BANK OF ENGLAND

Staff Working Paper No. 966

Collateral cycles

Evangelos Benos, Gerardo Ferrara and Angelo Ranaldo

December 2024

This is an updated version of the Staff Working Paper originally published on 11 March 2022

BANK OF ENGLAND

Staff Working Paper No. 966
Collateral cycles

Evangelos Benos,[1] Gerardo Ferrara[2] and Angelo Ranaldo[3]

Abstract

Using supervisory data from UK central counterparties (CCPs), our paper uncovers persistent collateral cycles in which cash goes back and forth from financial markets to CCPs. In the onward phase of the cycles, clearing members utilise repurchase agreements (repos) to provide cash to CCPs so as to meet their margin requirements. This pattern is procyclical, intensifying with market volatility and driving up repo rates. In the backward phase, CCPs comply with regulations by safely investing their cash holdings primarily in reverse repos, followed by safe bonds and, to a lesser extent, central bank deposits. The return of cash by CCPs, back to financial markets via reverse repos and bond purchases, exerts downward pressure on repo rates. Overall, our findings demonstrate that CCPs have become important non-bank entities, impacting funding markets, with significant implications for financial stability and policymaking.

Key words: Central clearing, collateral, margin procyclicality, repurchase agreement, regulation.

JEL classification: G10, G12, G14.

(1) University of Nottingham and University of Cyprus. Email: evangelos.benos@nottingham.ac.uk
(2) Bank of England. Email: gerardo.ferrara@bankofengland.co.uk
(3) University of St. Gallen and Swiss Finance Institute. Email: angelo.ranaldo@unisg.ch

The views expressed in this paper are those of the authors, and not necessarily those of the Bank of England or its committees. We would like to thank Iñaki Aldasoro, Narayan Bulusu, Fernando Cerezetti, Stefano Corradin, Andrew Diplock, Darrell Duffie, Eddie Gerba, Barry Green, Sinem Hacioglu, Malcolm Long, Giuseppe Maraffino, David Murphy, Benoit Nguyen, Martin Scheicher, Matt Roberts-Sklar, Manmohan Singh, David Skingle, Ellen van der Woerd, Nicholas Vause, Guillaume Vuillemey, Andrew Wong, seminar participants at the Bank of England, the European Central Bank, the 2021 INFORMS annual meeting, SFI Research Days, the OTC Derivatives Regulators' Forum Meetings, conference participants at the European Finance Association 2023 meetings, the American Social Science Association (ASSA) 2024 meetings and the Deutsche Bundesbank and Bank of Canada International Conference on Payments and Securities Settlement for providing helpful comments. We are particularly grateful for the assistance given by Thomas Ferry and Erik Senn in collecting the data. All errors remain ours.

The Bank's working paper series can be found at www.bankofengland.co.uk/working-paper/staff-working-papers

Bank of England, Threadneedle Street, London, EC2R 8AH
Email enquiries@bankofengland.co.uk

ISSN 1749-9135 (on-line)

1 Introduction

Central counterparties (CCPs) reduce counterparty risk in financial markets by the novation of trades; that is, by becoming a counterparty to both buyers and sellers in each trade and requiring collateral (or margin) to cover the resulting exposures. CCPs have become a critical component of the financial system since the 2008 Global Financial Crisis, as new regulation has sought to increase the collateralization of exposures in Over-The-Counter (OTC) derivatives markets, the majority of which are now centrally cleared. Although this has led to an overall increase in collateral demand (ISDA, 2021), the implications of central clearing for the overall flow and distribution of collateral are still unclear.

Our paper sheds light on this issue by examining the continuous flow of cash collateral from financial markets to clearing members, then to CCPs and back to financial markets. As outlined in Figure 1, two crucial mechanisms are at play: First, there is an *onward phase*, in which clearing members raise cash from the repurchase agreement (repo) and bond markets to meet the CCP margin requirements. Higher margin calls prompt clearing members to raise more cash, which in turn drives up repo rates. Given that margin requirements increase with market volatility, repo (net) borrowing becomes procyclical. Second, current regulation mandates that CCPs invest the collected cash in safe assets, including reverse repos, government bonds, and central bank deposits. We comprehensively analyze these investment options, demonstrating that the first two constitute the *backward phase* of the collateral cycles, as they effectively return cash to the financial markets, thus exerting downward pressure on repo rates.

Using supervisory data from UK CCPs, we provide compelling evidence that the combined effects of these two flows create persistent collateral cycles in which cash goes back and forth from financial markets to CCPs. Furthermore, we demonstrate the systematic effects of these dynamics on both repo flows and rates.[1] A difference-in-differences analysis of the policy-driven migration of euro-denominated repo trades from London-based

[1] Our paper focuses on the relation between CCP margin and repo markets. As such, we do not examine the impact of CCP margin requests on bond markets.

to EU-based CCPs, establishes a causal link between CCP margin requirements and repo rates in the onward phase of the collateral cycles.

Specifically, the *onward* phase of each collateral cycle is driven by the need for CCPs to collect initial margin to protect themselves against potential losses, resulting from the default of any of their members. Our empirical analysis shows that the average daily level of initial margin pledged by the clearing members of the main UK CCPs, between February 2019 and June 2020, in all major currencies (USD, EUR and GBP), was around £185 billion, about half of which was in cash. It is also well known that CCP margin requirements increase with market volatility, that is, in a procyclical manner. For visual evidence, Figure 2 shows that, at the peak of the COVID-19 pandemic in March 2020, the amounts of cash margin pledged with UK CCPs in the major currencies rose in tandem with implied market volatility.

What is less well known, however, is how clearing members obtain this cash and what effect clearing members have on funding markets by obtaining it. Our paper thus highlights the link between CCP margin requirements and the repo market, which is one of the main sources of funding liquidity. We show that CCP cash margin is *also* procyclical with respect to repo rates. To highlight this, Figure 3 shows that the CCP cash margin tends to comove with repo rate spreads, especially in times of stress.

To hone in on the link between CCP cash initial margin and repo rates, we first study their lead-lag relationship. We find that changes in repo rates reliably predict next-day margins. For example, every 1% increase in the GBP repo rate is followed by a next-day average increase of £0.38 billion in Sterling cash initial margin (IM) held across UK CCPs and this number increases to around £5 billion during times of stress, such as the period of the COVID-19 pandemic.

Of course, the decisions of clearing members to borrow and lend in the repo market are influenced by numerous endogenous factors. Nonetheless, we believe it is crucial to highlight a new systematic link between margin requirements and repo markets. Specifically, clearing members first form clear expectations about the direction of future margin

requirements. This is possible since the main principles governing the determination of CCPs' margins are well known. This incentivizes clearing members to hoard liquidity by tapping repo markets *in anticipation* of margin payments (Gai et al., 2011), especially in times of stress (Bakoush et al., 2019).

To provide causal evidence that the liquidity hoarding behavior of clearing members is influenced by margin requirements, we investigate the February 2019 policy-driven migration of EUR-denominated repos from a London-based to an EU-based CCP. We analyze this exogenous event using a difference-in-differences approach, which reveals a weakening in the onward phase of the EUR collateral cycle post-migration, relative to the other major currencies. Specifically, the migration-induced decrease in EUR margin requirements led to a diminished impact on EUR repo rates, suggesting that margin calls significantly affect repo rates.

We then extend our analysis to the clearing member level, where we present some direct evidence of liquidity hoarding. Utilizing *member-specific* data on Sterling cash margin payments and repo transactions, we show that UK CCP clearing members increase their borrowing and reduce their lending in the overnight Sterling repo market in anticipation of same-currency cash margin payments. We also show that this liquidity hoarding exerts upward pressure on clearing members' own repo borrowing rates. Taken together, these results help explain the procyclicality of CCP cash margin with respect to repo rates.

The mechanism determining the *backward phase* of each collateral cycle is a regulatory requirement that CCPs invest their cash holdings in safe assets. In the case of European clearing houses, including UK CCPs, this requirement is articulated in the European Markets Infrastructure Regulation (EMIR), which states that at least 95% of any cash position that remains overnight in a CCP's margin accounts, or default fund, must be invested in reverse repos, or government bonds, or be deposited with a central bank.[2] Our data allow us to quantify and analyze how UK CCPs invest their cash holdings.

[2]See Articles 44-45 of EMIR (European Commission, 2013). EMIR has been onshored into UK legislation.

For instance, the average outstanding investment in reverse repos by UK CCPs, over our sample period and across the major currencies (USD, EUR, GBP), is about £66.5 billion, that in bonds is £20.5 billion, whereas about £11 billion is held in central bank accounts.[3]

After documenting how CCPs invest their cash margin, we show that both reverse repos and bond investments by CCPs exert downward pressure on repo rates. We discuss potential channels through which this might happen. First, CCPs may exert a *direct* downward pressure on short-term repo rates when lending cash through reverse repos. Second, when purchasing safe bonds, CCPs may also exert an *indirect* downward pressure on short-term repo rates. Bonds purchased by CCPs become scarcer (Krishnamurthy, 2002) and since these bonds are the collateral assets to secure repos, their scarcity makes them "special," thus increasing their liquidity premium (or convenience yield) and lowering their rates (Duffie, 1996), even in General Collateral repos (Ballensiefen and Ranaldo, 2023).

Our empirical findings provide evidence for both the direct and indirect channels, showing that reverse repos and bond purchases conducted by CCPs, in compliance with existing regulations, exert downward pressure on repo rates. For example, a one-standard-deviation increase in Sterling-denominated bond purchases accounts for about 5% of the *daily* variation in GBP repo rates, on days when market volatility attains its maximum value in our sample, and Sterling-denominated CCP reverse repos account for up to 23% of the daily GBP repo rate variation. These effects hold after controlling for the amount of liquidity provided by central banks in the form of reserve balances, as well as for aggregate risk measures. They imply that the existing regulation may have a countercyclical effect that helps alleviate increases in short-term funding costs associated with margin calls, particularly at times of stress.

A natural question arising from our analysis of collateral cycles is whether the effects of the onward and backward phases might offset each other. While the two phases clearly

[3]For clarity, the figure for the bond investment includes only bonds that were purchased by the CCPs as part of their investment and, as such, does *not* include bonds directly pledged as collateral by the clearing members.

influence repo rates in opposite directions, they are not offsetting for a number of reasons: First, there is a time lag between clearing members' liquidity hoarding, their pledging of cash collateral and the CCPs' subsequent investment activity. Second, CCPs may choose to deposit part of their cash margin in a central bank account, in which case the cash is not injected back into financial markets and the backward phase of the cycle is weakened. Finally, clearing members and CCPs can access different segments of the repo market with CCPs only accessing the bilateral segment for their investments and clearing members relying heavily on the centrally cleared one. These points are discussed further in the paper.

The remainder of the paper is organized as follows: In Section 2, we position our paper in the related literature. In Sections 3 and 4, we describe the institutional setting and the data. In Section 5, we present our empirical analysis and its results. In Section 6, we discuss policy implications and conclude.

2 Contribution to the Literature

Our paper contributes to several strands of the literature on how regulatory and institutional frameworks shape the functioning of financial markets and determine asset prices. The first strand is the nascent literature on the importance of central clearing for the usage and distribution of collateral in the financial system.[4] A number of studies emphasize the benefits of central clearing for the efficient posting of costly collateral. Duffie et al. (2015) show that central clearing lowers collateral demand relative to bilateral clearing through multilateral netting and diversification. Benos et al. (2024) show that fragmentation in clearing results in costly excess collateral posting by liquidity providers (dealers), which then leads to significant price discrepancies across CCPs. The implication being that the more concentrated clearing services are, the more efficient the collateral usage.

[4]In addition to aggregate reported quantities of CCP collateral (e.g., CPMI-IOSCO, 2012, 2015), estimates of collateral demand are computed in Capponi et al. (2014), Ghamami and Samim (2017), Heller and Vause (2012), and Sidanius and Zikes (2012).

However, there are also potential drawbacks. Compared to bilateral netting, multilateral netting, operated by CCPs, can reduce risk exposures and collateral requirements within an asset class, but not (or less so) across asset classes (Duffie and Zhu, 2011).[5] Additionally, a key concern around central clearing is margin procyclicality, that is, the tendency of CCP requested collateral to increase with risk. This can be potentially destabilizing, particularly in times of stress, when margin requests are greatest, as it could lead to a system-wide liquidity squeeze (Bakoush et al., 2019; Glasserman and Wu, 2018; King et al., 2023). For this reason, efforts are being made to limit the procyclicality of the CCP margin (Murphy et al., 2014). There is, however, a trade-off because CCP collateral has to be sensitive to risk, to some extent. Otherwise, a clearing member's mark-to-market loss can exceed the posted collateral, resulting in a margin breach that can be systemically relevant, especially when many clearing members hold crowded positions (Menkveld, 2017) that cluster over time (Jones and Pérignon, 2013).

We contribute to this literature strand by documenting the existence of collateral cycles. We show that CCPs do not simply accept collateral from market participants, but instead set in motion a circular cash collateral flow consisting of an onward phase, where clearing members raise cash to meet margin requirements, and a backward phase, where CCPs return cash back to financial markets.

Second, we contribute to the literature on short-term funding markets in the post-crisis regulatory environment. The repurchase agreement (repo) is a prevalent instrument of wholesale funding for financial institutions in many countries, used to source both cash and securities.[6] A growing literature identifies instances where post-crisis regulations and policies have influenced repo market outcomes. For example, Kotidis and van Horen (2018a) show that a tightening of the Basel III leverage ratio requirement causes affected banks to reduce their repo volumes especially versus small clients. Arrata et al. (2020)

[5]Cont and Kokholm (2014) extend Duffie and Zhu (2011) by including heterogeneous assets in terms of risk characteristics.

