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Empirical analysis of collateral at central counterparties

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Abstract

This paper studies the risk management of central counterparties (CCPs) using a granular transaction-level dataset. We test whether margining practices are sufficient relative to portfolio risk and whether CCPs reduce margin requirements in a "race-to-the-bottom." We find that, for some CCPs, margin breaches are predictable ex ante, but the portfolios of more interconnected clearing members are associated with higher margin holdings. While margin requirements increased significantly around the onset of the Covid-19 pandemic, controlling for portfolio and macro-financial variables, margin breaches did not. Our results indicate that changes in margins should be analyzed alongside margin breaches.

Keywords:	CCP; risk management; initial margin; variation margin;
JEL classification:	G23; G21; G15;

1 Introduction

Following the 2008 financial crisis, the G20 and regulators around the world instituted a series of reforms to strengthen the financial system. One of the key objectives of the G20 Pittsburgh agenda was to move the over-the-counter (OTC) derivatives trading from bilateral transactions to transactions that are cleared through central counterparties (CCPs). This transition was implemented through a series of regulations, resulting in the requirement that "standardized OTC derivatives" be cleared through a CCP. While central clearing increases transparency and has the potential to improve risk management, it concentrates risk at CCPs.[1] For example, during the recent Covid-19 crisis, collateral called by CCPs increased substantially, and further regulatory measures were recommended to prevent liquidity risks from concentrated margin calls.[2]

Understanding the risk management practices of CCPs is important for financial stability, since many CCPs are systemically important financial institutions. Furthermore, because CCP regulation is principles-based, CCPs may follow different risk management strategies in practice. In this paper we use regulatory data collected through the European Market Infrastructure Regulation (EMIR) to study the first level of resources available to a CCP: margins provided by clearing members to CCPs. We make three contributions. First, we test whether margining practices are sufficient relative to portfolio risk and find that, for some CCPs, margin breaches - instances when a portfolio burns through its margin - are predictable ex ante. Second, we test whether CCPs engage in a "race-to-the-bottom" to increase market share by reducing margins, and find that on the contrary margin requirements are higher at more-interconnected clearing members,

[1]For detailed information on the effects of the G20 financial regulatory reforms, see Financial Stability Board (2018), as well as the overview in Menkveld and Vuillemey (2020). For a broader discussion on the impact of central clearing on market liquidity and collateral demand, see Duffie and Zhu (2011), Duffie (2018), Duffie, Scheicher, and Vuillemey (2015) and Cont (2017), as well as Wendt (2015).

[2]See Bank for International Settlements and International Organization of Securities Commissions (2021), European Systemic Risk Board (2020b) and European Systemic Risk Board (2020d), as well as Huang and Takáts (2020a). For earlier discussions of possible systemic risks related to margining, see European Systemic Risk Board (2017) and European Systemic Risk Board (2020c).

after controlling for portfolio characteristics. Third, we show that while margin requirements have risen during the Covid-19 pandemic, controlling for measures of risk at the portfolio and macro level, margin breaches have not become significantly more or less frequent. Overall, our results highlight the necessity of analysing the information on margin breaches alongside margins themselves when examining CCP risk management practices.

In the first of its three contributions, this paper considers determinants of initial margin, as well as excess collateral, posted at a CCP in terms of variables specific to each portfolio, information related to each clearing member, variables specific to each CCP and broader macro-financial variables, and tests whether margining practices—both over time and across CCPs—are sufficient relative to portfolio risk. We measure this risk by comparing margins (both required and excess) to daily fluctuations in portfolio values. Whenever the change in the portfolio value over the following day is greater than the total margin—an event that we term a margin breach, or "portfolio margin crossing"—the CCP would call on the clearing member to provide additional resources. If the clearing member is unable to cover the difference, that would trigger a default, and the CCP would resort to its additional layers of protection, starting with the defaulting clearing member's contribution to the guarantee fund, and moving if necessary to the CCP's own contribution (skin-in-the-game) and then other clearing members' contributions. Overall, we find a strong link between portfolio risk and the level of initial margins, as well as some evidence of predictability of margin crossings: the probability of a next-day margin crossing increases with the contract value of a portfolio, and, for some CCPs, crossings become more likely at times of higher financial market uncertainty (as measured by the VIX).

In more detail, we show that portfolio-specific variables that capture risk—such as the size of the portfolio, the total value of the portfolio, or the daily variation in portfolio value—correlate with higher initial margin. Financial market variables that capture systematic risks—such as the level of market volatility, the change of benchmark interest rates, or the change of exchange rates—are also significant in determining initial margins. Furthermore, we provide evidence that excess collateral—which is determined in part by the clearing member and is not required by the CCP— correlates with the same risk factors, though not as strongly as initial margin. In addition to portfolio-specific and aggregate financial variables, we also examine CCP-specific variables based on the public quantitative disclosures (PQDs) and find mixed evidence that CCP structure affects margins. We find that the share of client clearing, which captures the extent of indirect clearing and the associated risks above and beyond those captured by portfolio characteristics, is associated with higher levels of initial margin. This finding is consistent with the analysis of safety of central counterparties related to the exposures to member and client portfolios in Paddrik and Young (2018). Overall, our results are in line with the principles for financial market infrastructures, proposed by the Committee on Payments and Market Infrastructures at the Bank for International Settlements (CPMI) and the International Organization of Securities Commissions (IOSCO), that the level of initial margin should reflect the risk of the underlying portfolio (Bank for International Settlements, 2012). For example, many CCPs internalize this principle by setting the initial margin as a function of a portfolio's Value-at-Risk.[3]

In the second contribution, this paper tests whether CCPs engage in a "race to the bottom" by relaxing their risk management practices in an attempt to gain market share, as they are for-profit institutions (Glasserman, Moallemi, and Yuan, 2016).[4] One way for CCPs to compete is to reduce initial margin; in that scenario, CCPs would reduce initial margin for clearing members with large exposures to other CCPs, relative to other comparable clearing members. Alternatively, CCPs might factor in a clearing member's additional exposure and increase initial margins to account for the increased intercon-

[3]Our results also link to the literature on the procyclicality of initial margins across CCPs, as for example discussed in Bank for International Settlements and International Organization of Securities Commissions (2021), as well as in Murphy and Vause (2021) and Murphy, Vasios, and Vause (2016).

