (Avg breach), and that in model (3) and (4) is the maximum size of breaches (Max breach). The independent variables are skin-in-the-game (SITG), CCPs' other capital than SITG (Other Equity), profitability (Profits), initial margin (IM), and total asset (Asset). The panel regressions incorporate the time and CCP entity fixed effects.

	(1)	(2)	(3)	(4)
	Avg breach	Avg breach	Max breach	Max breach
SITG	**-0.04****	**-0.04***	**-1.12****	**-1.51***
	(-2.19)	**(-1.81)**	**(-2.23)**	**(-1.89)**
Other Equity	**-0.12**	**-0.16**	**-1.28**	**-1.91***
	(-0.93)	**(-1.25)**	**(-1.27)**	**(-1.79)**
Profit	**-0.00**	**-0.00**	**-0.00**	**0.00**
	(-0.19)	**(-0.23)**	**(-0.18)**	**(0.09)**
IM		-0.04		-1.92**
		(-0.66)		(-2.53)
Asset		0.00		-0.06
		(0.38)		(-1.06)
Constant	3.45***	4.03***	70.52***	110.91***
	(5.01)	(3.63)	(3.63)	(3.32)
R-sq	0.010	0.012	0.045	0.095
N	186	168	186	168

t statistics in parentheses
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

less prudent risk management. Therefore, it is unclear what these two channels combined imply for the relationship between profits and risk management.

To disentangle the two channels in Hypothesis 3, we divide the sample into subsamples where the "risky profit" channel works either less or more intensely. Comparing these subsamples helps to identify the two channels. We use ownership and profitability for forming the groups.

Ownership matters because user-owned CCPs internalise part of the risks they place on member banks (as they are themselves owners). Therefore, user-owned CCPs have weaker incentives to chase profit, i.e., they have a weaker "risky profit" channel. In contrast, for-profit CCPs do not internalise risks faced by their members to the same degree, and hence the "risky profit" channel is likely to work more strongly for them.

Profitability also matters, because CCPs with higher profits are, on average, more likely to be situated in a profitable market segment, where the "risky profit" channel is also stronger. That is to say, a relaxation of prudent risk management yields stronger (short-term) financial rewards in more profitable markets.

The two criteria above divide our sample into four groups:

1. CCPs that are user-owned and have low profits (below median)
2. CCPs that are for-profit and have high profits (above median)
3. CCPs that are user-owned and have high profits (above median)
4. CCPs that are for-profit and have low profits (below median)

While we have no reason to expect differences across these groups in terms of the "franchise value" channel, the "risky profit" channel is likely to perform most weakly in Group 1 and most strongly in Group 2.[5] As the "risky profit" channel posits a negative association between risk management and profits (higher profits being associated with less prudent risk management), we would expect that Group 2 relative to Group 1 would exhibit a more negative association between risk management and profits.

[5] Groups 3 and 4 are unclear in this respect.

We formalise this logic in the following regression setup. We denote D0 and D1 the dummy variables for group 1 and group 2 and estimate the following regression:

$$\begin{aligned} RiskManagement_{i,t} &= \beta_0 + \beta_1 SITG_{i,t} + \beta_2 OtherEquity_{i,t} + \beta_3 Profit_{i,t} \\ &\quad + \beta_4 Profit_{i,t} \times D_0 + \beta_5 Profit_{i,t} \times D_1 + \gamma ControlVariables_{i,t} + \alpha_t + \iota_i + \varepsilon_{i,t} \end{aligned} \tag{2}$$

The coefficients before the interaction terms (β_4, β_5) indicate the incremental effect of profit conditional on being a group 1 or a group 2 CCP.

The estimated signs are consistent with our expectation (Table 4). As a group 1 CCP, compared with the other CCPs, a higher profit is associated with more prudent risk management, ie, a smaller number of breaches, a higher achieved coverage, a greater difference between achieved and target coverage, a smaller average size of margin breaches, and a smaller maximum size of margin breaches. The opposite holds for group 2 CCPs. The results are more significant with group 1 CCPs, suggesting that the "risky profit" channel dominates in this group when compared with other CCPs.

In sum, our results in this subsection are consistent with both the "franchise value" channel and the "risky profit" channel of Hypothesis 3 to be at work. Furthermore, the "risky profit" channel seems to dominate in the group of for-profit CCPs that are in the more profitable market segments.