[6]For an excellent discussion on the importance of repos and a comprehensive review of the related literature, see Munyan (2023).

show that asset purchases by the European Central Bank, as part of its quantitative easing program, lead to scarcity in high-quality bonds, which depresses their (special) repo rates.

Our study highlights the dual usage of repos, as it relates to another major post-crisis market reform, namely centralized clearing. We show that repos are used first as a tool for clearing members to source cash, in the onward phase of collateral cycles, and second, as a mechanism for CCPs to secure that cash in their backward phase. By studying the onward phase of collateral cycles, we uncover a previously unknown connection between repo borrowing rates and CCP margin demands at both the aggregate market and clearing member levels. Our evidence shows that this connection is procyclical, with repo market rates increasing in anticipation of higher margin requirements, and that it intensifies during periods of market stress. We are also the first to analyze the migration of London-based clearing for EUR-denominated repos to EU-based CCPs in February 2019, thus providing causal evidence that CCP margin requirements induce liquidity hoarding, a key feature of the onward phase of collateral cycles. Finally, at the clearing member level, our findings align with theoretical predictions that banks hoard liquidity from the interbank repo market to fund margin calls due to central clearing (Bakoush et al., 2019).

Third, our paper contributes to the growing literature on the impact of non-bank financial institutions on financial markets. Prior research has mostly regarded CCPs as passive components of the financial system and market infrastructure, rather than as major market participants and investors. Our analysis of the backward phase of collateral cycles reveals that, in accordance to regulatory requirements, CCPs act as large investors and frequent market participants, seeking collateral, primarily in the form of safe assets and secure placements. Using supervisory data from UK CCPs, we demonstrate how this demand is operationalized through reverse repos (primarily), bond purchases, and central bank deposits (to a lesser extent).

Ranaldo et al. (2021) also examine CCP reverse repos but their analysis is limited to this single instrument. In contrast, our paper is the first to provide a comprehensive study encompassing all investment options available to CCPs. Furthermore, we study the

effect of CCP investments on repo rates during a time period characterized by substantially larger amounts of aggregate liquidity.[7] This matters because central bank liquidity injections simultaneously render cash more abundant and government bonds more scarce which can change the relative importance of the direct (i.e. via reverse repos) versus the indirect (i.e. via bond purchases) effects of CCP investments on repo rates. In this respect, we are the first to show that the downward pressure, that CCP reverse repo trades exert or repo rates, intensifies during periods of high volatility and that CCP bond purchases also contribute to reduced repo rates. Thus, we show that regulatory-induced CCP investments have a countercyclical effect.

3 Institutional Framework

In reference to Figure 1, it is important to explain why and how collateral cycles occur. We begin with the onward phase of the cycle, which is the left side of the figure, where cash flows from repo and bond markets to clearing members and then on to clearing houses. Through clearing, a CCP becomes a counterparty in every trade. In this role, the CCP contributes to credit risk mitigation and to collateral efficiency since clearing member exposures are margined on a multilateral net basis.

In turn, clearing members must satisfy initial margin (IM) requirements and contribute to other financial safeguards that mitigate credit risk in the event of a clearing member's default.[8] Importantly, IM requirements increase when market conditions worsen, i.e. a CCP will increase IM requirements in response to higher market volatility. As such, IM

[7]For example, the aggregate amount of euro reserves balances issued by the ECB averages about 2.5 trillion during our sample period, whereas it is on average about 1 trillion during the period studied by Ranaldo et al. (2021). This is due to accommodating central bank policies, which were further expanded as a result of the COVID-19 pandemic in the United States, the United Kingdom, and the eurozone.

[8]CCPs collect two types of margin: Variation margin (VM) is intended to cover clearing members' current exposures as market conditions change. It is thus transferred via the CCP from one clearing member to another. IM is intended to cover clearing members' potential future exposures that may arise in case of a clearing member's default. IM is collected by the CCP from all clearing members, regardless of the current exposure of their portfolios. CCPs also collect contributions for the benefit of a default fund which is an additional resource aimed to cover losses that may arise in the case of a member's default. Unlike VM and IM however, these contributions are not calibrated on a daily frequency.

requirements are highly predictable by clearing members both because clearing members know exactly what their cleared position is at any point in time, but also because they know the general features of CCPs' clearing models, which are used to calculate IM requirements.[9]

To fulfil these requirements, clearing members must pledge a corresponding amount of cash or securities collateral with the CCP. Compared to non-cash (i.e., securities) collateral, cash offers some advantages including lower haircuts (when cash collateral of a different currency is pledged than of the currency requested), being easier to handle, and being the only type of collateral accepted for variation margin in UK clearing houses. For this reason, market participants tend to gravitate to cash collateral when conditions in financial markets are volatile. Another reason is that the value of securities may decrease in volatile conditions, thus requiring a larger quantity of securities to satisfy a given margin request.[10] Our first contribution is to highlight how clearing members pledge collateral with CCPs and how doing so affects repo markets.

We now turn to the right side of Figure 1, which shows how cash collateral flows from CCPs back to financial markets. This backward phase is less known, and analyzing it is the second contribution of our paper. To understand the backward phase, a few observations are in order. First, CCPs hold a significant amount of collateral. For instance, CPMI-IOSCO Public Quantitative Disclosures in 2017 indicate that the aggregate initial margin requested by the top-10 EMIR-regulated CCPs from their clearing members was approximately 280 billion euro, half of which was submitted in cash. Second, while security collateral can be held by CCPs, EMIR states that at least 95% of any cash position in CCPs' margin accounts or default fund held overnight must be invested in a safe and

[9]The UK CCPs that we study even provide to their members tools to simulate their expected margin requirements across various products. For example, information on LCH's SMART tool, can be found here:`https://www.lseg.com/content/dam/post-trade/en_us/documents/lch/fact-sheets/lch-smart-factsheet-2.pdf`

[10]The "dash for cash" episodes during the COVID-19 market events, in a number of jurisdictions, are a case in point.

liquid manner.[11]

The law essentially gives CCPs three options for complying with this rule: reverse repos, purchases of government bonds and central bank deposits.[12] There are several reasons why reverse repos are a favorable method of cash investment for CCPs. First, (overnight) reverse repos allow CCPs to obtain their invested cash the next day. This gives them more flexibility compared to a bond investment that requires one or two additional days (depending on the settlement convention) to be converted back into cash. Second, the repo market possesses such attractive features for CCPs as: (a) high liquidity, (b) a broad set of collateral assets, most of which are government bonds (such as German bunds) and (c) several General Collateral (GC) baskets that offer higher lending rates compared to "special" (or specific) repos.[13] Thus, investing in a GC basket that satisfies the safety and liquidity requirements stipulated by law represents a more convenient and efficient option for CCPs. Third, the repo is a secured loan over a very short period. The vast majority of European repos are traded with one-day tenors[14] or a maturity no longer than one week. This makes CCPs' investment in reverse repos a flexible and effective way to comply with an additional regulatory constraint,[15] which is that the average time-to-maturity of CCP

[11]See the Article 47 of EMIR and Commission Delegated Regulation (EU) No 153/2013 (European Commission, 2013, p. 63, Article 45). The latter says that "where cash is maintained overnight [...] not less than 95% of such cash, calculated over an average period of one calendar month, shall be deposited through arrangements that ensure the collateralisation of the cash with highly liquid financial instruments [...]."

[12]Article 43 of the EMIR Delegated Regulation requires that financial instruments in which the CCP invests to be "debt instruments meeting each of the conditions set out in Annex II." (European Securities and Markets Authority, 2022). Specifically, the Annex II lists the conditions applicable to highly liquid financial instruments: (a) they are issued or explicitly guaranteed by a government bond, a central bank, a multilateral development bank, or the EFSF / ESM; (b) the CCP can demonstrate that they have low credit and market risk; (c) the average time-to-maturity of the CCP's portfolio does not exceed two years; (d) a currency the risks of which the CCP can demonstrate that it is able to manage; (e) they are freely transferable and without any regulatory constraint or third party claims that impair liquidation; (f) they have an active outright sale or repurchase agreement market, with a diverse group of buyers and sellers, including in stressed conditions and to which the CCP has reliable access; and (g) reliable price data on these instruments are published on a regular basis.

[13]The asset being used as collateral can be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral repo"). In the United States, a special repo is sometimes referred to as a "specific" repo, with the term "special" referring to specific repo rates being below prevailing short-term money market rates.

[14]The one-day tenors are overnight, spot-next, and tomorrow-next.

[15]See Hüser et al. (2021) for evidence.

investment portfolios should not exceed two years (European Commission, 2013, p. 74). As such, reverse repos offer several advantages over (long-term) government bonds.

Regarding the other two options, only some CCPs have access to central bank deposits.[16] According to 2018 CPMI-IOSCO disclosures, for instance, some CCPs like Eurex Clearing, LCH SA, and CC&G had access to and deposited cash with central banks, while others like EuroCCP, LCH Limited, and ICE either had not sought access or used their central bank accounts only to a small extent. Furthermore, anecdotal evidence suggests that even if CCPs do have access to central bank accounts, they may not use them as the primary means for cash investment so as to avoid interfering with the central bank's (conventional) monetary policy implementation.[17][18]

On the contrary, CCPs regularly access the bond market. To comply with the regulation, however, CCPs can only purchase a selected set of specific government bonds of the highest credit quality and liquidity (or safe assets). Furthermore, compared to the repo market, the bond market is more segmented, as it is articulated into various maturities and debt-issuing nations, and longer-term financial securities expose CCPs to duration risk. Bonds also provide less flexibility than repos, given that trades in bonds take longer to settle. Finally, the market regulator raises awareness that "diversification of investment possibilities can reduce risks, via the mitigation of collateral concentration and a reduction of the counterparty credit risk" (European Securities and Markets Authority, 2022). Since

[16]Some CCPs have no access to central bank facilities, either for regulatory reasons (because of the added cost of obtaining a banking license or because the local central bank does not wish to take on CCP risk) or because the financial instruments cleared by the CCP are not denominated in the currency of the local central bank (European Securities and Markets Authority, 2022). In the latter case, some central banks (e.g. the European Central Bank), allow CCPs in foreign jurisdictions to create accounts and deposit their cash with the issuing central bank whereas other central banks (e.g. the Federal Reserve), do not provide this option to foreign CCPs.

[17]If a "large" CCP were to exclusively use its central bank account to secure its cash holdings, that would potentially create sizeable fluctuations in the demand for central bank reserves. Such fluctuations would then be incompatible, for example, with a reserves targeting regime whereby the central bank attempts to control interest rates by supplying a quantity of reserves that is proportional to the expected demand for reserves.

[18]For a recent announcement by the ECB on changes of its reserves remuneration policy so as to incentivize non-EEA, non-monetary policy account holders (such as UK CCPs) to reduce their cash holdings with the ECB, see here: `https://www.ecb.europa.eu/press/pr/date/2024/html/ecb.pr240417~1f4431a9d4.en.html`

we do not have access to CCPs' individual investment positions, we cannot assess their portfolio risk and diversification policies. However, we do quantify the aggregate CCPs' investments in repos and bonds as well as their central bank deposits.

A natural question arising from the collateral cycle represented in Figure 1 is whether the effects from the onward and backward phases might offset each other, canceling out any impact on repo markets. It would be erroneous to assume so for several reasons. First, the two phases do not occur simultaneously. Given that clearing members hoard liquidity *in anticipation* of margin payments, the tapping of repo markets to raise cash for new margin requests does not occur on the same day as the reinvestment of that cash by CCPs. Second, to the extent that CCPs fulfill the requirements of EMIR via central bank deposits, the effect of the backward phase on repo rates is weakened, as cash held with the central bank does not exert price pressure on repo markets. Third, clearing members pledging cash to CCPs are not necessarily the cash borrowers in CCP reverse repos, which implies that the onward and backward phases of the collateral cycle may affect different market participants. Furthermore, a substantial fraction of cash borrowing occurs in the centrally cleared segment of the repo market, operating via anonymous trading platforms such as BrokerTec, MTS, and Eurex.[19] In contrast, the backward phase operates exclusively through bilateral or triparty repos. These segments are not fully integrated with the cleared segment due to limits in interoperability and collateral transfer, rendering them partially disconnected (Schaffner et al., 2019).

4 Data and Summary Statistics

We combine three different supervisory data sets pertaining to the two largest UK-based CCPs: LCH Limited and the Inter-Continental Exchange (ICE) Clear Europe. The two CCPs in our sample account for around 94% of total cash collateral pledged across all

[19]For instance, Hüser et al. (2021) report that about 36% of the Sterling overnight repo volumes are centrally cleared.

UK CCPs over our sample period.[20] As such, our data cover the vast majority of clearing activity in the United Kingdom. The cash collateral pledged with the two CCPs spans seven different clearing services, each accounting for a particular asset class.

The first data set contains information on the amount of initial margin pledged with the two CCPs. In particular, for each clearing service of the two UK-based CCPs, we observe, on a daily basis, the stock of initial margin pledged from the clearing members and their clients in each of the main currencies: USD, EUR, GBP. We also observe the breakdown of pledged margin between cash and securities collateral. Figure 4 shows that interest rate contracts, cleared by the SwapClear serice of LCH, account for about 64% of cash collateral pledged across these clearing services in our sample. These are followed by futures and options, written on a variety of underlying assets, which account for about 22% of cash margin and are cleared by ICE Clear Europe.

Our second data set contains information on the CCPs' investment activity. In particular, we observe the aggregate daily outstanding positions in reverse repos and government bonds of each CCP, in each currency.[21] Given the size of the two London-based clearing houses in our sample, these investments correspond to a substantial fraction of the investments, in each of the three currencies, done by all CCPs globally.[22]. We also observe the daily amounts of CCP deposits with central banks. This data only pertains to EUR and GBP deposits since UK CCPs do not have access to Federal Reserve accounts.