[4]For a related discussion from the policy perspective, see also Krahnen and Pelizzon (2016).

nectedness; a CCP might engage in such a practice in order to, for example, signal its resilience. We test for both possibilities by including clearing member-specific information that captures total initial margin posted at other CCPs.[5] For some markets, we find statistically significant evidence that an increase of the total initial margin towards other CCPs increases initial margin. Thus, we reject the race-to-the-bottom hypothesis; our results suggest that CCPs actually increase initial margin for clearing members with large exposures towards other CCPs.

In its final contribution, this paper highlights that changes in margins should be analyzed alongside margin breaches, using as an example the analysis of the behavior of initial margins collected by CCPs around the onset of the Covid-19 pandemic in March 2020. Similar to previous studies (European Systemic Risk Board, 2020b,d; Huang and Takáts, 2020a), we find that initial margins increased significantly in 2020, but we show that margins increased even after controlling for measures of risk at the portfolio and macro level (for example, the level of the VIX). At the same time, margin breaches did not significantly vary during this period, which could be consistent with the hypothesis that the higher margins were driven by the level of risk and uncertainty in the economy. Thus, our results underline the importance of analyzing margins alongside margin crossing information, rather than in isolation.

Our paper contributes to a relatively small empirical literature on CCP risk management. One paper that considers the empirical determinants of initial margin requirements is Capponi, Cheng, Giglio, and Haynes (2017) who analyze margins for CDS contracts at a single CCP – Ice Clear Credit. They find that margins are set based on extreme tail risks. We use a different dataset, and study determinants of initial margin, excess collateral, and predictability of margin crossings, taking into account portfolio-specific, CCP-specific and clearing member-specific information, as well

[5] Notice that regulatory guidelines suggest that information specific to clearing members themselves, rather than their portfolios, should not influence a portfolio's initial margin (Bank for International Settlements, 2012).

as broader macro-financial variables.

The remainder of the paper is structured as follows. Section 2 describes the transaction-level EMIR data, as well as CCP-specific and macro-financial variables. Section 3 discusses the determinants of initial margins and excess collateral. Section 4 analyses the predictability of margin crossings. Section 5 presents the analysis of the behavior of margin requirements around March 2020, and Section 6 concludes.

2 Data

We have access to the regulatory dataset of EMIR data available to the European Systemic Risk Board, under Bridge Programme 003620. The data include all outstanding exchange-traded and over-the-counter derivatives transactions where at least one of the counterparties is domiciled in the European Union. The data are provided daily through various trade repositories and include information on each counterparty, the transaction, as well as on collateral – initial margin, excess collateral and variation margin. For our study we limit ourselves to transactions where one of the counterparties is a CCP domiciled in the European Union.

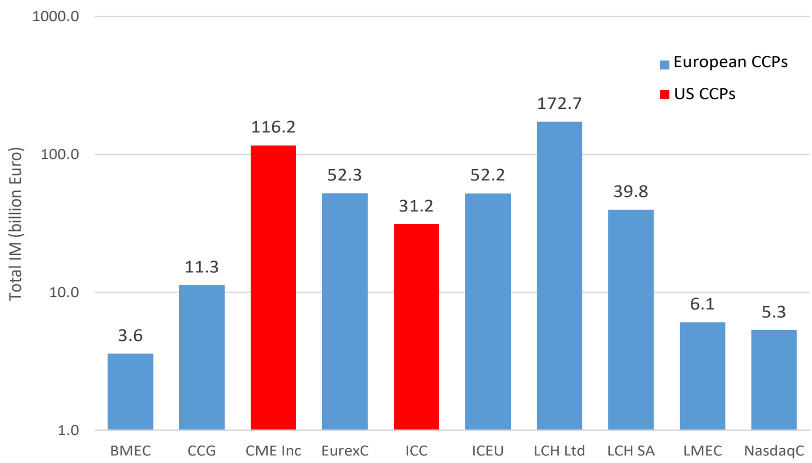

Figure 1: CCP Total Initial Margin Held, 2019Q1

NOTE: The figure plots total initial margin held at various CCPs in the first quarter of 2019 (i.e., the first quarter of our sample), based on CPMI-IOSCO Public Quantitative Disclosures.

According to EMIR, both counterparties report transactions to a trade repository. To avoid double counting, we only use information reported by the CCPs. Our sample covers the period between 1 May 2018 and 31 March 2021, from which we select the period between 1 January 2019 and 31 December 2020 (i.e., 512 trading days) to mitigate data quality issues and changes in coverage. Each data point is a portfolio of a clearing member at a CCP for one day.[6] To account for the fact that large financial institutions may own various entities through which they access the derivatives markets, we use the Legal Entity Identifier (LEI) of each clearing member matched with the LEI of its ultimate parent, as available in the Global Legal Entity Identifier Foundation (GLEIF) database.

Before analyzing the data, we apply the following filters:

1. We remove portfolios when the LEI for the clearing member is missing
2. We remove portfolios with missing portfolio codes
3. We remove portfolios with zero, or negative, total notional
4. We remove portfolios with missing values for initial margin
5. We remove portfolios at a CCP with broader data reporting issues

Among the variables available via the EMIR data, we focus on the information related to the initial and variation margins, and to excess collateral. Because margin and excess collateral information is only available at the portfolio level – where portfolios at individual CCPs are defined using the collateral portfolio code field in EMIR[7] – we

[6]A clearing member may have multiple portfolios with each CCP, corresponding to different house and client accounts. For information on the European cleared derivatives market and descriptive statistics, see European Systemic Risk Board (2021), European Systemic Risk Board (2020a), European Securities and Markets Authority (2020b) and European Securities and Markets Authority (2020a). Bank for International Settlements (2020) provides a global markets overview.

[7]See Delegated Regulation (EU) 2017/104, Annex "Details to be reported to trade repositories", Table 1, item 23.

aggregate transaction-level information to the portfolio level. In particular, we aggregate notional and contract value to the portfolio level by summing across individual transactions within a reported collateral portfolio code.[8] For initial margin and excess collateral we use the reported initial margin and excess collateral received.[9] We convert currency values to euros using the appropriate daily exchange rate.

Variation margin (VM) in EMIR, both posted and received, is reported as a stock variable; to convert it to a flow, we take a forward time difference of the net variation margin position (VM received less VM posted), as follows:[10]

$$\begin{aligned} \text{VM\_flow}_{i,t} \equiv & \left[\text{VM\_received}_{i,t+1} - \text{VM\_posted}_{i,t+1}\right] \\ & - \left[\text{VM\_received}_{i,t} - \text{VM\_posted}_{i,t}\right] \end{aligned}$$

where i is the portfolio index.