7 Conclusion

We are the first – to the best of our knowledge – to investigate empirically CCP model risk, a critical risk for CCP resilience. We examine portfolio-specific initial margin-setting and thereby contribute to the literature, which – so far – has investigated only aggregate IM-setting.

We present three main findings. First, CCP skin-in-the-game is associated with lower model risk. Second, other capital (which is not linked to credit risk) does not reduce model risk. Third, our results suggest that higher profits might reduce risk-taking in itself, but often higher profits themselves are the result of lax risk management, particularly for for-profit CCPs operating in

Table 4: Regression results with profit identification

This table presents the regression results for the size of margin breaches. The dependent variables in model (1) to (5) are the number of margin breaches (Number of breaches), the achieved coverage ratio (Achieved coverage), the difference between the achieved coverage and the target coverage (Diff coverage), the average size of breaches (Avg breach), and the maximum size of breaches (Max breach), respectively. The independent variables are skin-in-the-game (SITG), CCPs' other capital than SITG (Other Equity), profitability (Profits), initial margin (IM), and total asset (Asset). The dummy variable D0 takes 1 when a CCP is a user-owned one and has a lower than median profit, and 0 otherwise. The dummy variable D1 takes 0 when a CCP is a for-profit one and has a higher than median profit. The panel regressions incorporate the time and CCP entity fixed effects.

	(1)	(2)	(3)	(4)	(5)
	Number of breaches	Achieved coverage	Diff coverage	Avg breach	Max breach
SITG	-0.25**	0.08**	0.10**	-0.04*	-1.58*
	(-2.18)	(2.04)	(2.42)	(-1.77)	(-1.89)
Other Equity	1.08	-1.07***	-1.36***	-0.16	-2.09**
	(0.58)	(-3.23)	(-3.55)	(-1.30)	(-2.03)
Profit	0.00	-0.00	-0.00	-0.00	-0.00
	(0.06)	(-1.45)	(-1.32)	(-0.29)	(-0.06)
Profit × D0	**-9.63**	**1.64**	**1.87**	**-0.78**	**-32.42**
	(-1.22)	**(0.73)**	**(0.79)**	**(-0.27)**	**(-1.43)**
Profit × D1	**3.15**	**-0.73***	**-1.09**	**1.05***	**44.39***
	(1.55)	**(-1.85)**	**(-1.63)**	**(1.72)**	**(2.93)**
IM	-0.16	-0.04	0.01	-0.04	-2.06***
	(-0.74)	(-1.10)	(0.14)	(-0.73)	(-3.12)
Asset	-0.01	0.01*	0.01*	0.00	-0.06
	(-0.25)	(1.83)	(1.79)	(0.38)	(-1.00)
Constant	45.29***	9992.03***	143.12***	3.76***	99.49***
	(6.86)	(5299.08)	(66.69)	(3.12)	(3.42)
R-sq	0.009	0.010	0.000	0.013	0.101
N	557	557	557	168	168

t statistics in parentheses
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

highly profitable market segments. The results are robust across five proxies of risk management and different specifications.

The results, particularly the first one on skin-in-the-game reducing model risk, are relevant for policy. They suggest that changing skin-in-the-game might influence how CCPs manage risks. While our paper does not attempt a normative analysis of the optimal level for CCP skin-in-the-game, the findings might serve as a useful starting point for such thinking.

We also hope that our empirical work will also contribute to the ongoing empirical and theoretical research on CCP functioning. Given the systemic role of CCPs and their relatively new emergence at the centre of the financial system, such research remains critical.

Appendix

A Quarterly increment in the number of margin breaches

In the quantitative disclosure data, CCPs report the number of margin breaches for the past 12 months. Let X_t denote the number of breaches reported at time t where $t = 0, 1, 2, \dots T$. Let Y_t denote the quarterly increment at time t where $t = -3, -2, \dots T$. Thus,

$$X_0 = Y_{-3} + Y_{-2} + Y_{-1} + Y_0.$$

To back out the Quarterly increment for all periods, we assume $Y_{-3} = Y_{-2} = Y_{-1} = Y_0$, which equals to $X_0/4$. With that, we have

$$Y_t = X_t - X_{t-1} + Y_{t-4}. \tag{A1}$$

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