Our third data set consists of all Sterling denominated repo transactions that are cleared via the RepoClear service of LCH. Since RepoClear is the main CCP for Sterling repos, this data set captures the vast majority of cleared Sterling repo transactions.[23] Importantly, with this data set we can exactly identify the repo counterparties, which

[20]The remaining is accounted for by cash collateral pledged with the London Metal Exchange (LME) Clear. Because of lack of sufficient data, we do not include this CCP in our sample.

[21]Unfortunately, we do not observe the counterparties to these CCPs' transactions, and, as such, we cannot precisely identify those market participants who receive cash from CCPs.

[22]For example, a comparison with CCP public quantitative disclosures, suggests that the reverse repo activity of the two CCPs in our sample, accounts for about 68%, 97% and 50% of the EUR, GBP and USD global CCP reverse repo volumes respectively.

[23]However, the cleared Sterling repo segment accounts for only about 36% of the total repo Sterling market, the rest being mostly accounted for by bilaterally cleared repos (Hüser et al., 2021).

allows us to associate their repo activity with their margin payments.

Finally, we obtain from Bloomberg a number of market variables, such as implied equity market volatility indices in each currency and the general collateral USD and GBP overnight repo rates. We compute general collateral EUR overnight repo rates based on the same comprehensive data set used in Ballensiefen and Ranaldo (2023). All of our data sets span the period from February 2019 to June 2020, thus including the period of market stress associated with the COVID-19 pandemic.

Table 1 shows summary statistics for the aggregate variables used in our analysis. Panels A and B show some figures related to the onward and backward phases of the collateral cycle, respectively. Specifically, Panel A shows that the majority of outstanding cash margin ($CashIM$) is denominated in USD and is almost double what is being pledged in EUR and GBP. On the other hand, securities collateral is mostly split between US Treasuries and eurozone bonds at around double the amount of UK government bonds. This results in an approximate equal mix of cash and securities for the USD and GBP, whereas only about 36% of the euro-denominated collateral is in the form of cash, with the rest being securities. Another interesting feature is that the percentage of cash collateral varies substantially for each currency, fluctuating throughout our sample period by as much as 15%. As we will explore later in Section 5.1, this change in the collateral mix contributes to cash margin procyclicality.

Concerning the backward phase of collateral cycles, Panel B of Table 1 shows that the CCPs in our sample lend most of their cash on a secured basis using the repo market. Their lending activity is consistent with the composition of the cash margin they receive and most of their reverse repos are USD-denominated. The second investment option used is in government bonds, which is smaller than reverse repos and concentrated in US Treasuries. This is partly because UK CCPs do not have the option of depositing cash with the Federal Reserve. The central bank deposits for the other two main currencies are shown at the bottom row of Panel B. One can see that these deposits are also smaller than CCPs' reverse repos. Importantly, these deposits are not part of the collateral cycle

since they are kept with a central bank and are therefore not returned to financial market participants.

Overall, the daily average outstanding investment of cash by the CCPs in our sample is about £66.5 billion for reverse repos, £20.5 billion for bonds and £11 billion for central bank deposits, across all main currencies. The predominant use of the reverse repo is consistent with the previously mentioned advantages it brings to CCPs, namely, the effectiveness of the contract design, safety, liquidity, and flexibility.

Given that our sample overlaps with the beginning of the COVID-19 pandemic, it captures both the elevated volatility in financial markets during this period and the associated central bank policy responses. This is reflected in the statistics for our market variables shown in Panel C, where both the implied volatility indices and the aggregate amounts of central bank reserves exhibit substantial variability. On the other hand, repo rates exhibit much less variation.[24]

5 Empirical Analysis

5.1 The Onward Phase and Cash Margin Procyclicality

We start our analysis by assessing the degree to which the cash initial margin (IM) is procyclical with respect to repo rates. The common understanding of procyclicality is that margins increase with volatility. This is a direct result of the way margin requirements are calculated by CCPs.[25] Margin procyclicality is visible in Figure 2, which shows a tandem movement between margins and volatility intensifying at the peak of the COVID-19 pandemic in March 2020. The positive relationship between the two variables emerges systematically when regressing today's initial margins on yesterday's volatility, as shown

[24]The maximum value of 5.25% for the USD overnight repo rate corresponds to the well-documented spike in USD repo rates on September 17, 2019. With the exception of this spike, USD overnight repo rates are relatively stable throughout our sample period.

[25]CCP typically use Value-at-Risk (VaR) models for the calculation of their margin requirements.

in column 1 of Table 2.[26]

What is less well known however, is the relation between margins and funding costs. More precisely, it is not clear whether the procyclicality of margin with respect to volatility also extends to repo rates. The theoretical mechanism behind this additional type of procyclicality is based on the need of clearing members to meet margin requests from CCPs (Gai et al., 2011). As the models that determine CCP margins are sufficiently well known, they allow clearing members to form precise expectations about the likely evolution of margins as volatility increases. Thus, clearing members may revise their liquidity buffers in a consistent and procyclical manner (Bakoush et al., 2019) by tapping into the main segment of the money market, that is, the repo market. This liquidity hoarding could elevate repo rates, especially if repo borrowers are exposed to urgent liquidity needs, such as in periods of stress (Bechtel et al., 2022).[27]

Of course, agents can consider alternative ways of obtaining short-term liquidity from financial markets, such as unsecured money market borrowing and asset liquidation. However, these options are generally less efficient, more costly, and unstable.[28] As a result, expected increases in cash IM induce clearing members to hoard liquidity by raising cash from repo borrowing or by refraining from giving away cash via repo lending. The large demand for cash (as shown in Table 1, Panel A) creates *upward* price pressure on repo rates and gives rise to a dynamic statistical relationship between repo rates and cash IM that we test as follows:

- *Hypothesis 1*: Repo rates rise in anticipation of increases in cash IM pledged with CCPs.

Such a relation would suggest that cash IM is also procyclical with respect to repo

[26]Given that margin payments are made daily, and sometimes intra-daily, the lagged relationship between margin and volatility mainly emerges because volatility is persistent; that is, yesterday's volatility is a good predictor of today's volatility.

[27]Acharya and Skeie (2011) propose a theoretical model in which a financial firm's propensity to hoard liquidity increases with its exposure to rollover risk.

[28]For instance, the unsecured money market segment is much smaller than the secured one, and it is subject to counterparty credit risk, while liquidation of assets can trigger "fire sales" and liquidity spirals.

rates. Furthermore, the comovement between CCP cash IM and repo rates could be time-varying with this relationship becoming stronger at times of market stress when funding liquidity is likely to be scarce. As such, we also test the following hypothesis:

- *Hypothesis 2*: The procyclical relationship between the cash IM requested by CCPs and repo rates is stronger at times of high market volatility.

Here, we note that the relations described in these hypotheses are statistical in nature and do not have a direct causal interpretation. That is, we do not argue that repo rates "cause" changes in the cash margin. Rather, the economic mechanism at play is that expected changes in the cash margin induce clearing members to hoard liquidity, which results in increases in repo rates. However, casting this relation in the form of our hypotheses makes economic sense because from the point of view of both CCP clearing members and regulators, it is important to know if clearing members are likely to encounter elevated funding costs whenever they need to fund their upcoming margin payments.

To test these hypotheses, we estimate the following empirical panel specification:

$$\begin{aligned} CashIM_{it} =& a + bCashIM_{it-1} + c_1 \Delta Repo_{it-1} + c_2 Stress_{it-1} \\ &+ c_3 Stress_{it-1} \times \Delta Repo_{it-1} + v_i + u_{it}, \end{aligned} \tag{1}$$

where i denotes currency, t denotes days, $CashIM$ is the aggregate cash initial margin pledged with the UK CCPs in our sample, in each currency, and *Repo* is the currency-specific overnight repo rate. *Stress* is an indicator of stressed market conditions. We consider two stress indicators: First, a time dummy variable taking the value of one from February 19, 2020, that is, during the period of heightened market volatility due to the COVID-19 pandemic. Second, we measure market stress with a currency-specific implied stock market volatility index. The specification includes a first lag of the cash IM to control for persistence in this variable, and we also include the repo rate in differences

so as to render it stationary.[29] The specification is estimated using currency fixed effects with standard errors being clustered by currency.[30] As mentioned above, this specification is purely predictive in that it captures dynamic correlations and should not be interpreted as causal. The goal is to identify any instances of cash margin procyclicality with repo rates as per our hypotheses.

The results for this estimation are shown in Table 2 (columns 2-5). Two findings stand out: First, CCP cash IM is (also) procyclical with respect to repo rates. Second, this relation appears to be stronger at times of stress as indicated by the significant coefficient for the interaction term between repo rates and VIX (column 5). The estimated coefficients in that specification, for example, suggest that a 1% increase in the GBP repo rate is associated with a next-day increase in aggregate GBP cash IM by £0.38 billion across UK CCPs. However, this increases to £5 billion when volatility attains its maximum value in our sample. Overall, these findings point to margin-repo rate procyclicality, consistent with (time-varying) liquidity hoarding.

5.1.1 Relative Cash Margin Procyclicality

When issued a margin call by the CCP, clearing members have the option to pledge either cash or eligible securities as collateral. For a visual inspection of how the composition of collateral pledged with CCPs evolves over time, we compare in Figure 5 the aggregate cash IM pledged across UK CCPs with the ratio of cash over total collateral pledged by clearing members. It is notable that the relative amount of cash pledged as collateral with CCPs comoves with total cash IM. This implies that variations in the levels of cash IM are partly driven by changes in the composition of CCP pledged collateral with clearing members shifting toward cash.

[29] The inclusion of a lagged dependent variable in our panel regression does not bias our results on account of the long time dimension ($T = 346$) of our sample.

[30] It is well known that the repo market has been characterized by quarter-end seasonal patterns, especially in jurisdictions whose regulations dictate "monthly averaging," rather than "daily averaging." The United Kingdom adopted the latter method in 2017, and the Sterling repo market is no longer affected by these patterns (Kotidis and van Horen, 2018b). This should not be an issue for our analysis because our sample period starts in 2019.

In Section 3, we discussed some of the institutional and regulatory reasons a clearing member might prioritize cash collateral rather than securities. For example, clearing members could be accumulating cash in anticipation of market volatility and the associated variation margin payments that are payable in cash.[31] If clearing members then acquire sufficient cash, they might use proportionally more of it to meet their IM obligations. Alternatively, securities may lose value at times of stress making them a less reliable option for covering margin requests.

Given that clearing members tap repo markets to obtain their cash and can move repo rates by doing so, this would also give rise to a positive dynamic relationship between repo rates and the *proportion* of cash pledged as collateral. This intuition motivates the next hypothesis that we test:

- *Hypothesis 3*: Repo rates rise in anticipation of increases in the proportion of cash IM pledged as collateral with CCPs.

To formally test this hypothesis, we estimate the following panel specification:

$$\begin{aligned} CashIM(\%)_{it} =& a + bCashIM(\%)_{it-1} + c_1 \Delta Repo_{it-1} + c_2 \Delta Reserves_{it-1} \\ &+ c_3 Stress_{it-1} + c_4 \Delta Repo_{it-1} \times Stress_{it-1} + v_i + u_{it}, \end{aligned} \tag{2}$$

where, as before, i denotes currency and t denotes days. $CashIM(\%)_{it}$ is the ratio of cash over total margin (i.e., cash plus securities) pledged with UK CCPs by their clearing members, *Repo* is the currency-specific overnight repo rate, *Stress* is the previously used indicator of stressed market conditions and *Reserves* are the aggregate central bank reserves in each currency. This variable acts as a control for the effects of (unconventional) monetary policies, such as Quantitative Easing programs that inject liquidity in the financial system by expanding central bank balance sheets. In fact, the decision to pledge proportionally more cash or securities may well depend on the aggregate amount of

[31] Corroborating this, Huang and Takáts (2020) document a significant increase in cash holdings for US banks ahead of the COVID-19 pandemic in March 2020.

liquidity available in the form of such central bank reserves balances. As in the previous specification, we include the first lag of $CashIM(\%)$, the repo rate in differences, as well as currency fixed effects.

The results of this estimation are shown in Table 3. As one can see, increases in the repo rate predict increases in the percentage of cash pledged as CCP collateral, even when controlling for volatility and central bank liquidity. This result indicates that the proportion of margins pledged as cash rather than securities increases right after an increase in funding costs. As mentioned earlier, this is consistent with cash hoarding because the increase in repo rates could be caused by market participants tapping repo markets to raise the desired amounts of cash. However, this effect does not intensify during volatile conditions as the insignificant coefficients of the interaction terms suggest.

5.1.2 The migration of EUR repo clearing from London to Paris

In this section we provide further support for the hypotheses tested so far by exploiting an exogenous event captured in our sample, namely the migration of EUR-denominated repo volumes from LCH Limited (in London) to LCH SA (in Paris), in February 2019. To our knowledge, ours is the first paper to utilize this important market event in a study.

Against the backdrop of the UK's departure from the European Union (EU) and repeated calls by EU authorities for London-based clearing in EUR denominated contracts to migrate to EU-based CCPs, clearing in EUR-denominated repos shifted almost entirely from London to Paris on the 19th of February, 2019. This move appears to have been planned by clearing members in consultation with LCH and was justified on the basis that it allowed clearing members "...to consolidate euro repo and bond clearing in one place to obtain efficiency savings".[32]. Using our proprietary trade data, we plot in Figure 6 the daily EUR-denominated repo volumes and number of trades processed by RepoClear. As one can see, the migration out of LCH Limited in EUR repos was both nearly complete

[32]See `https://www.reuters.com/article/us-britain-eu-clearing-idUSKCN1QA2EY/`. Furthermore, note that this event occurred at a time when EUR repo rates were close to a historically low level so it is highly unlikely that the migration itself was influenced by repo market conditions.

and permanent.