Beyond these variables, we also construct indicator variables showing whether the initial margin (or the initial margin plus the excess collateral) posted for a portfolio on a day t was sufficient to cover the variation margin from the price movement on a day $t+1$, as measured by the variation margin flow between days t and $t+1$. We define the variable called "portfolio margin crossing" as the difference between the initial margin, including the excess collateral, on t and the absolute variation margin flow between days t and $t+1$:

$$\text{PMC}_{i,t} = \mathbb{1}\left\{\text{VM\_flow}_{i,t} > \text{IM\_received}_{i,t} + \text{EX\_received}_{i,t}\right\} \quad (1)$$

where $\mathbb{1}\{\cdot\}$ is the indicator function.

The number of observations after we apply each data filter is listed in Table 1. The table shows that, initially, there are almost 3.5 million portfolio-day observations in the

[8]Ibid, Table 2, item 20 (notional) and Table 1, item 17 (contract value).

[9]Ibid., Table 1, items 28 (initial margin) and 34 (excess collateral).

[10]Ibid., items 26 (posted) and 30 (received).

No. observations before drops	3,573,974
No macro data	95,312
Missing portfolio code	97,376
Missing CM LEI	1,362,974
Missing IM	407,068
Missing VM	373,037
Missing Notional	49,271
Selected CCP portfolios of poor data quality	48,784
Multi-asset class portfolios	39,676
No. observations after drops	1,100,475

Table 1: Number of portfolio-day observations and sample cleaning

NOTE: The table reports the number of portfolio-day observations in the sample, both before drops (top row) and after all drops (bottom row). Intermediate rows report the number of observations dropped for each step of the cleaning procedure.

sample. The data filters reduce the coverage to approximately 1.1 million observations. The filter dropping missing LEI of the clearing member or the missing portfolio codes leads to most of the removals (approximately 1.3 million observations), while the filter that requires margin information removes approximately 770 thousand observations. We also drop approximately 49 thousand observations reported by one CCP due to broader data quality issues. Finally, to maintain consistency across portfolios, we require that at least 90% of the portfolio, measured by notional, is in one asset class, where the asset classes we consider are interest rate, credit, equity, and commodity. This additional requirement results in the removal of an additional 40 thousand observations.

Table 2 reports summary statistics for our sample. The table shows that the median notional value is approximately EUR 1611 million, while the median aggregate portfolio contract value is close to zero.

In our data we observe both the initial margin — i.e. the required collateral — on each portfolio, as well as the excess collateral. Excess collateral is additional margin the clearing members may keep in their portfolios; it is not required by the CCP. The median initial margin received is approximately EUR 11.13 million across portfolios in all asset classes; we observe excess collateral for only 73% of portfolios, and for these portfolios the median excess collateral is just over EUR 2.43 million. The median variation margin across portfolios in all asset classes is approximately EUR 0.30 million.

	Obs	Mean	Std Dev	p10	p50	p90
# Transactions	1,100,475	710.31	5333.01	2.00	22.00	544.00
Gross Notional	1,100,475	440316.69	3.64e+06	19.68	1611.25	124635.68
Gross Contract Value	1,100,475	83.80	3237.92	-262.70	0.07	263.68
Initial Margin Received	1,100,475	97.82	409.06	0.29	11.13	221.17
Variation Margin	1,100,475	7.67	41.87	0.00	0.30	11.93
Portfolio Crossings (IM)	6,522	20.73	97.68	0.02	1.28	39.08
Ind. for Ex Coll	1,100,475	0.73	0.44	0.00	1.00	1.00
Excess Collat. Received	803,796	17.36	57.86	0.08	2.43	43.28
Portfolio Crossings (IM + EX)	5,344	21.51	103.18	0.02	1.30	40.51

Table 2: Summary statistics

NOTE: The table shows the summary statistics of portfolio-day observations in the sample. All reported values, except the number of transactions, are in EUR million. The rows labeled "Portfolio Crossings (IM)" and "Portfolio Crossings (IM + EX)" report summary statistics for the size of the portfolio margin crossing, conditional on a crossing occurring, for margin including only initial margin or initial margin plus excess collateral, respectively.

We also observe several margin crossings; i.e., instances when the initial margin held on a given day turns out to be lower than the change in the value of the portfolio on the following day. The median amount by which variation margin exceeds initial margin, given a margin crossing, is approximately EUR 1.27 million for both crossings including and excluding excess collateral. Overall, the difference between means and medians suggests that the crossings are significantly skewed to the right, which suggests a number of very large trades.

After applying all our filters, we merge the resulting data with macroeconomic variables. The variables are the: short- and longer-term interest rates (1-month EURIBOR and 5-year euro area overnight-indexed swap rates as available from Bloomberg); exchange rates (EUR-GBP as available from the European Central Bank) and option-implied volatility of stock markets (VIX). The results are robust to including other macro control variables, for example EUR-USD, stock prices and the CDS index for European financial institutions (iTraxx Europe Financials as available from Bloomberg), as well as to controlling for VIX only. Table 1 lists the number of portfolio-day observations where the macroeconomic data are not available.[11]

CCPs make quarterly, public filings that provide information on their aggregate

[11] These missing observations are, for example, due to potential data errors where data are reported for days that markets may be closed.

default resources, as well as measures of concentration of exposures towards clearing members.[12] To capture CCP-specific effects, we include the following variables from CCPs' public quantitative disclosures:[13]

1. Prefunded default resources (own capital to default funds, item 8.1 in European Systemic Risk Board 2021)
2. Collateralisation (collateral posted to margin required, item 8.3 in European Systemic Risk Board 2021)
3. The share of client clearing (share of total initial margin required for client clearing, item 8.9 in European Systemic Risk Board 2021)

To capture effects specific to the clearing members, we include their total exposures towards other European CCPs, as based on the available EMIR data. In particular, we use total initial margin posted at other CCPs. Including this variable allows us to test whether CCPs adjust their margining practices towards more interconnected clearing members.[14]

3 Determinants of Required and Excess Margin Holdings

In this section we analyze the determinants of initial margin set by CCPs, as well as the excess collateral provided by clearing members in addition to required initial margin. We consider determinants of initial margin in terms of variables specific to each portfolio, macro-financial variables, information related to each clearing member, and variables specific to each CCP.