We exploit this exogenous event to provide further evidence in support of our hypotheses pertaining to the onward phase of the collateral cycle. In particular, we hypothesize that the onward phase of the EUR collateral cycle, induced by UK CCPs, will likely have *weakened* as a result of EUR-denominated repos migrating to Europe. This is because there will be less margin being requested and posted for these trades, since the migration was carried out in order to realize netting efficiencies with EUR-denominated repo positions already cleared through LCH SA in Paris.

At this point we should mention that the effect of the EUR repo migration on the collateral cycle is likely to be economically small. Figure 4 shows that RepoClear accounts for less than 5% of the total cash IM in our sample and this includes IM posted in all main currencies and not just the EUR, which is the one affected by the migration. Table 4 shows average daily cash IM amounts requested and posted with RepoClear over a short time window around the migration day. One can see that there is a (statistically) significant drop in EUR IM requested by RepoClear but no such drop for the other two currencies. Furthermore, the amount of cash IM posted both with RepoClear drops more for the EUR than it does for the other currencies. Nevertheless, the amounts involved are small with daily EUR cash IM dropping by only about euro 0.43 billion.[33]

The small amounts suggest that any effects on the collateral cycle would likely be economically small. However, testing for such effects is useful as this would provide additional support for the (onward phase) procyclicality hypotheses in our paper. Our prediction is that the dynamic relationship between EUR cash IM and EUR repo rates will weaken as a result of reduced liquidity hoarding due to the EUR repo migration. Given that only EUR-denominated repos migrated to Paris whereas USD and GBP-denominated ones continued to clear in London, we test this by estimating two difference-in-differences variations of

[33]The values of cash IM paid can be smaller than those of requested IM if clearing members satisfy part of the IM requirement by pledging bonds. They can also be larger than requested IM if clearing members satisfy the IM requirement by pledging cash in a different currency than that requested.

models (1) and (2) over a short period around the EUR repo migration:

$$\begin{aligned} CashIM_{it} =& a + bCashIM_{it-1} + c_1\Delta Repo_{it-1} + c_2 Event_t \\ &+ c_3 Event_t \times EUR_i \times \Delta Repo_{it-1} + v_i + u_{it}, \end{aligned} \tag{3}$$

and

$$\begin{aligned} CashIM(\%)_{it} =& a + bCashIM(\%)_{it-1} + c_1\Delta Repo_{it-1} + c_2\Delta Reserves_{it-1} \\ &+ c_3 Event_t + c_4 Event_t \times EUR_i \times \Delta Repo_{it-1} + v_i + u_{it}, \end{aligned} \tag{4}$$

In these specifications i denotes currency and t denotes days. As before, the dependent variables are $CashIM$ and $CashIM(\%)_{it}$. The first is the aggregate cash initial margin pledged with the UK CCPs in our sample, in each currency, while the second is the ratio of cash over total margin (i.e., cash plus securities) pledged with UK CCPs by their clearing members. *Repo* is the currency-specific overnight repo rate, *Event* is a dummy variable that takes the value of 1 after February 19, 2019 and 0 before that and EUR is a dummy variable that takes the value of 1 for EUR and 0 for USD and GBP. The models are estimated over the period between February 8 and March 4, 2019, approximately 10 ten days before and after the EUR repo migration. For both models we use currency fixed effects and standard errors are clustered by currency.

The coefficients of interest are those of the interaction terms which capture any incremental changes in the relationship between EUR cash IM and repo rates relative to the other two currencies in the wake of the EUR repo migration. The results of these regressions are reported in Table 5. As one can see, the coefficients of the interaction terms are negative and significant at the 5% level. This suggests that the migration of EUR repo contracts away from LCH Limited led to a small but measurable weakening of the collateral cycle. That is, the relationship between EUR repo rates and EUR Cash IM became weaker in the wake of the migration compared with the other two currencies.

5.1.3 Clearing Member Liquidity Hoarding

So far, we have argued that the procyclicality between cash IM and market repo rates is suggestive of liquidity hoarding by clearing members. In this section, we provide more supporting evidence of this effect by analyzing the repo trading activity of *individual clearing members* of UK CCPs. For this purpose, we combine our data on clearing members' Sterling-denominated cash margin with the data on their activity in the cleared segment of the Sterling repo market. Liquidity hoarding would occur if individual clearing members tap repo markets to accumulate cash *in advance* of expected margin payments. Accumulating cash in repo markets, in turn, occurs when clearing members borrow more and lend less cash.

Furthermore, repo rates will be rendered procyclical with respect to cash margin payments if the increased borrowing and reduced lending by clearing members has an impact on their borrowing costs. Thus, we postulate the following hypotheses:

- *Hypothesis 4a*: Clearing members hoard liquidity in anticipation of cash margin payments by borrowing (lending) more (less) cash in the repo market *ahead* of cash IM payments.

- *Hypothesis 4b*: Clearing members' increased borrowing and reduced lending in the repo market exert upward price pressure on their borrowing costs.

To test *Hypothesis 4a*, we estimate the following panel specification:

$$\begin{aligned} CashIM_{jt} =& a + bCashIM_{jt-1} + c_1 ON\_Repo\_Borrowing_{jt-1} + c_2 ON\_Repo\_Lending_{jt-1} \\ &+ dVIX_{t-1} + v_j + u_{jt}, \end{aligned} \tag{5}$$

where j denotes clearing members and t denotes days. The dependent variable is the cash IM pledged, exclusively in Sterling, by each clearing member, across the clearing services of CME and LCH (the UK CCPs in our sample). $ON\_Repo\_Borrowing$ ($ON\_Repo\_Lending$) is the daily overnight borrowing (lending) volume by clearing mem-

bers in the Sterling repo market. Given that the repo transactions in our sample are overnight, whose second leg settles the next day, we use lagged values for these variables to account for potential liquidity hoarding over the day prior to the cash margin being paid.[34] Finally, VIX is (in this case) the 30-day implied volatility of the FTSE 100 UK equity market index. This is included to control for the effects of market risk on posted cash margin.

To test *Hypothesis 4b*, we estimate the following panel specification:

$$\begin{aligned} Repo_{jt} =& a + bRepo_{jt-1} + c_1 ON\_Repo\_Borrowing_{jt} + c_2 ON\_Repo\_Lending_{jt} \\ &+ d\Delta CDS_{jt-1} + v_j + u_{jt}, \end{aligned} \tag{6}$$

where as before j denotes clearing members and t denotes days. The dependent variable is the volume-weighted average overnight borrowing repo rate of each clearing member. The main independent variables are the same as in the previous specification, and CDS is the CDS spread of each clearing member controlling for its credit risk (Bechtel et al., 2022).[35]

Table 6 shows summary statistics for the clearing-member-specific variables (Panel A) and the regression specification results (Panels B and C). The results (in Panel B) first show that clearing members tend to increase their overnight borrowing and decrease their overnight lending in the cleared segment of the Sterling repo market ahead of increased Sterling cash margin payments. However, the magnitude of the documented effect is

[34]Sterling cash margin intended to cover overnight margin calls is due at 9:00 am London time for LCH and 10:00 am for ICE Clear. In the case of LCH, the calls themselves are sent by 8:00 am in the morning giving clearing members an hour to replenish their margin accounts, should that be necessary. For more information on LCH collateral management processes, see `https://www.lch.com/collateral-management/ltd-collateral-management/ltd-acceptable-collateral/ltd-acceptable-cash`. For ICE Clear, see `https://www.theice.com/clear-europe/treasury-and-banking`.

[35]The repo transactions in our sample are centrally cleared and therefore one might expect the impact of clearing member credit risk on repo rates to be limited. However, the centrally cleared segment of the Sterling repo market is only a fraction of the overall Sterling repo market. As such, riskier clearing members might be willing to borrow at a higher rate in the cleared segment, if faced with higher borrowing costs in the uncleared one. Unfortunately, we do not observe clearing members' transactions in the uncleared segment and thus cannot empirically confirm this hypothesis.

relatively small. We think this is because the cleared Sterling repo segment that we analyze, represents only about a third of the total overnight Sterling repo market, with the rest being bilaterally cleared (Hüser et al. (2021)). As such, it is possible that clearing members rely substantially less on the cleared segment and more on the bilateral segment to hoard liquidity in anticipation of IM increases. Nevertheless, these findings do provide an indication of clearing member liquidity hoarding by both tapping into repo markets and reducing repo lending in anticipation of margin payments. This effect is consistent with the cash margin being procyclical with respect to repo rates, as discussed in previous sections.

Second, the results (in Panel C) show that liquidity hoarding by clearing members elevates their funding costs, thereby supporting the idea that repo borrowers exposed to urgent liquidity needs are willing to pay a markup for immediate funding (Bechtel et al., 2022). Taken together, anticipatory liquidity hoarding and its contemporaneous repo rate impact provide an explanation as to why cash margin pledged with UK CCPs is procyclical with respect to repo rates.

At this point, it is also worth noting that the effects we have described so far collectively imply that at times of high market volatility and stress, increased amounts of cash (in both absolute and relative terms) are transferred from funding markets to CCPs. The next step is the analysis of the backward phase of the collateral cycle, whereby cash is recycled from CCPs back to financial markets.

5.2 The Backward Phase and CCP Investment Activity

As discussed previously, the EMIR legislative framework, under which UK CCPs operate, mandates that CCPs invest the vast majority of their cash collateral in a safe and liquid manner, that is, by lending it on a secured basis, by investing in safe bonds, or by depositing it with a central bank account. What our summary statistics revealed is that the cash amount invested daily by CCPs is substantial and that most of the cash collateral pledged with UK CCPs is reverse repoed, with a smaller fraction being invested in bonds or held

with a central bank deposit account (Table 1, Panel B).[36] Given that our data include information on both daily CCP investments (in reverse repos, bonds, and central bank deposits) and collected cash IM, it allows us to thoroughly examine the relation between cash collateral pledged and CCP investment activity.

Figure 7 shows the amount of cash pledged across all UK CCPs and across currencies alongside the CCPs' daily reverse repo volumes, the stock of their government bond purchases as well as the amounts held by CCPs in central bank deposit accounts. The first thing to notice is that the sum of CCP secure investments (i.e. repos, bonds and deposits) is approximately equal to the amount of cash margin received by CCPs. This is expected as CCPs are required by law to secure at least 95% of the cash margin they receive.[37]

The second thing to notice is that in periods of elevated volatility and higher levels of accumulated cash collateral, such as the market events associated with the COVID-19 pandemic, CCPs return increased amounts of this cash back to the market via repos and bond purchases. This flow constitutes the *backward* phase of the collateral cycle. On the contrary, any amount of cash deposited with a central bank is no longer available to other market participants.

To pin down the sensitivity of CCP investments to incoming cash margin flows, we test the following hypothesis:

- *Hypothesis 5*: The more cash collateral is pledged with CCPs in a particular currency, the *larger* the size of CCP investments (reverse repos, bonds and central bank deposits) in the same currency.

Using our daily time series for each currency, we test this hypothesis by estimating the

[36]For a detailed description of the investment choices and the overall distribution of collateral held by by several global CCPs, see Aldasoro et al. (2023a) and Holden et al. (2016).

[37]The slight discrepancy between cash received and secured is accounted for by unsecured deposits with commercial banks. However, these are small in size and for this reason we ignore them.

following panel specification:

$$CCP\_Inv_{it} = a + \sum_{k=1}^{5} b_k \Delta CashIM_{it-k} + v_i + u_{it}. \tag{7}$$

Our dependent variable CCP_Inv is the daily aggregate and currency-specific investment by UK CCPs in either reverse repos ($VlmRR$) or bonds ($\Delta Bonds$) or central bank deposits ($\Delta Deposits$).[38] $CashIM$ is the absolute aggregate level of cash in each currency pledged with CCPs. We use up to five lags of the daily changes in $CashIM$ for two reasons. First, we are agnostic about the time it takes a CCP to invest its cash collateral, and we therefore want to capture any lagged effects associated with this process. Second, since CCPs engage in overnight reverse repos, these have to be rolled over on a daily basis. As a result, an increase in cash collateral could potentially increase CCP reverse repo volumes over several subsequent days. This specification, too, features currency fixed effects, and inference is done by clustering at the currency level.

The results for this specification are shown in Table 7. They suggest that both CCP reverse repo volumes and bond investments in a given currency positively respond to the amount of cash collateral pledged in the same currency over the previous five days, with both effects being statistically significant as indicated by the associated F-statistics. However, central bank deposits do not significantly respond to incoming cash margin. We interpret this as evidence that CCPs prioritize repos and bonds when it comes to investing their cash and only use central bank deposits as a residual third option. Anecdotal evidence suggests that one reason for this is that central banks discourage CCPs from heavily using their reserve accounts, on a regular and ongoing basis, as that might interfere with the central bank's monetary policy implementation.[39] Another reason for that is that, as custodians of clearing members' money, CCPs' investment returns should not significantly

[38] In the case of central bank deposits the estimation is done only for cash margin denominated in EUR and GBP as UK CCPs do not have access to Federal Reserve deposit accounts.

[39] CCPs are granted access to central bank accounts mainly for financial stability purposes. For example, at times of severe market stress, access to such an account would enable the CCP to obtain emergency liquidity assistance from the central bank.

diverge from market rates. As such, CCPs may generally prefer reverse repos over deposits as the former typically pay higher rates.

It is also worth noting that the sum of lagged $CashIM$ coefficients is greater than one in the case of reverse repo volumes but less than one in the case of bond investments. For example, a one-billion increase in cash collateral (in any currency) leads, on average, to a cumulative increase in CCP reverse repo volume over the next five days by about 2.5 billions and to a cumulative increase in bond investments by about 0.1 billion for any of the three currencies. The larger cumulative effect for reverse repos is driven by the subsequent rolling-over of these reverse repo positions on a daily basis.

As mentioned earlier, the result that CCP investments (reverse repos and bond purchases) respond to changes in same-currency cash IM implies a cash collateral cycle that siphons liquidity back to the market with the "recycled" amount being higher at times of stress, that is, when cash IM also increases. This is important because it implies that this part of the cash collateral cycle might have a *countercyclical* effect if CCP investments also affect prevailing repo rates. We turn to this question next.

5.3 Countercyclical Effects of the Cash Collateral Cycle

Having documented that CCPs recycle a large proportion of the cash they receive as IM collateral, an important question is whether this recycling also affects funding costs. There are two main channels through which CCP activities can lead to a decrease in repo rates. First, the *direct* channel arises from CCPs' demand for safe collateral assets through reverse repos. As shown in Table 1, this demand is sizable and presumably inelastic, as it is driven by regulatory requirements. Consequently, CCP reverse repos flood the repo market with cash while withdrawing safe collateral assets, thereby exerting a *direct* downward pressure on repo rates. This mechanism was previously studied by (Ranaldo et al., 2021); however, our analysis extends it by uncovering a potential countercyclical effect: the downward pressure intensifies during periods of heightened risk and stress, as captured by increases in the VIX index.

Second, the *indirect* channel operates through CCP bond purchases, which reduce the net supply of bonds in the market, increasing their scarcity and forcing bond investors to accept a price premium (Krishnamurthy, 2002). This scarcity makes the bonds "special" in the repo market, thereby lowering their associated repo rates (Duffie, 1996). Moreover, asset scarcity can increase the liquidity premium (convenience yield) of these bonds, even when they are included in a General Collateral basket (Ballensiefen and Ranaldo, 2023). This indirect channel, unlike the direct channel, was not examined by (Ranaldo et al., 2021).

Studying both channels alongside the remaining option available to CCPs — depositing cash at central banks — is essential for providing a comprehensive analysis of the impact of CCP investments on repo rates. This is because monetary policies can influence how the two channels operate. For instance, the larger amounts of available liquidity and the increased scarcity of safe assets during our sample period, both induced by central bank quantitative easing programs, may have rendered the indirect (bond purchasing) channel more important than the direct (reverse repo) channel.

This discussion motivates the following hypotheses:

- *Hypothesis 6*: CCP reverse repo activity and outright bond purchases exert downward pressure on repo rates.

- *Hypothesis 7*: The negative effects of CCP reverse repos and outright bond purchases on repo rates are more pronounced at times of higher market volatility.

To test these hypotheses, we estimate the following panel specification:

$$\begin{aligned} Repo_{it} = a + b_1 Repo_{it-1} + b_2 VlmRR_{it-1} + b_3 \Delta Bonds_{it-1} + b_4 \Delta Reserves_{it-1} \\ + b_5 VIX_{it-1} + b_6 (VIX_{it-1} \times VlmRR_{it-1}) + b_7 (VIX_{it-1} \times \Delta Bonds_{it-1}) + v_i + u_{it}, \end{aligned} \tag{8}$$

where i and t denote currencies and days, respectively. *Repo* is the overnight repo rate in currency i, $VlmRR$ is the aggregate volume of reverse repos in currency i across all UK

CCPs and *Bonds* is the total amount of government bond investments in currency i by UK CCPs. As control variables we use *Reserves* which is the aggregate amount of central bank reserves balances in currency i, and VIX which is the implied volatility for a broad equity market index in each currency. We include in the model any of two interaction terms that are intended to capture countercyclical effects, that is, whether the impact of reverse repos and bond purchases vary with aggregate market volatility. We include a first lag of the repo rates to account for persistence in this variable and otherwise difference all variables for which we cannot reject the presence of a unit root.[40] The specifications nested in this model are all estimated using fixed effects, while the standard errors are clustered by currency.

A potential concern of this specification is that CCP investments (both reverse repos and bond purchases) may be endogenous to the prevailing repo rate. For instance, CCP investments in reverse repos (bonds) might increase (decrease) with the repo rate. We think that such an effect is unlikely. First, with respect to reverse repos, a potential bias would actually operate in the opposite direction of the effects we are trying to capture. Second, while CCPs may aim to avoid investing their cash collateral at rates far below the prevailing market rates, a bigger concern is liquidity and the extent to which they can easily access these funds. Corroborating this, we find that daily variations in the relative allocation of CCP cash between repos, bonds and central bank deposits are insensitive to daily changes in repo rates.[41]

Table 8 shows the estimation results. The first result to notice, in the baseline regressions (columns 1-4), is that between the two CCP investment options that return cash back to the financial markets (i.e., reverse repos and bond purchases), only bond purchases have a negative and statistically significant effect on repo rates. This supports the indirect channel meaning that CCPs exert downward pressure on repo rates mainly via the collateral scarcity channel. This is likely due to the abundance of reserves balances

[40] As a result of differencing, our estimation method is highly conservative.

[41] These results are not reported here but are available upon request.

during this period, an explanation corroborated by the negative and significant effect of reserves balances on repo rates (column 4). Compared with the findings in Ranaldo et al. (2021), these findings suggest that the indirect effect of CCP bond purchases on repo rates may have gained strength, over our sample period, relative to the direct effect of reverse repo volumes.

Second, our results also show that the effects of CCP reverse repo investments on repo rates become significant when market volatility is high. This is indicated by the significantly negative coefficient in the interaction term between the volatility index and CCP reverse repos (column 5) . On the contrary, the moderating effect of bond purchases seems to be more persistent, as the lack of significance of its interaction term with the volatility index suggests (column 6).

These effects are economically significant as well. For example, the estimated coefficients on bond purchases suggest that a one-standard-deviation increase in daily Sterling denominated bond purchases (£0.29 bn) accounts for about 5% of the daily variation in GBP repo rates.[42] The counter-cyclicality of CCP reverse repos implies that they also have a more pronounced effect at times of stress. For example, on days when market volatility attains its maximum value in our sample, GBP reverse repos account for up to 23% of the daily GBP repo rate variation. These effects apply, on average, across all three main currencies in our sample.

Overall, these results show that CCPs can set in motion cash collateral cycles consisting of an onward and a backward phase, both of which have measurable effects on repo markets. In the former, the well-known procyclicality between CCP margins and volatility has consequences for repo rates, rendering them procyclical as well. In the latter, the regulatory-driven cash investment by CCPs has significant countercyclical effects on repo rates. This could at least partly explain why repo rates remain relatively subdued, even at times of stress, such as during the period of the COVID-19 pandemic, which is covered

[42]To obtain the effect of CCP bond purchases, we multiply the bond purchase coefficient from column 2 (-0.0106) with the daily standard deviation of bond purchases (£0.29 bn) and then divide this product with the daily standard deviation of GBP repo rates (0.22%).

in our sample.

6 Summary and Policy Implications

Using supervisory data from UK CCPs, our study reveals that cash collateral follows persistent cycles that comprise two phases. In the onward phase, cash collateral flows from clearing members to clearing houses (CCPs) in order to fulfil CCP margin requirements. This flow is known to be procyclical, that is, CCPs' initial margin (IM) increases with market volatility. Our analysis reveals that repurchase agreement (repo) rates increase in anticipation of larger CCP cash margin payments, suggesting that clearing members hoard liquidity to meet them. This implies that IM is *also* procyclical with respect to repo rates. Furthermore, this effect is more pronounced in times of stress and higher volatility.

In the backward phase, cash collateral flows back from CCPs to financial markets. This part of the collateral flow is driven by CCPs complying with the law. More specifically, to comply with the EMIR regulation, CCPs reinvest cash via reverse repos and government bonds. Our analysis shows that in an environment of abundant central bank liquidity, CCP bond investments exert persistent downward pressure on repo rates whereas CCP reverse repos only do so at times of heightened volatility.

Our findings should be of interest to policy makers. First, a better understanding of CCP margin procyclicality and of the underlying cash collateral flow is relevant because, as a result of post-crisis regulations, margin requests originating from CCPs simultaneously affect a large proportion of market participants. This could potentially create system-wide liquidity shocks as market participants scramble to source the necessary collateral in response to these margin calls. Thus, examining how margin calls relate to funding costs is an economically sensible way of capturing this liquidity risk.

Second, the case of the migration of EUR repo clearing from London to Paris demonstrates how CCP location policies can potentially affect the collateral cycle and ultimately repo rates. Location policies, whereby certain asset classes are mandated to be cleared in

specific jurisdictions, can have a substantial effect on the overall size of CCP IM. This is because changing the location of clearing, for a given asset class, influences the netting set against which the margin of this asset class is calculated. A key message of our paper in this respect is that location policies that maximize netting opportunities will result in weaker collateral cycles and smaller overall effects on repo markets.

Third, the post-crisis regulatory framework has also rendered CCPs themselves large actors in financial markets (Aldasoro et al., 2023b), where they "...act as major repo counterparties when reinvesting the large amounts of collateral they collect" (Cœuré, 2019). This means that CCP investment activity is potentially consequential for funding markets. For instance, the downward pressure on repo rates that we document could be important for monetary policy since money market rate dispersion between repo and other rates (Duffie, 2018) causes "a reduction in the efficacy and transmission of monetary policy" (Bank for International Settlements, 2017, p. 32).

Finally, CCPs are only able to return their cash collateral to the market if it is not needed to cover losses from a potential default of a clearing member, which is more likely to materialize in highly stressed periods. Thus, the cash collateral cycle documented in this paper could potentially be broken if CCPs are not able to reinvest liquidity collected from clearing members and cannot transfer it back to market participants. Although an extreme scenario, this potential systemic adverse scenario deserves further research and reflection by policy makers.

Overall, our results demonstrate that the new regulation on market infrastructures has transformed CCPs into sizable *non*-bank entities that significantly and systematically impact financial markets.

Figure 1: The Cash Collateral Cycle

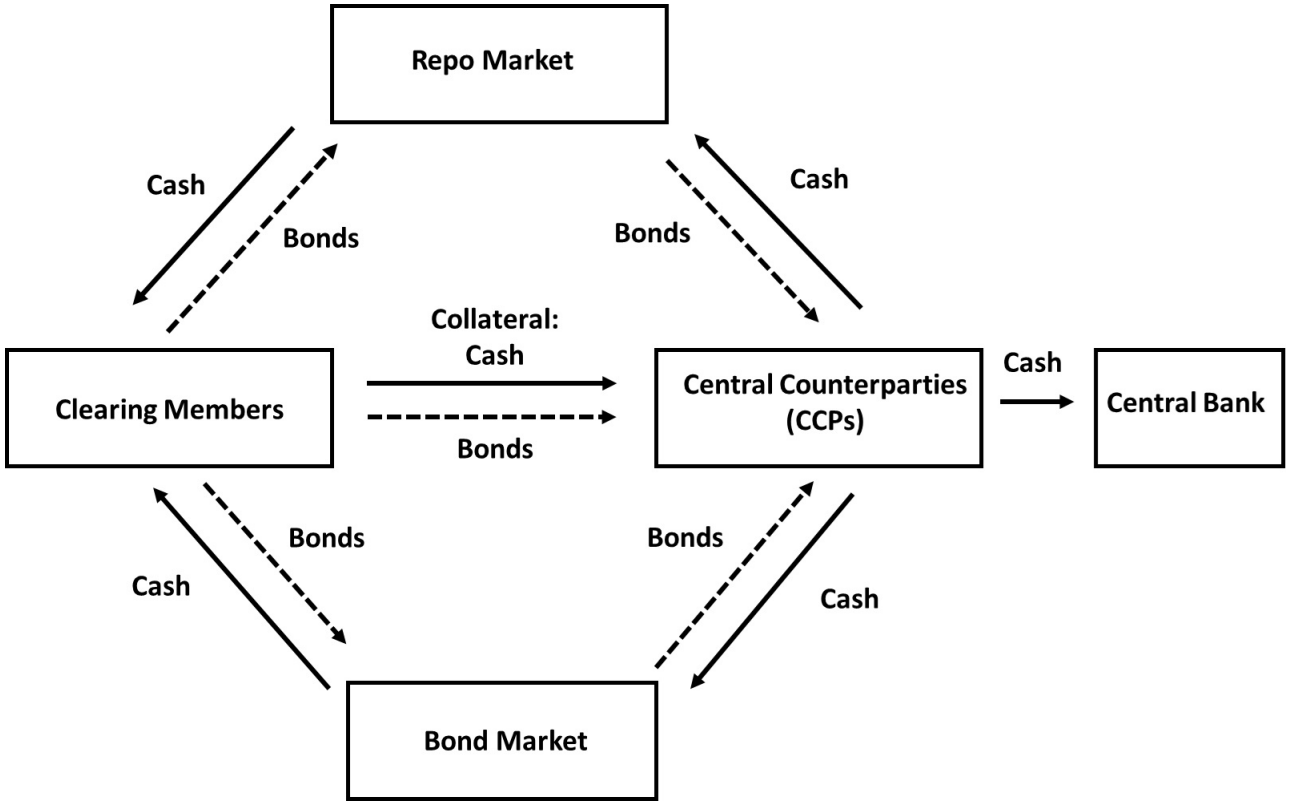

Figure 2: Initial margin and volatility This figure shows the time series of the aggregate cash initial margin across UK CCPs and average implied market volatility. The cash initial margin (converted to GBP) is paid in the three major currencies: USD, EUR, and GBP. The implied volatility index is the average of the VIX, VSTOXX, and IVUKX30 indices. The time period is from February 2019 to June 2020.