[12] CCPs vary in many ways: from their ownership structure, to the markets they clear, to the supervisors they report to. The Office of Financial Research published a Viewpoint where it compares the financial resources backing a CCP and found evidence of this variation – see Office of Financial Research (2017).

[13] The variables are described in Abad, Aldasoro, Aymanns, D'Errico, Rousová, Hoffmann, Langfield, Neychev, and Roukny (2016) and/or are regularly reported – see European Systemic Risk Board (2021).

[14] For robustness purposes, we also tested other measures of exposures like total notional posted at other CCPs, or total contract value.

	(1)	(2)	(3)	(4)	(5)
Log Notional	0.416***	0.379***	0.388***	0.389***	0.413***
	(17.71)	(16.91)	(17.29)	(17.43)	(17.65)
Log Abs VM Flow	0.0634***	0.0573***	0.0514***	0.0511***	0.0478***
	(16.92)	(15.55)	(14.43)	(14.40)	(13.74)
Log Abs Contract Value		0.0720***	0.0654***	0.0637***	0.0724***
		(8.045)	(7.893)	(7.951)	(10.10)
Prefunded default resources				0.0390	1.782
				(0.0920)	(1.029)
Collateralisation				-0.258***	-0.702***
				(-3.739)	(-3.402)
Client clearing				0.778***	0.716***
				(4.268)	(3.461)
Log IM at Other CCPs					0.151***
					(6.524)
Macro Controls	NO	NO	YES	YES	YES
Observations	1,101,770	1,056,309	1,025,607	1,025,607	929,490
R-squared	0.191	0.200	0.209	0.212	0.243
Number of portfolios	7,540	7,334	7,306	7,306	5,021
Number of CMs	845	827	821	821	103

Table 3: Determinants of initial margin

NOTE: The table shows the regression coefficients corresponding to equation (2), where the endogenous variable is log of initial margin. Robust t-statistics in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

To identify the determinants of initial margin, we run regressions of the form

$$\log{(\mathrm{IM})}_{i,j,t} = \alpha + \beta_1' X^P_{i,j,t} + \beta_2' X^{CCP}_{j,t} + \beta_3' X^M_t + \beta_4' X^{CM}_{i,(-j),t} + \epsilon_{i,j,t} \qquad (2)$$

where $\mathrm{IM}_{i,j,t}$ is value of total initial margin required for portfolio i, at CCP j, at time t, and the independent variables are

$X^P_{i,j,t}$: a vector of characteristics for portfolio i, at CCP j, at time t;

$X^{CCP}_{j,t}$: a vector of CCP characteristics for CCP j at time t;

X^M_t: a vector of macroeconomic variables at time t;

$X^{CM}_{i,(-j),t}$: log IM held at *other* CCPs by the clearing member that corresponds to portfolio i, at time t.

We expect that, all else equal, riskier portfolios require more initial margin. Equation (2) tests this hypothesis using several variables that proxy for risk, including the absolute value of variation margin flow, the gross notional of the portfolio, and the absolute value of the portfolio's contract value. We proxy for risk using the one-day ahead variation margin flow $\log |\text{VM\_flow}_{i,t}|$: all else equal, portfolios that experience *ex post* large variation margin flows (in either direction) are likely to be more risky *ex ante*. Regarding the gross notional of a portfolio, larger portfolios will have greater price impact upon a default event, and CCPs may require more margin for larger portfolios. Likewise, portfolios with larger absolute contract values are likely to represent greater risks to CCPs, because the large portfolio contract values may reflect large directional bets — either short or long — which the CCP may have difficulty off-loading if the corresponding clearing member were to default. In addition, many of the macro variables included in equation (2) have a direct relationship to aggregate risk, allowing us to test whether CCPs increase margin when, for example, the VIX is high. The regression also includes portfolio fixed effects.

We also consider how initial margin relates to CCP-specific variables, in particular their share of prefunded default resources, how collateralized they are, and their share of client clearing, as reported in their Public Quantitative Disclosures. A positive relationship between prefunded default resources (or "skin-in-the-game") and initial margin would suggest that CCPs that post a large amount of their own resources as collateral require higher initial margins.[15] This may be due to these CCPs either performing better diligence than others, or having larger default funds to absorb potential losses — in either case we would expect more portfolio margin crossings for CCPs with relatively less skin-in-the-game. But it may also indicate that CCPs with higher skin-in-the-game clear relatively safer contracts — in that case we would not expect to see any difference in portfolio margin crossings. Regarding collateralisation, a positive coefficient would

[15]In a recent study, Huang and Takáts (2020b) find, based on the public quantitative disclosures data, that the amount of skin-in-the-game is significantly associated with more prudent modeling by CCPs. In a theoretical paper, Wang, Capponi, and Zhang (2021) consider the trade-offs between initial margin vs. default fund contributions. They show that, although default fund contributions are more efficient under distressed market scenarios, CCPs may rely more on initial margins when capital requirements are stringent.

indicate that required margin and excess collateral are complementary, whereas a negative coefficient would suggest that as clearing members post more excess collateral, CCPs actually reduce their required margin. We expect a positive relationship between required initial margin and the share of client clearing, since all else equal clearing for clients represents greater risks and fewer netting opportunities. Our results on these PQD variables may lack power since PQD variation is by CCP-quarter, while our other variables vary daily and by portfolio. We find that the share of client clearing is associated with higher levels of initial margin. On the other hand, we find no evidence that the share of skin-in-the-game in the CCP's waterfall is related to initial margins, when controlling for portfolio-specific risk characteristics.

Finally, we consider whether there is empirical evidence to support theoretical predictions of a "race to the bottom" (Glasserman, Moallemi, and Yuan, 2016). The theory suggests that competing CCPs may reduce initial margin requirements in an attempt to poach market share from their competitors — an action that would induce their competitors to then lower *their* initial margin requirements, resulting in far too little margin relative to the risks of the portfolios. Such a "race to the bottom" scenario is particularly concerning given the systemic nature of CCPs. We test for this possibility by including explanatory variables that capture the total initial margin posted at other CCPs, in our baseline regression specification.[16] If CCPs engage in a race-to-the-bottom, then we would expect to find both a negative coefficient for the total initial margin posted at other CCPs, and an increase in the number of portfolio margin crossings.

Table 3 reports the results for the full sample. As portfolios grow in terms of gross notional, required initial margin increases, although the elasticity is significantly less than 1. The estimated elasticity in column 1 of Table 3 suggests that as a portfolio doubles in size, its required initial margin grows by 44%. This could be because as portfolios grow, their total riskiness actually declines due to increased netting across positions within the

[16] As robustness checks, we also considered other measures of exposures, i.e., aggregate notional towards other CCPs and total contract value with other CCPs.

portfolio. Portfolios with larger susbsequent VM flows also have more initial margin ex ante. In line with the assumption that portfolios with larger contract values are riskier, Column 2 shows that portfolios whose values are further from zero are also associated with more required initial margin. Columns 3 and 4 add macroeconomics variables and CCP-level PQD controls, respectively, which do not substantially alter the estimated coefficients on these three portfolio-specific variables.

We find no evidence that CCPs engage in a "race to the bottom." In fact, the coefficient on initial margin held at other CCPs (final column of Table 3) is positive and statistically significant, suggesting that CCPs actually require *more* collateral, all else equal, from clearing members as their positions at other CCPs grow.

Table 4 reports the results of estimating equation (2) on individual CCPs; it includes macroeconomic variables as well as initial margin held at other CCPs similar to column 5 of Table 3. The regression does not include the PQD controls since there is not enough variation within a CCP to estimate the coefficients of these variables. Table 4 reveals that the full-sample regression masks substantial heterogeneity across CCPs. In Table 4, margin is increasing in gross notional at all CCPs, but with elasticities ranging from 0.35 to 0.56; likewise, the elasticity of margins with respect to the absolute variation margin flow the next day also varies across CCPs. Margin is increasing in the absolute contract value at all CCPs, apart from CCP D. There is also substantial variation in how well these regressions can explain CCPs' margining practices, with R^2 ranging from about 0.06 to around 0.5.

Table 4 includes macroeconomic variables and margin held at other CCPs to the CCP-specific regressions, and shows that broader economic developments influence initial margins at some CCPs. For example, initial margins respond to the changes in shorter- and longer-term interest rates, and increase when market uncertainty — measured by option-implied stock-market volatility — increases. Higher values of market-wide risk indicators, like the VIX or the CDS index for financial institutions, are also related with

	(1) CCP A	(2) CCP B	(3) CCP C	(4) CCP D	(5) CCP E
Log Notional	0.403***	0.489***	0.358***	0.560***	0.349***
	(6.553)	(21.85)	(9.806)	(6.440)	(5.050)
Log Abs VM Flow	0.125***	0.0689***	0.0292***	0.0504***	0.0984***
	(6.614)	(11.44)	(12.97)	(3.947)	(6.421)
Log Abs Contract Value	0.0605***	0.130***	0.106***	-0.136***	0.0241
	(2.770)	(8.613)	(15.18)	(-3.460)	(1.341)
Chg in Euribor 1-month	-1.092***	-2.613***	-0.504***	1.740	-2.053***
	(-2.887)	(-11.68)	(-3.452)	(1.507)	(-3.471)
Chg in 5y EA OIS	-0.306**	0.281***	0.122**	0.131	-0.352**
	(-2.147)	(5.413)	(2.315)	(0.344)	(-2.637)
VIX	0.00441***	0.00909***	0.00388***	-0.00111	0.00354**
	(3.611)	(11.59)	(6.835)	(-0.397)	(2.452)
Chg in EUR-GBP Exchg Rate	0.147***	-0.216***	0.0542***	0.0830	-0.0757
	(3.656)	(-4.566)	(3.002)	(1.110)	(-0.394)
Log IM at Other CCPs	-0.0124	0.104***	0.121***	-0.0716	0.0606
	(-0.317)	(3.942)	(3.726)	(-0.789)	(0.749)
R-squared	0.191	0.493	0.261	0.062	0.287

Table 4: Determinants of initial margin, by CCP

NOTE: The table shows the regression coefficients corresponding to equation (2), where the endogenous variable is log of initial margin. Robust t-statistics in parentheses: *** p<0.01, ** p<0.05, * p<0.1. For confidentiality reasons, the table does not disclose the number of observations or portfolios underlying the regressions. The ordering of CCPs may vary across various tables in this paper.

higher initial margins.

In addition to portfolio-specific and aggregate financial variables, we also examine CCP-specific variables based on the public quantitative disclosures (PQDs) and find mixed evidence that CCP structure affects margins. We find that the share of client clearing, which captures the extent of indirect clearing and the associated risks above and beyond those captured by portfolio characteristics, is associated with higher levels of initial margin.

The last row of Table 4 shows that there is substantial variation across CCPs in how initial margin responds to margin held at *other* CCPs. The effect is positive and statistically significant in two of the CCPs. In other words, for some CCPs, there appears to be a relationship between initial margin and exposure to other CCPs. However, since the effect of initial margin at other CCPs is never negative, we can still rule out a "race to the bottom" hypothesis even in the individual CCP regressions.

Excess collateral behaves similarly to initial margin: Tables 5 and 6 report the results

	(1)	(2)	(3)	(4)	(5)
Log Notional	0.293***	0.249***	0.261***	0.261***	0.286***
	(12.67)	(10.38)	(10.77)	(10.83)	(11.41)
Log Abs VM Flow	0.0433***	0.0385***	0.0333***	0.0333***	0.0315***
	(13.12)	(12.92)	(11.94)	(11.87)	(10.91)
Log Abs Contract Value		0.0843***	0.0729***	0.0717***	0.0679***
		(10.85)	(10.27)	(10.34)	(9.461)
Prefunded default resources				2.506**	3.313*
				(2.067)	(1.866)
Collateralisation				-0.0803**	-0.346***
				(-2.269)	(-2.679)
Client clearing				0.287*	0.385**
				(1.759)	(2.418)
Log IM at Other CCPs					0.131***
					(5.596)
Macro Controls	NO	NO	YES	YES	YES
Observations	790,148	753,699	732,375	732,375	677,303
R-squared	0.052	0.060	0.067	0.067	0.077
Number of portfolios	4,113	3,947	3,937	3,937	3,566
Number of CMs	405	387	387	387	102

Table 5: Determinants of excess collateral

Note: The table shows the regression coefficients corresponding to equation (2), where the endogenous variable is the log of excess collateral. Robust t-statistics in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

of estimating equation (2) using the log of excess collateral, instead of required initial margin, as the dependent variable. The results are broadly similar to the required-margin results in Tables 3 and 4, though somewhat weaker. Excess collateral increases with the gross notional value and riskiness of the portfolio and decreases with the contract value. Among the macroeconomic variables, those related to the overall risk in the financial sector significantly influence the build-up of excess collateral held by CCPs. For example, Table 6 shows that excess collateral is positively related to the level of the VIX at 3 out of 5 CCPs.