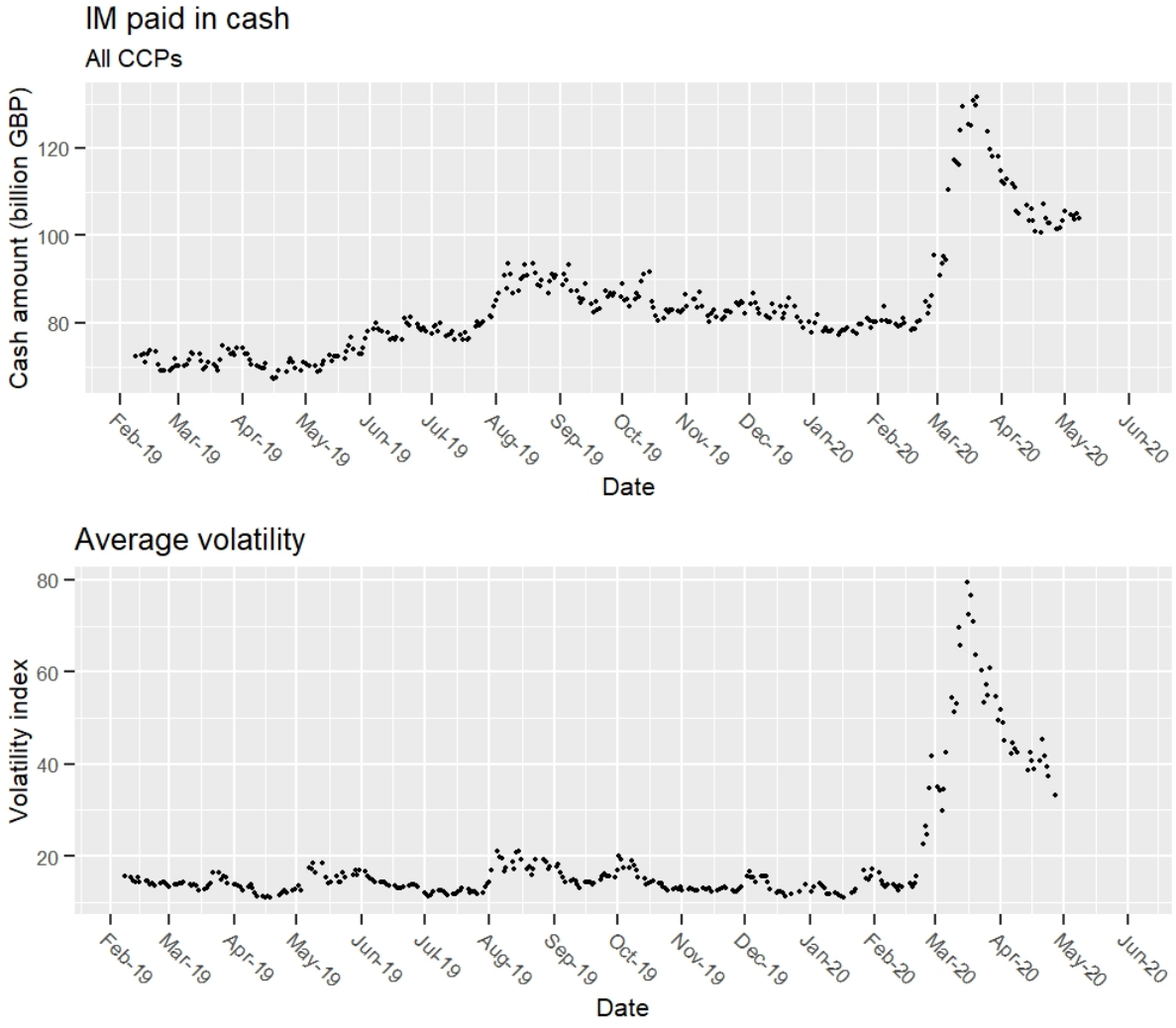

Figure 3: Initial margin and repo rates This figure shows the time series of the aggregate cash initial margin across UK CCPs and average adjusted repo rates. The cash initial margin (converted to GBP) is paid in the three major currencies: USD, EUR, and GBP. To aid visualization, we adjust the overnight repo rates for these currencies by subtracting the central bank policy rate and then averaging across currencies. The time period is from February 2019 to June 2020.

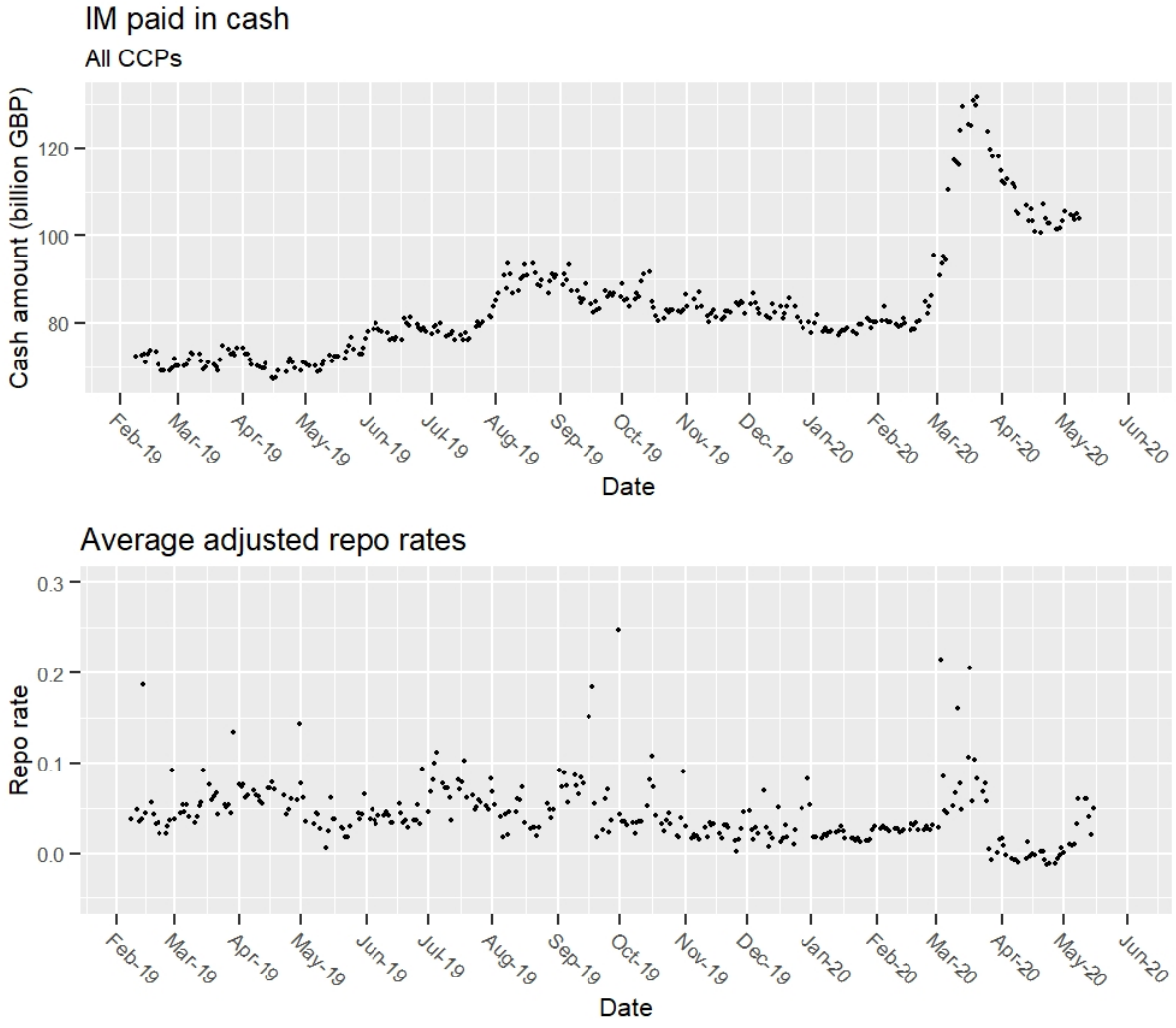

Figure 4: Percentage of cash initial margin. This figure shows the percentage of cash initial margin, across all main currencies, that corresponds to each of the clearing services in our sample. The CDS and Futures and Options (FAO) services are part of ICE Clear Europe, while the remaining services are part of LCH Limited. The time period is from February 2019 to June 2020.

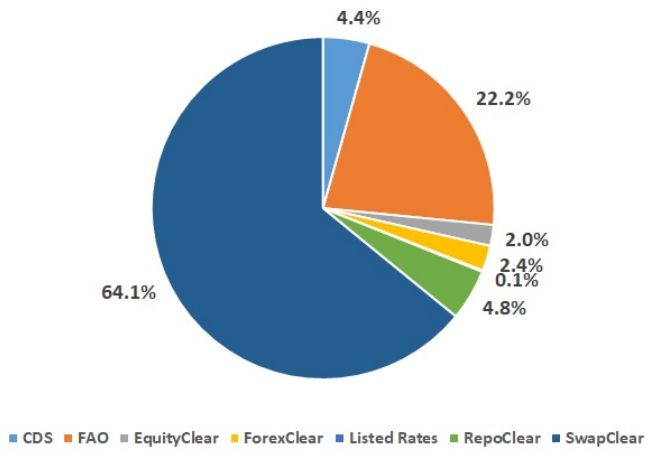

Figure 5: Initial margin and collateral ratio This figure shows the time series of the aggregate cash initial margin across UK CCPs and cash collateral ratio. The cash initial margin (converted to GBP) is paid in the three major currencies: USD, EUR, and GBP. The cash collateral ratio is the percentage of the initial margin paid in cash across all three currencies. The time period is from February 2019 to June 2020.

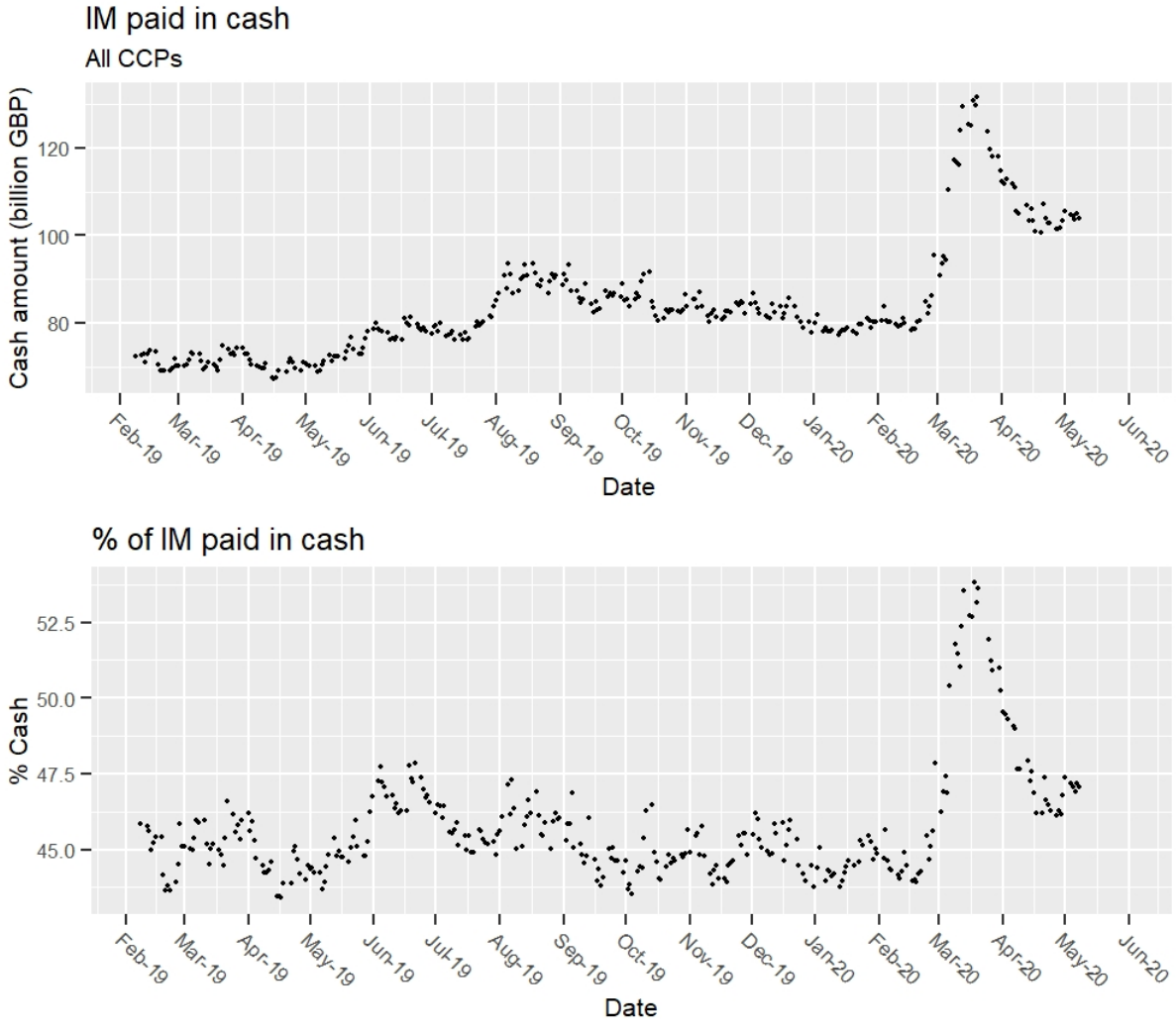

Figure 6: EUR Repo migration: Daily trading volumes (in GBP billion, top chart) and number of trades (bottom chart) for EUR-denominated repos cleared by the RepoClear service of LCH. The vertical dotted red line corresponds to February 19, 2023. The time period is from February 2019 to March 2020.