4 Predictability of Portfolio Margin Crossings

In this section we analyze the determinants of portfolio margin crossings, by which we mean the times when the initial margin (and excess collateral) of a portfolio held in the morning of a trading day are insufficient to cover the portfolio loss due to market

	(1) CCP A	(2) CCP B	(3) CCP C	(4) CCP D	(5) CCP E
Log Notional	0.282***	0.295***	0.283***	0.442***	0.148**
	(2.927)	(8.905)	(8.665)	(5.268)	(2.478)
Log Abs VM Flow	0.0972***	0.186***	0.0170***	0.0521***	0.0821***
	(5.198)	(15.54)	(7.740)	(6.657)	(4.175)
Log Abs Contract Value	0.0703***	0.198***	0.0643***	-0.0766***	0.132***
	(3.194)	(5.499)	(9.472)	(-5.011)	(3.581)
Chg in Euribor 1-month	1.404*	4.713***	0.672	1.013	1.273*
	(1.699)	(3.301)	(1.427)	(0.767)	(1.829)
Chg in 5y EA OIS	-0.0552	-1.433***	0.230**	1.365***	0.138
	(-0.216)	(-4.818)	(2.294)	(4.000)	(0.343)
VIX	-0.00247	0.0209***	0.00503***	0.00123	0.00752***
	(-1.520)	(11.63)	(5.882)	(0.650)	(5.097)
Chg in EUR-GBP Exchg Rate	-0.142*	-0.176**	0.114***	-0.191*	-0.256
	(-1.979)	(-2.153)	(3.041)	(-1.718)	(-0.949)
Log IM at Other CCPs	-0.0294	0.0658***	0.151***	-0.0253	0.330**
	(-1.456)	(2.961)	(4.141)	(-0.491)	(2.646)
R-squared	0.042	0.183	0.082	0.040	0.119

Table 6: Determinants of excess collateral, by CCP

NOTE: The table shows the regression coefficients corresponding to equation (2), where the endogenous variable is the log of excess collateral. Robust t-statistics in parentheses: *** p<0.01, ** p<0.05, * p<0.1. For confidentiality reasons, the table does not disclose the number of observations or portfolios underlying the regressions. The ordering of CCPs may vary across various tables in this paper.

movements incurred on that day. Portfolio margin crossings occur with some frequency since, in general, CCPs set their initial margin requirements in order to satisfy a value-at-risk constraint. Table 2 shows that crossings occur in our sample, unconditionally, about 0.59% of the time; the value is 0.48% when considering excess collateral in addition to required initial margin.

To identify the determinants of next-day portfolio margin crossings, we run regressions of the form

$$\text{PMC}_{i,j,t} = \alpha + \beta_1' X_{i,j,t}^{P} + \beta_2' X_{j,t}^{CCP} + \beta_3' X_t^{M} + \beta_4' X_{i,(-j),t}^{CM} + \epsilon_{i,j,t} \quad (3)$$

where the dependent variable, defined in equation (1), is an indicator function equal to 1 whenever the change in the portfolio value from t to $t+1$ (for portfolio i, at CCP j, on day t) is greater than the initial margin plus excess collateral held at time t, i.e.

before the opening of the trading day $t+1$.[17] When this occurs, the clearing member must either cover the difference — potentially through gains at other portfolios or by providing additional resources — or default. Notice that a margin crossing does not in general indicate that a clearing member is in default; it simply indicates that the initial margin and excess collateral were not, ex post, sufficient to cover that day's market movement for that portfolio. The independent variables in equation (3) are the same as equation (2), with the exception of $\log |\text{VM\_flow}_{i,t}|$ which we do not include in the regressions in this section. Similar to equation (2), equation (3) includes portfolio fixed effects.

Although portfolio margin crossings (PMCs) are expected to occur, they should not be predictable *ex ante*. If they were, that would indicate that the CCPs are either requiring too much initial margin — if PMCs are lower than expected — or too little. In either case, any predictability in PMCs suggests that CCPs could improve their risk management practices.

Likewise, the amount of initial margin held by a clearing member at *other* CCPs should not predict crossings. One consequence of a "race to the bottom" would be that, because CCPs do not require "enough" collateral at clearing members whose business they are trying to attract, margin crossings are more likely for the portfolios of such clearing members. Thus, a "race to the bottom" predicts that crossings are more likely at clearing members with larger positions at other CCPs. Notice that this is possible even though we found in Section 3 that CCPs do not require more collateral from such clearing members; because these clearing members may also be riskier than others, it could be that this additional collateral is actually insufficient to cover their additional risk, and that initial margin at other CCPs positively predicts crossings.

Table 7 reports the results of estimating equation (3) for the full sample. All regressions include portfolio fixed effects, so that these results should be interpreted as

[17] In addition, we also check the portfolio margin crossings variable without taking the excess collateral into account. The results are qualitatively similar.

reflecting within-portfolio (and thus within clearing member and CCP) variation, not across-portfolio variation.

The first column of Table 7, which includes only the log notional of the portfolio and portfolio fixed effects as independent variables, shows that although larger portfolios are less likely to cross, the effect is small and barely significant. However, adding more independent variables (the log absolute contract value in column 2, macroeconomic variables in column 3, and CCP-level PQD controls in column 4) increases the statistical significance for the coefficient of log notional substantially. These estimated values are large: the coefficient on log notional in column 4 suggests that when a portfolio doubles in size, its probability of crossing is reduced by 12 basis points, on a base probability of 48 basis points.

The last column of Table 7 includes the log of the initial margin held by portfolio i's clearing member at all other CCPs. Although the number of observations is somewhat less than in column 4, the number of included clearing members is much smaller, reflecting the fact that most clearing members in the data clear at only a single CCP, so that this additional variable is not defined for them. Thus the regression reported in column 5 is run on the sub-sample of clearing members that clear at least at two CCPs, which tend to be larger. Interestingly, the coefficients on log notional and absolute contract value are not very different across these specifications.

Table 7 shows that, all else equal, initial margin held at other CCPs is insignificant when it comes to the probability of margin crossing.

The coefficients of the PQD variables reveal that collateralization and margin crossings are positively related. This result is surprising and an indication of endogeneity – one would expect that the amount of collateral posted relative to the required margin would be negatively related to the probability of a portfolio margin crossing. The results also indicate a negative relation between the share of client clearing at a CCP and portfolio margin crossings – a result in line with increased scrutiny of client clearing by

	(1)	(2)	(3)	(4)	(5)
Log Notional	-0.000554**	-0.00203***	-0.00200***	-0.00195***	-0.00178***
	(-2.110)	(-4.282)	(-4.246)	(-4.146)	(-3.818)
Log Abs Contract Value		0.00222***	0.00217***	0.00216***	0.00175***
		(5.287)	(5.262)	(5.128)	(4.475)
Prefunded default resources				-0.0639***	-0.306***
				(-3.117)	(-4.071)
Collateralisation				0.0130***	0.0419***
				(3.371)	(3.490)
Client clearing				-0.0104	-0.0108
				(-1.407)	(-1.242)
Log IM at Other CCPs					-0.00131*
					(-1.712)
Macro Controls	NO	NO	YES	YES	YES
Observations	1,194,696	1,137,456	1,105,098	1,105,098	997,931
R-squared	0.000	0.001	0.001	0.001	0.002
Number of portfolios	7,579	7,375	7,348	7,348	5,046
Number of CMs	846	829	823	823	104

Table 7: One-day ahead predictability of portfolio crossings

NOTE: The table shows the regression coefficients corresponding to equation (2), where the endogenous variable is the indicator variable of one-day ahead portfolio crossings. Robust t-statistics in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

CCPs.

Although Table 7 shows that portfolio margin crossings are predictable *ex ante* on average, it masks the substantial heterogeneity across different CCPs. Table 8 reports the results from estimating equation (3) at individual CCPs, where we have dropped the PQD variables (since they only vary very little within CCP) but now report the coefficient values for the macroeconomic indicators.[18] The reported R^2 in Table 7 are low, indicating that although some variables do predict crossings, in general crossings are very difficult to predict reliably. Table 8 shows that at some CCPs (in this case, CCP E) crossings are substantially more predictable than the average.[19]

Table 8 shows that many of the results in Table 7 are driven by particular CCPs. For example, it is only at CCPs A, B and D that larger portfolios, and portfolios with larger absolute contract value, are significantly less likely to cross. Likewise, only at CCP B

[18]These coefficients are omitted from Table 7 for confidentiality reasons.

[19]To protect the confidentiality of the CCPs reporting in EMIR, the ordering of CCPs may vary across tables.

	(1) CCP A	(2) CCP B	(3) CCP C	(4) CCP D	(5) CCP E
Log Notional	-0.000397	-0.00312***	-0.000217	-0.0115***	-1.42e-05
	(-0.350)	(-2.988)	(-0.573)	(-3.275)	(-0.0545)
Log Abs Contract Value	0.00110*	0.00198***	2.35e-05	0.0190***	6.74e-05
	(1.937)	(2.700)	(0.157)	(7.679)	(0.448)
Chg in Euribor 1-month	0.0664	-0.0585	0.0131	0.117	0.125
	(1.323)	(-1.064)	(1.387)	(0.969)	(1.476)
Chg in 5y EA OIS	-0.0183	-0.0581***	0.00527	0.0696*	0.0249
	(-1.063)	(-3.229)	(1.430)	(1.996)	(1.626)
VIX	8.13e-05*	3.84e-05	-1.64e-05*	0.000251	0.000107*
	(1.823)	(0.796)	(-1.842)	(1.619)	(1.910)
Chg in EUR-GBP Exchg Rate	-0.00398***	0.00850**	0.000273	0.00576	0.00260*
	(-3.290)	(2.525)	(0.253)	(0.795)	(1.762)
Log IM at Other CCPs	0.000751	-0.00228**	-7.71e-05	0.00352	0.000258
	(1.085)	(-2.080)	(-0.398)	(0.812)	(0.527)
R-squared	0.001	0.001	0.000	0.020	0.002

Table 8: One-day ahead predictability of portfolio crossings by CCP

NOTE: The table shows the regression coefficients corresponding to equation (2), where the endogenous variable is the indicator variable of one-day ahead portfolio crossings. Robust t-statistics in parentheses: *** p<0.01, ** p<0.05, * p<0.1. For confidentiality reasons, the table does not disclose the number of observations or portfolios underlying the regressions. The ordering of CCPs may vary across various tables in this paper.

are portfolios held by more-interconnected clearing members less likely to cross—though at none of the CCPs is the estimated coefficient positive and significant, which again runs counter to the "race to the bottom" hypothesis.

Finally, Table 8 shows that crossings can be predicted — at some CCPs — using macroeconomic variables alone. Which variables are predictive, and in which direction, varies by CCP, but some of the estimated effects are large. For example, the coefficient on the VIX for CCP D suggests that a 10-point increase in the VIX increases the probability of a crossing by almost 8 bps on a base probability of 48 bps. CCP B could maintain the same value at risk, with less collateral on average, by increasing required initial margin in times of high market volatility (and reducing it in times of low market volatility).]

5 Margin Requirements during the Covid-19 pandemic

A large shock to asset prices occurred during the period of our study in March 2020, due to the onset of the Covid-19 pandemic. We analyze the impact of this shock to initial margins collected by CCPs, as well as on breaches of initial margins using the framework we have developed. Specifically, we adjust the regressions for initial margin and for margin crossings to include time fixed-effects, beyond controlling for portfolio-specific, CCP-specific and broader macro-financial effects.

$$\log\left(\mathrm{IM}\right)_{i,j,t} = \alpha + \beta_1' X^{P}_{i,j,t} + \beta_2' X^{CCP}_{j,t} + \beta_3' X^{M}_{t} + \beta_4' X^{CM}_{i,(-j),t} + \sum_{j=1}^{14} \beta_{4+j} i_j + \epsilon_{i,j,t} \tag{4}$$

$$\mathrm{PMC}_{i,j,t} = \alpha + \beta_1' X^{P}_{i,j,t} + \beta_2' X^{CCP}_{j,t} + \beta_3' X^{M}_{t} + \beta_4' X^{CM}_{i,(-j),t} + \sum_{j=1}^{14} \beta_{4+j} i_j + \epsilon_{i,j,t} \tag{5}$$

where the variables X^P, X^M are the same as in equations (2) and (3). Equations (4) and (5) capture time fixed effects through indicator variables for different time periods: i_1 for February to June 2019, i_2 for July to December 2019, and i_{3-14} for each month between January 2020 and December 2020.