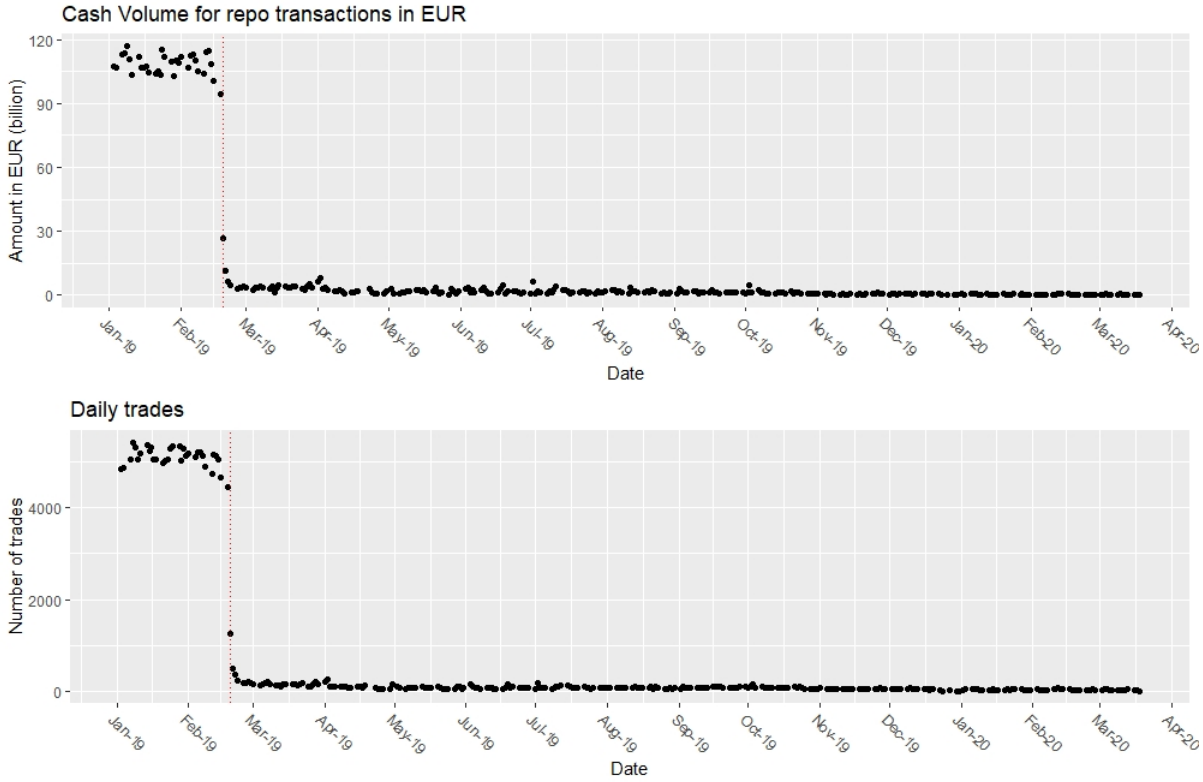

Figure 7: Cash initial margin and CCP investments: This figure shows the daily level of aggregate cash margin paid by clearing members across UK CCPs, alongside daily levels of CCP investments. These include reverse repos, bonds as well as central bank deposits in the three major currencies (USD, EUR, and GBP). All currencies are converted to GBP to facilitate aggregation. The time period is from February 2019 to June 2020.

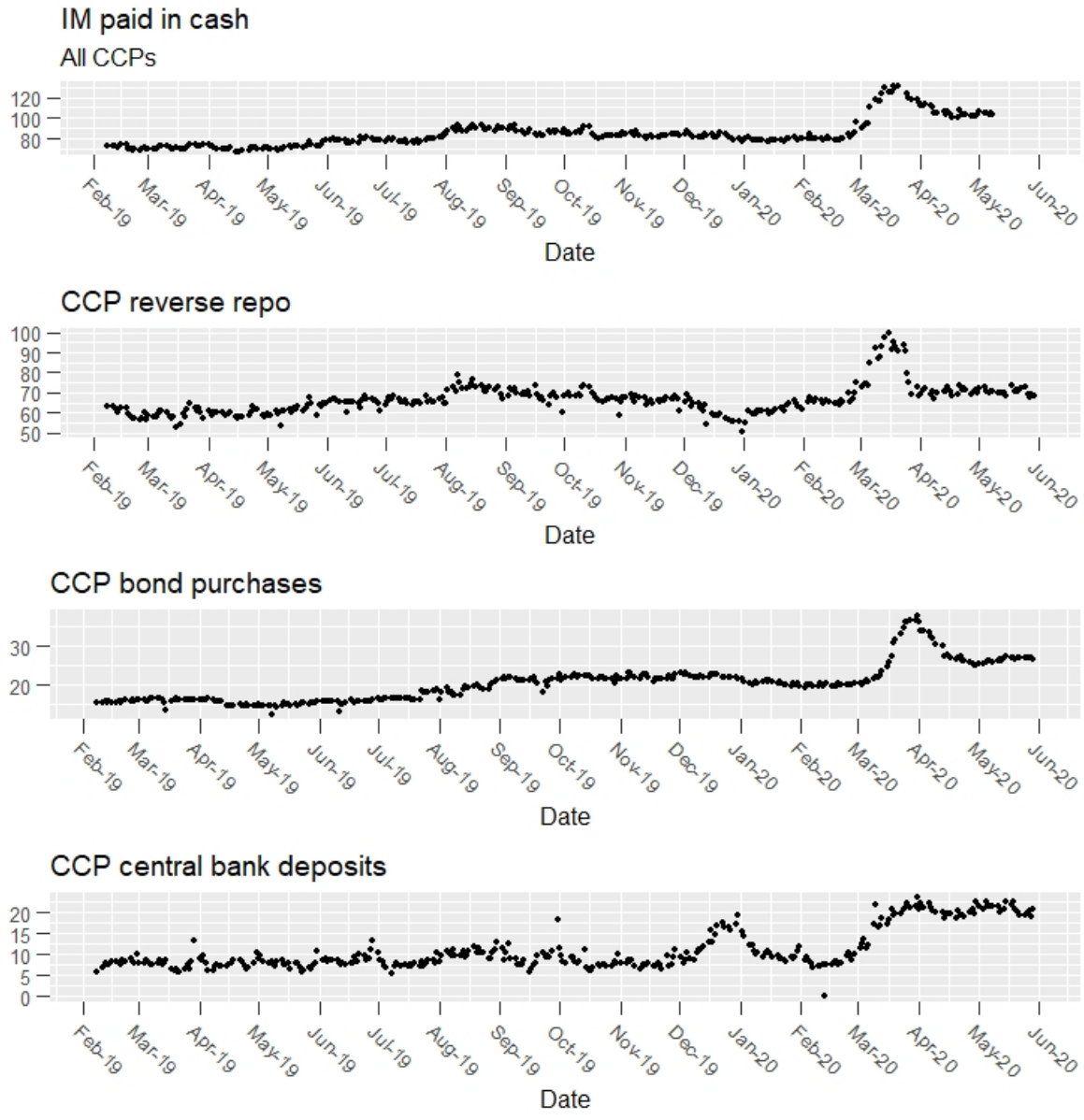

Table 1: Summary statistic This table shows the summary statistics of the variables used in the empirical analysis. The statistics are reported separately for each currency in which they are denominated. For comparability, all values expressed in currency units have been converted to GBP at the prevailing market exchange rate. $CashIM$ and $SecIM$ are the daily amounts of initial margin in cash and securities, respectively, pledged by all clearing members of the two CCPs in our sample. $CashIM(\%)$ is the percentage of cash over total initial margin. $VlmRR$ is the aggregate daily volume of reverse repo activity by the CCPs in our sample, *Bonds* is the daily value of their investments in government bonds and *Deposits* is the daily level of CCP deposits held with a central bank account. *Repo* is the daily overnight general collateral repo rate. *Reserves* are the daily values of central bank reserves balances in each currency, and VIX is the implied volatility of broad equity market indices in the US, UK, and Eurozone. The sample time period is from February 2019 to June 2020.

		EUR				**GBP**				**USD**			
	Units	*mean*	*sd*	*min*	*max*	*mean*	*sd*	*min*	*max*	*mean*	*sd*	*min*	*max*
A. CCP Collateral													
CashIM	GBP bn	24.02	6.14	17.21	39.12	21.19	6.15	14.07	39.28	43.14	7.25	33.57	72.89
SecIM	GBP bn	39.57	4.00	32.91	46.43	18.09	1.90	15.07	22.65	41.46	4.11	33.39	51.89
CashIM(%)	%	36.21	2.95	32.22	45.32	51.28	2.64	45.23	60.58	50.19	2.68	45.33	59.37
B. CCP Investments													
VlmRR	GBP bn	13.79	1.88	7.75	17.83	21.48	3.20	15.33	35.92	31.22	4.33	24.18	51.40
Bonds	GBP bn	3.51	0.87	2.43	6.25	2.17	1.04	0.61	3.94	14.87	3.57	8.82	30.71
Deposits	GBP bn	8.67	4.16	3.66	19.61	2.49	1.07	0.85	6.14	–	–	–	–
C. Other Variables													
Repo	%	–0.47	0.04	–0.56	–0.40	0.69	0.22	0.02	0.95	1.78	0.81	0.01	5.25
Reserves	GBP bn	2249.96	137.86	2009.31	2595.66	498.16	42.51	460.13	627.40	2276.25	641.72	1717.24	3978.64
VIX		19.61	13.63	10.60	85.60	18.32	11.99	9.63	69.73	20.40	13.29	11.54	82.69

Table 2: Cash Margin procyclicality This table shows the estimation results for specification (1). $CashIM$ is the daily aggregate amount of cash collateral pledged with all UK CCPs in each currency. *Repo* is the overnight repo rate for each currency. VIX is the implied volatility index associated with a broad stock market index for each currency. *Covid* is a dummy that equals one from February 19, 2020, when market volatility increased as a result of the COVID-19 pandemic. Δ indicates that the variable is taken in differences. The sample time period is from February 2019 to June 2020. Robust p-values are in parentheses. *, ** and *** denote significance at 10%, 5%, and 1% levels, respectively.

	$CashIM_t$				
	(1)	(2)	(3)	(4)	(5)
$\Delta Repo_{t-1}$		0.3998**	0.4262**	0.1632**	–1.2676**
		(0.019)	(0.013)	(0.019)	(0.021)
$Covid_t$				1.5086*	
				(0.061)	
VIX_{t-1}	0.4270**		0.0437		0.0452
	(0.026)		(0.184)		(0.202)
$\Delta Repo_{t-1} \times Covid_t$				2.7207	
				(0.118)	
$\Delta Repo_{t-1} \times VIX_{t-1}$					0.0926**
					(0.028)
cons	25.6874***	1.0573	2.7554	3.0781**	2.6054
	(0.003)	(0.191)	(0.133)	(0.039)	(0.131)
R^2	0.703	0.939	0.932	0.942	0.933
N	944	952	918	952	918
Lagged dep. var.	No	Yes	Yes	Yes	Yes

Table 3: Procyclicality in cash margin shares. This table shows the estimation results for model (2). $CashIM(\%)$ is the ratio (in %) of cash collateral over total collateral (cash plus securities) pledged with all UK CCPs in each currency. $CurrIM(\%)$ is the ratio (in %) of cash collateral pledged in a given currency over total cash collateral pledged in all currencies. *Repo* is the overnight repo rate for each currency. VIX is the implied volatility index associated with a broad stock market index for each currency. *Covid* is a dummy that equals one from February 19, 2020, when market volatility increased as a result of the COVID-19 pandemic. Δ indicates that the variable is taken in differences. The sample time period is from February 2019 to June 2020. Robust p-values are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.

	$CashIM(\%)_t$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Repo_{t-1}$	0.2712**	0.2707**	0.2861***	0.3037***	0.2852***	0.1170
	(0.018)	(0.020)	(0.010)	(0.004)	(0.002)	(0.152)
$\Delta Reserves_{t-1}$		–0.0002				
		(0.694)				
$Covid_t$			0.3014*		0.3015*	
			(0.067)		(0.067)	
VIX_{t-1}				0.0113*		0.0116**
				(0.058)		(0.044)
$\Delta Repo_{t-1} \times Covid_t$					0.0116	
					(0.966)	
$\Delta Repo_{t-1} \times VIX_{t-1}$						0.0102
						(0.126)
cons	1.8815	1.8930	2.6787**	3.2193**	2.6780**	3.2006**
	(0.138)	(0.128)	(0.011)	(0.012)	(0.012)	(0.012)
R^2	0.901	0.901	0.903	0.897	0.903	0.897
N	910	907	910	899	910	899
Lagged dep. var.	Yes	Yes	Yes	Yes	Yes	Yes

Table 4: Initial Margin (IM) statistics around the migration of EUR-denominated repo contracts on Fberuary 19, 2019. The table shows daily average values in billions of each currency (Panel A) and in billions of EUR (Panel B) for IM requested and cash IM paid to the RepoClear service of LCH. The top panel shows numbers for EUR-denominated IM and the middle and bottom panels show averages for GBP and USD-denominated IM respectively. The "Before" period includes the dates of February 8 to February 18 whereas the "After" period includes the dates of February 19 to March 4, 2019. The conversion of the GBP and USD-denominated IM in Panel B was done using the average exchange rate throughout the migration window. *, ** and *** denote significance at 10%, 5%, and 1% levels, respectively of a Welch t-statistic of mean equality.