Figure 2 plots the coefficients of the time indicator variables for the initial margin regression (4), along with two standard deviation bands around the value of each coefficient. The figure illustrates that, all else equal, initial margin increased somewhat during 2019. The increase accelerated during 2020, both prior to March, and afterwards. In particular, the rise in margin time-fixed effects in March 2020 was not as pronounced as the rise in margin values documented in the literature (see, e.g., European Systemic Risk Board (2020b)). This is related to the fact that our analysis accounts for portfolio-specific, CCP-specific and macro-financial characteristics. However, the rise in margin time-fixed effects in April 2020 was very pronounced, amounting to close to 20% compared to March 2020. The increase continued in May 2020, and was followed by a slight decline in the subsequent months. We note that this behavior already accounts for changes in macro-financial variables used as controls; for example VIX.

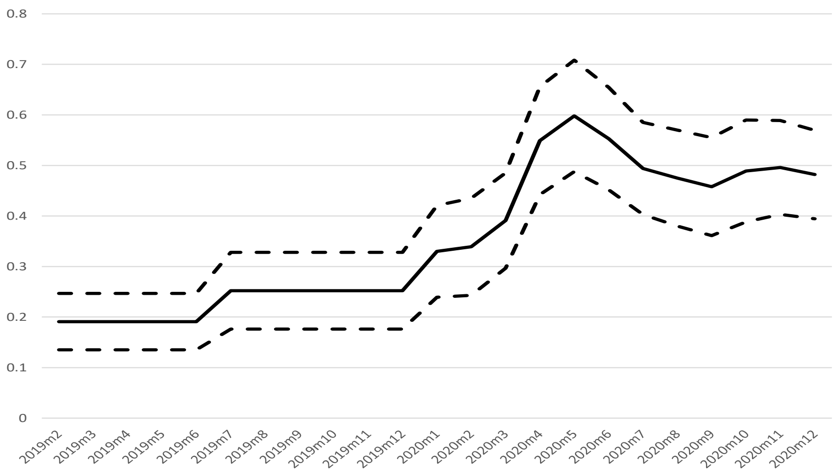

Figure 2: Log Initial Margin over Time Controlling for Portfolio-specific, CCP-specific and Macro-financial Effects

NOTE: The figure plots the time fixed effects from equation (4) along with two-standard-deviation bands over time.

Figure 3 plots the coefficients of the time indicator variables for the margin crossings from regression (5), along with two standard deviation bands around the value of each coefficient. The figure illustrates that margin crossings did not change substantially until March 2020. At the onset of the pandemic, in March 2020, we observe an increase in the margin crossings, although the increase is not statistically significant. Following March 2020, margin crossings decline and stay somewhat below the level observed in 2019 until August 2020, when they slowly revert.[20] This pattern indicates that the large increase in initial margins after March 2020 contributed, all else equal, to the decline in margin crossings to a somewhat lower level than before the pandemic. Overall, the patterns observed in both Figure 2 for initial margins, and Figure 3 suggest that the framework in our paper can be used to monitor risk management at CCPs.

[20]We have also performed this analysis by CCP and by portfolio size. We note that the relatively lower level of margin crossings post-March 2020 is not statistically significant for several portfolio size groups and some CCPs.

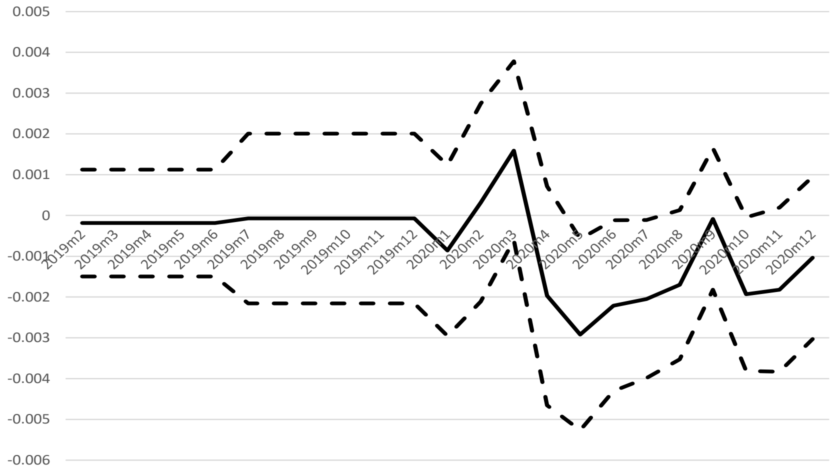

Figure 3: Log Portfolio Margin Crossings over Time Controlling for Portfolio-specific, CCP-specific and Macro-financial Effects

NOTE: The figure plots the time fixed effects from equation (5) along with two-standard-deviation bands over time.

6 Conclusion

We have provided an empirical study of collateral posting practices at central counterparties, based on regulatory data collected through the European Market Infrastructure Regulation (EMIR). Using EMIR data, we analyze not just initial margin but also variation margin flows, allowing us to analyze not only the determinants of initial margin—including portfolio-specific and macro-financial variables as well as the dramatic rise over time in margins during the Covid-19 pandemic—but also whether one-day-ahead margin crossings are predictable ex ante. We find that although margin crossings are predictable for some CCPs, they did not become more frequent during the pandemic. Our results indicate that any study of margining practices should also include margin breaches.

One theoretical prediction that our data allowed us to examine empirically is whether CCPs engage in a race-to-the-bottom when two or more CCPs compete in the same market. We have found the opposite: initial margins at CCPs increase, rather than decrease, when exposure of a clearing member to other CCPs increases, and exposure of a clearing member to another CCP is not a significant determinant of one-day ahead margin crossings.

Overall, our results and methodology are a first step towards using transaction-level data to investigate and monitor margin practices by CCPs. Our methodology could be used by regulators to assess CCP risk management over time. The richness of the data also allows several other tests, including testing for cyclicality in margin requirements. We leave these extensions for future research.

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