	Panel A: Local currency		Panel B: EUR	
EUR	IM requested	Cash IM paid		
Before	8.59	3.29		
After	6.28	2.86		
Difference	−2.31***	−0.43***		
GBP	IM requested	Cash IM paid	IM requested	Cash IM paid
Before	11.08	1.88	12.75	2.16
After	10.85	1.70	12.48	1.95
Difference	−0.23	−0.18*	−0.27	−0.21*
USD	IM requested	Cash IM paid	IM requested	Cash IM paid
Before	0	0.48	0	0.42
After	0	0.31	0	0.27
Difference	0.00	−0.17**	0	−0.15**

Table 5: EUR repo migration effects. This table shows estimation results of models (3) and (4). *Event* is a dummy variable that takes the value of 1 after February 19, 2019 and 0 before that and EUR is a dummy variable that takes the value of 1 for EUR and 0 for USD and GBP. The models are estimated over the period between February 8 and March 4, 2019, approximately 10 ten days before and after the EUR repo migration. For both models we use currency fixed effects and standard errors are clustered by currency. *, ** and *** denote significance at 10%, 5%, and 1% levels respectively.

	$CashIM_{it}$	$CashIM(\%)_{it}$
$\Delta Repo_{it-1}$	–0.1827	0.4959
	(0.753)	(0.648)
$Event_t$	–0.2873	–0.3593
	(0.168)	(0.315)
$Event_t \times EUR_i \times \Delta Repo_{it-1}$	−24.3570**	−51.4470**
	(0.023)	(0.028)
$\Delta Reserves_{it-1}$		0.0033
		(0.524)
cons	8.1946***	12.2209**
	(0.004)	(0.014)
R^2	0.723	0.812
N	45	45
Lagged dep. var.	Yes	Yes

Table 6: Clearing member analysis Panel A shows summary statistics of our clearing-member variables. *CashIM* is the cash pledged by each clearing member with all UK CCPs. *ON_Repo_Borrowing* (*ON_Repo_Lending*) is the daily borrowing (lending) volume of each clearing member in the centrally cleared Sterling overnight repo market. *Repo* is the volume-weighted average overnight borrowing repo rate of each clearing member. *CDS* is the daily CDS spread for those clearing members with a CDS contract traded in their name. Panels B and C show the estimation results for specifications (5) and (6), respectively. Δ indicates that the variable is taken in differences. The sample time period is from February 2019 to June 2020. Robust p-values are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.

Panel A	Units	*mean*	*sd*	*min*	*max*
CashIM	GBP bn	0.43	0.72	0.00	5.00
ON_Repo_Borrowing	GBP bn	1.32	1.72	0.00	17.99
ON_Repo_Lending	GBP bn	1.31	1.73	0.00	16.56
Repo	%	0.66	0.20	0.00	0.99
CDS	bps	55.30	26.58	16.89	204.09

Panel B	$CashIM_{jt}$		
	(1)	(2)	(3)
VIX_{t-1}	0.0003**		0.0003
	(0.015)		(0.173)
$ON\_Repo\_Borrowing_{jt-1}$		0.0079*	0.0079*
		(0.092)	(0.095)
$ON\_Repo\_Lending_{jt-1}$		–0.0019*	–0.0018*
		(0.054)	(0.086)
cons	0.0172***	0.0201*	0.0171
	(0.003)	(0.099)	(0.131)
R^2	0.90	0.89	0.89
N	9,844	5,458	5,437
Lagged dep. var.	Yes	Yes	Yes

Panel C	$Repo_{jt}$		
	(1)	(2)	(3)
ΔCDS_{jt-1}	0.0015***		0.0015***
	(0.000)		(0.000)
$ON\_Repo\_Borrowing_{jt}$		–0.0006	0.0023*
		(0.757)	(0.081)
$ON\_Repo\_Lending_{jt}$		–0.0042**	–0.0030**
		(0.048)	(0.022)
cons	0.0100**	0.0182***	0.0101**
	(0.015)	(0.000)	(0.013)
R^2	0.93	0.89	0.92
N	3,782	4,429	3,496
Lagged dep. var.	Yes	Yes	Yes

Table 7: Cash margin and CCP investment activity: This table shows the estimation results for specification (7). $VlmRR$ is the daily amount of reverse repo volume executed by all UK CCPs. *Bonds* is the daily amount (stock) of CCP bond investments and *Deposits* is the daily amount (stock) of cash held by CCPs in a central bank account. $CashIM$ is the absolute amount (stock) of cash pledged with all UK CCPs. Specification (3) excludes the USD cash margin as non-US CCPs cannot deposit their dollar holdings with the Federal Reserve. Δ indicates that the variable is taken in differences. The F-statistics and associated p-values test whether the sum of the coefficients on the lagged changes in cash margin is zero (i.e. $\sum_{k=1}^{5} b_k = 0$). The sample time period is from February 2019 to June 2020. Robust p-values are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.

	$VlmRR_{it}$	$\Delta Bonds_{it}$	$\Delta Deposits_{it}$
	(1)	(2)	(3)
$\Delta CashIM_{it-1}$	0.4900**	0.0408*	–0.1504
	(0.031)	(0.081)	(0.306)
$\Delta CashIM_{it-2}$	0.5462**	0.0070*	–0.0886*
	(0.017)	(0.066)	(0.099)
$\Delta CashIM_{it-3}$	0.5244**	0.0174	–0.0199
	(0.018)	(0.171)	(0.820)
$\Delta CashIM_{it-4}$	0.5098**	0.0204**	0.0465
	(0.015)	(0.043)	(0.251)
$\Delta CashIM_{it-5}$	0.3967**	0.0102***	0.0671
	(0.034)	(0.000)	(0.221)
cons	25.5270***	0.0135***	0.0216
	(0.000)	(0.006)	(0.249)
R^2	0.135	0.022	0.027
N	978	975	650
F-statistics	45.37	14.15	0.51
p-values	0.02	0.06	0.60

Table 8: Cash collateral counter-cyclical effects This table shows the estimation results for specification (8). All variables are currency-specific and on a daily frequency. *Repo* is the ON repo rate. $VlmRR$ is the daily amount of reverse repo volume executed by all UK CCPs. *Bonds* is the outstanding amount of government bond investments by CCPs. *Reserves* is the aggregate amount of central bank reserves balances. VIX is the implied volatility index associated with a broad stock market index. Δ indicates that the variable is taken in differences. The sample time period is from February 2019 to June 2020. Robust p-values are in parentheses. *, ** and *** denote significance at 10%, 5%, and 1% levels, respectively.

	$Repo_{it}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$VlmRR_{it-1}$	–0.0015		-0.0012	0.0016	0.0089	0.0016
	(0.156)		(0.251)	(0.684)	(0.209)	(0.682)
$\Delta Bonds_{it-1}$		–0.0106***	–0.0094**	–0.0082**	–0.0025	–0.0078**
		(0.004)	(0.024)	(0.011)	(0.275)	(0.036)
$\Delta Reserves_{it-1}$				–0.0000**	–0.0000*	–0.0000***
				(0.013)	(0.063)	(0.005)
VIX_{it-1}				–0.0019	0.0016	–0.0019
				(0.480)	(0.271)	(0.481)
$VIX_{it-1} \times \Delta VlmRR_{it-1}$					–0.0002**	
					(0.049)	
$VIX_{it-1} \times \Delta Bonds_{it-1}$						–0.0000
						(0.801)
const	0.0578*	0.0203**	0.0528	0.0348	–0.1134	0.0347
	(0.066)	(0.012)	(0.107)	(0.324)	(0.343)	(0.321)
R^2	0.917	0.916	0.916	0.917	0.919	0.917
N	957	950	950	914	914	914
Lagged dep. var.	Yes	Yes	Yes	Yes	Yes	Yes

References

Acharya, V., Skeie, D., 2011. A model of liquidity hoarding and term premia in inter-bank markets. Journal of Monetary Economics 58, 436–447.

Aldasoro, I., Avalos, F., Huang, W., 2023a. Liquid assets at ccps and systemic liquidity risks. BIS Quarterly Review December, 33–46.

Aldasoro, I.n., Avalos, F., Huang, W., 2023b. Liquid assets at CCPs and systemic liquidity risks. URL: `https://www.bis.org/publ/qtrpdf/r_qt2312c.pdf`.

Arrata, W., Nguyen, B., Rahmouni-Rousseau, I., Vari, M., 2020. The scarcity effect of quantitative easing on repo rates: Evidence from the euro area. Journal of Financial Economics 137, 837–856.

Bakoush, M., Gerding, E.H., Wolfe, S., 2019. Margin requirements and systemic liquidity risk. Journal of International Financial Markets, Institutions and Money 58, 78–95.

Ballensiefen, B., Ranaldo, A., 2023. Safe asset carry trade. Review of Asset Pricing Studies 13, 223–265.

Bank for International Settlements, 2017. Repo market functioning. CGFS Papers No. 59.

Bechtel, A., Ranaldo, A., Wrampelmeyer, J., 2022. Liquidity Risk and Funding Cost. Review of Finance 27, 399–422.

Benos, E., Hung, W., Mnkveld, A., Vasios, M., 2024. The cost of clearing fragmentation. Management Science 70, 3581–3596.

Capponi, A., Cheng, W.A., Giglio, S., Haynes, R., 2014. The collateral rule: An empirical analysis of the cds market. Working Paper .

Cont, R., Kokholm, T., 2014. Central clearing of otc derivatives: Bilateral vs multilateral netting. Statistics and Risk Modeling 31, 3–22.

CPMI-IOSCO, 2012. Principles for financial market infrastuctures .

CPMI-IOSCO, 2015. Public quantitative disclosure standards for central counterparties .

Cœuré, B., 2019. The case for cooperation: cross-border CCP supervision and the role of central banks. URL: https://www.ecb.europa.eu/press/key/date/2019/html/ecb.sp190227~cf2acdb23d.en.html.

Duffie, D., 1996. Special repo rates. Journal of Finance 51, 493–526.

Duffie, D., 2018. Financial regulatory reform after the crisis: An assessment. Management Science 64, 4835–4857.

Duffie, D., Scheicher, M., Vuillemey, G., 2015. Central clearing and collateral demand. Journal of Financial Economics 116, 237–256.

Duffie, D., Zhu, H., 2011. Does a central clearing counterparty reduce counterparty risk? Review of Asset Pricing Studies 1, 74–95.

European Commission, 2013. Commission Delegated Regulation (EU) No 153/2013. Official Journal of the European Union L52, 41–74. URL: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:052:0041:0074:EN:PDF.

European Securities and Markets Authority, 2022. Final report on highly liquid financial instruments for ccp investment policies. URL: https://www.esma.europa.eu/press-news/esma-news/esma-publishes-report-highly-liquid-instruments.

Gai, P., Haldane, A., Kapadia, S., 2011. Complexity, concentration and contagion. Journal of Monetary Economics 58, 453–470.

Ghamami, S., Samim, P., 2017. Does otc derivatives reform incentivize central clearing? Journal of Financial Intermediation 32, 76–87.

Glasserman, P., Wu, Q., 2018. Persistence and procyclicality in margin requirements. Management Science 64, 5705–5724.

Heller, D., Vause, N., 2012. Collateral requirements for mandatory central clearing of over-the-counter derivatives. URL: https://www.bis.org/publ/work373.pdf.

Holden, H., Houllier, M., Murphy, D., 2016. I want security: Stylized facts about central counterparty collateral and its systemic context. Journal of Financial Market Infrastructures 5, 53–75.

Huang, W., Takáts, E., 2020. The CCP-bank nexus in the time of Covid-19. Bank for International Settlements Bulletin No 13 .

Hüser, A.C., Lepore, C., Veraart, L., 2021. How does the repo market behave under stress? evidence from the covid-19 crisis. Bank of England Staff Working Paper No. 910.

ISDA, 2021. Evolution of OTC derivatives markets since the financial crisis. Research Note .

Jones, R.A., Pérignon, 2013. Derivatives clearing, default risk, and insurance. Journal of Risk and Insurance 80, 373–400.

King, T., Nesmith, T., Paulson, A., Prono, T., 2023. Central clearing and systemic liquidity risk. International Journal of Central Banking 19, 85–142.

Kotidis, A., van Horen, N., 2018a. Repo market functioning: The role of capital regulation. Bank of England Staff Working Paper No. 746 .

Kotidis, A., van Horen, N., 2018b. Repo market functioning: the role of capital regulation. Bank of England Staff Working Paper 746.

Krishnamurthy, A., 2002. The bond/old-bond spread. Journal of Financial Economics 66, 463–506.

Menkveld, A.J., 2017. Crowded trades: An overlooked systemic risk for central clearing counterparties. Review of Asset Pricing Studies 7, 209–242.

Munyan, B., 2023. The repo market, in: Gurkaynak, R., Wright, J. (Eds.), Research Handbook of Financial Markets. Edward Elgar Publishing, Cheltenham, UK, p. Chapter 11. URL: https://www.elgaronline.com/view/book/9781800375321/9781800375321.xml, doi:10.4337/9781800375321.

Murphy, D., Vasios, M., Vause, N., 2014. An investigation into the procyclicality of risk-based initial margin models. Bank of England Financial Stability paper No. 29 .

Ranaldo, A., Schaffner, P., Vasios, M., 2021. Regulatory effects on short-term interest rates. Journal of Financial Economics 141, 750–770.

Schaffner, P., Ranaldo, A., Tsatsaronis, K., 2019. Euro repo market functioning: Collateral is king. BIS Quarterly Review December 2019, 95–108.

Sidanius, C., Zikes, F., 2012. Otc derivatives reform and collateral demand impact. Financial Stability Paper No 18 .